ACCIDENT REPORT

Report on the investigation of the collision

between the stern trawler

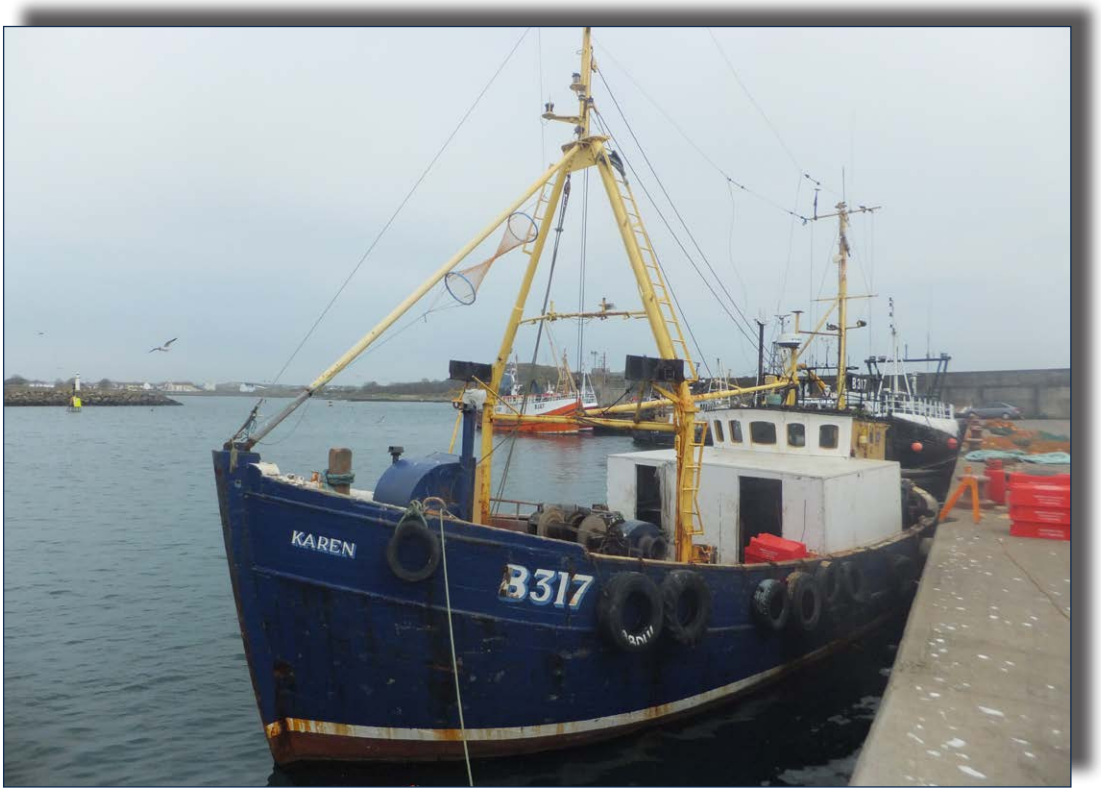
Karen (B317)

and a dived

Royal Navy submarine

in the Irish Sea

on 15 April 2015



MAIB
MARINE ACCIDENT INVESTIGATION BRANCH

SERIOUS MARINE CASUALTY REPORT NO 20/2016 OCTOBER 2016

Extract from

The United Kingdom Merchant Shipping

(Accident Reporting and Investigation)

Regulations 2012 – Regulation 5:

"The sole objective of the investigation of an accident under the Merchant Shipping (Accident Reporting and Investigation) Regulations 2012 shall be the prevention of future accidents through the ascertainment of its causes and circumstances. It shall not be the purpose of an investigation to determine liability nor, except so far as is necessary to achieve its objective, to apportion blame."

NOTE

This report is not written with litigation in mind and, pursuant to Regulation 14(14) of the Merchant Shipping (Accident Reporting and Investigation) Regulations 2012, shall be inadmissible in any judicial proceedings whose purpose, or one of whose purposes is to attribute or apportion liability or blame.

All MAIB publications can be found on our website: www.gov.uk/maib

For all enquiries:
Marine Accident Investigation Branch
Spring Place
105 Commercial Road
Southampton
United Kingdom
SO15 1GH

Email: maib@dft.gsi.gov.uk
Telephone: +44 (0) 23 8039 5500
Fax: +44 (0) 23 8023 2459

Press enquiries during office hours: 01932 440015
Press enquiries out of hours: 020 7944 4292

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GLOSSARY OF ABBREVIATIONS, ACRONYMS AND SUBMARINE TERMINOLOGY

AIS	-	Automatic Identification System
ALRS	-	Admiralty List of Radio Signals
BR	-	Book of Reference
cm	-	centimetre
COG	-	Course over Ground
COLREGs	-	International Regulations for the Prevention of Collisions at Sea, 1972 as amended
COMOPS	-	Commander Operations
CPA	-	Closest Point of Approach
CTF	-	Commander Task Force
DSC	-	Digital Selective Calling
EPIRB	-	Electronic Position Indicating Radio Beacon
ETA	-	Estimated Time of Arrival
ETD	-	Estimated Time of Departure
EU	-	European Union
FISG	-	Fishing Industry Safety Group
FV Code	-	Royal Navy Code of Practice for Fishing Vessel Avoidance
FVSS	-	Fishing Vessel Safety Ship
GPS	-	Global Positioning System
HF	-	High Frequency
HMNB	-	Her Majesty's Naval Base
HMS	-	Her Majesty's Ship
HQ	-	Headquarters
HVME	-	Hull Vibration Monitoring Equipment
JTEPS	-	Joint Tactical Exercise Planning Staff
kt	-	knot

kW	-	kilowatt
m	-	metre
MCA	-	Maritime and Coastguard Agency
MGN	-	Marine Guidance Note
mm	-	millimetre
MoD	-	Ministry of Defence
MP	-	Member of Parliament
MSA	-	Marine Safety Agency
MTL	-	Materials Technology Limited
NATO	-	North Atlantic Treaty Organisation
NAVTEX	-	Navigational and Meteorological Warning Broadcast Service
nm	-	nautical mile
NTSB	-	National Transportation Safety Board
PD	-	Periscope Depth
rpm	-	revolutions per minute
SOA	-	Speed of Advance
SOG	-	Speed over Ground
STCW	-	International Convention on the Standards of Training, Certification and Watchkeeping for Seafarers 1978, as amended
SUBFACTS	-	Submarine Information Broadcast
TMA	-	Target Motion Analysis
TSS	-	Traffic Separation Scheme
UK	-	United Kingdom
UTC	-	Universal Co-ordinated Time
VHF	-	Very High Frequency
VLF	-	Very Low Frequency
VMS	-	Vessel Monitoring System
yds	-	yards

SUBMARINE TERMINOLOGY

Close quarters procedure	-	Rapid, predetermined reactions taken by a submarine to avoid collision
Deep	-	Submarine is submerged and below a depth where periscopes can be used
Masking	-	Inability of a submarine sonar to detect an individual contact when more than one ship exists on a similar bearing
Passive contact	-	A contact detected by a submarine by listening only to the noise emanating from a surface vessel
Periscope depth	-	A depth where a submerged submarine is capable of using its periscopes
Ranging manoeuvre	-	An alteration of course and/or speed by a submarine intended to change the bearing movement of a passive sonar contact, allowing a calculation of the contact's range
Safe depth	-	A depth where a submarine can, if necessary, pass safely beneath the deepest draught merchant vessel that could be encountered
Solution	-	The assessed range, course and speed of another vessel, calculated by a submarine's command team, using sonar information
Surfaced	-	Submarine is fully buoyant with the fin and casing exposed
Trawl noise	-	Discrete noises made by vessels engaged in fishing that can be heard by submarine sonars and used as an aid to contact classification

TIMES: all times used in this report are UTC+1 unless otherwise stated

SYNOPSIS

At 1605 on 15 April 2015, a dived Royal Navy submarine snagged the fishing gear of the UK registered trawler *Karen*, 15 miles south-east of Ardglass, Northern Ireland. *Karen* had been trawling for prawns on a westerly heading at 2.8 knots when its fishing gear was snagged and it was dragged backwards at about 7 knots. *Karen*'s crew managed to release both winch brakes, freeing the trawl warps; the starboard warp ran out completely but the port warp became fouled on the winch drum, causing *Karen* to heel heavily to port and its stern to be pulled underwater. *Karen* broke free from the submarine when the port warp parted; there was structural damage to the vessel but it returned to Ardglass safely under its own power. Evidence of the collision on board the submarine was either not observed or misinterpreted. This meant that the submarine did not render immediate assistance as the command team was unaware of the collision until about 3 hours later.

The collision occurred because the submarine's command team assessed that *Karen* was a merchant vessel, primarily because no trawl noise[1] was heard. The submarine was at a depth where it could, if necessary, pass safely beneath a merchant vessel, therefore the command team would not have perceived any risk of collision; as a result, no avoiding action was taken.

The submarine's command team had assessed that the majority of shipping contacts in the area were merchant vessels. However, most were actually trawlers; this was predictable and should have been identified as a significant risk to the safety of the submarine and other vessels when preparing the submarine's passage plan. Had the submarine's command team appreciated the high density of fishing vessels and then followed Royal Navy guidance on fishing vessel avoidance, the accident would have been avoided because the submarine would have been slowed down and returned to periscope depth when the density of shipping increased.

This investigation was conducted without the full co-operation of the Royal Navy. The involvement of a submarine was not revealed until nearly 5 months after the accident and it took 10 months for the Royal Navy to submit evidence to the investigation team. These delays impeded the progress of the independent investigation, and the evidence submitted was insufficient to determine all the causal factors.

This report makes safety recommendations to the Royal Navy to review the procedures and training necessary to ensure that submarine operations in the vicinity of vessels engaged in fishing are conducted safely, and to provide assurance that actions have been taken to prevent recurrence.

[1] See Section 1.8.1.

SECTION 1 – FACTUAL INFORMATION

1.1 PARTICULARS OF *KAREN*, THE SUBMARINE AND THE ACCIDENT

SHIP PARTICULARS		
Vessel's name	*Karen*	Not declared
Flag	United Kingdom	United Kingdom
IMO / Fishing number	B317	Not declared
Type	Stern trawler	Submarine
Registered owner	T Wills and Son (Northern Ireland) Ltd	UK Ministry of Defence
Construction	Wood	Steel
Year of build	1975	Not declared
Length overall	19.23m	Not declared
Registered Length	17.71m	Not declared
Gross tonnage	50	Not declared
Authorised cargo	Fish	Not applicable
Port of departure	Ardglass, Northern Ireland	HMNB Clyde, Faslane
Intended port of arrival	Ardglass, Northern Ireland	HMNB Clyde, Faslane
Type of voyage	Commercial fishing	Military operations
Cargo information	Prawns	Not applicable
Manning	4	Not declared
MARINE CASUALTY INFORMATION		
Date and time	15 April 2015, 1605	
Type of marine casualty or incident	Serious Marine Casualty	
Location of incident	54°03.3'N - 005°20.4'W	
Place on board	Ship	Not declared
Injuries/fatalities	None	None reported
Damage/environmental impact	Net, trawl warps and trawl doors lost. Structural damage to port gallows, deck and hydraulic winch bedplate crossbeam.	None reported
Ship operation	Engaged in fishing	Military operations
Voyage segment	Mid-water	Mid-water
External & internal environment	Wind: westerly, force 3 Visibility: good Sea State: slight	
Persons on board	4	Not declared

1.2 NARRATIVE

1.2.1 Events prior to the collision

In early April 2015, a pre-deployment brief was held on board a Royal Navy submarine (the submarine) while it was berthed at Her Majesty's Naval Base, Clyde in Faslane, Scotland (HMNB Clyde). At the briefing, which was attended by the captain of the submarine flotilla based in Faslane, consideration was given to potential routing options for the submarine's departure from UK waters. During this discussion, the submarine's Commanding Officer stated his intention to conduct a dived transit south through the Irish Sea.

At an undisclosed time, the submarine sailed from HMNB Clyde, dived, then conducted routine equipment performance checks. Once these checks were complete, the submarine commenced its dived passage south towards the Irish Sea, proceeding below periscope depth[2] **(Figure 1)**.

At 0430 on 15 April 2015, the stern trawler *Karen* sailed from Ardglass, Northern Ireland and headed out to sea. When *Karen* reached its intended fishing grounds, the crew shot the nets and, about 3 hours later, hauled the gear and landed the first catch. This process was repeated and, at about 1500, the crew landed their second haul of the day and shot the net for the third time. Once the gear was away, the skipper settled the vessel on an autopilot controlled heading of 267° at a speed over the ground of about 2.8 knots (kts). The skipper then kept watch in the wheelhouse while the rest of the crew processed the previous catch.

During the afternoon, as the submarine progressed its passage south, the Commanding Officer noted that the traffic density had increased; most of the sonar contacts were assessed to be merchant vessels. The submarine's Commanding Officer considered that it would be impractical to conduct a close quarters procedure[3] for every contact so a decision was taken to continue the dived transit, accepting that the submarine would pass close to merchant vessels.

At 1556, the submarine was on a south-westerly heading at 10kts and the sonar operators identified a new contact, fine on the port bow, that had previously been masked by several other vessels **(Figure 2)**; this was *Karen*. In order to determine the contact's range, the submarine's heading was altered 15° to starboard[4]. The sonar operators listened to *Karen* and analysed the acoustic information; this included an assessment of its shaft revolutions per minute (rpm), propeller configuration and aural characteristics. Based on this information and the absence of trawl noise, the submarine's command team assessed that *Karen* was a small merchant vessel. The submarine's heading was then altered to port onto a south-easterly course in order to determine the ranges of other passive sonar contacts.

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[2] See Section 1.7.3 for description of periscope depth.

[3] A close quarters procedure is a rapid, predetermined set of reactions taken by a submarine to avoid a collision. See also Section 1.8.3.

[4] A description of how a submarine uses passive sonar to detect, locate and classify vessels is at Section 1.8.

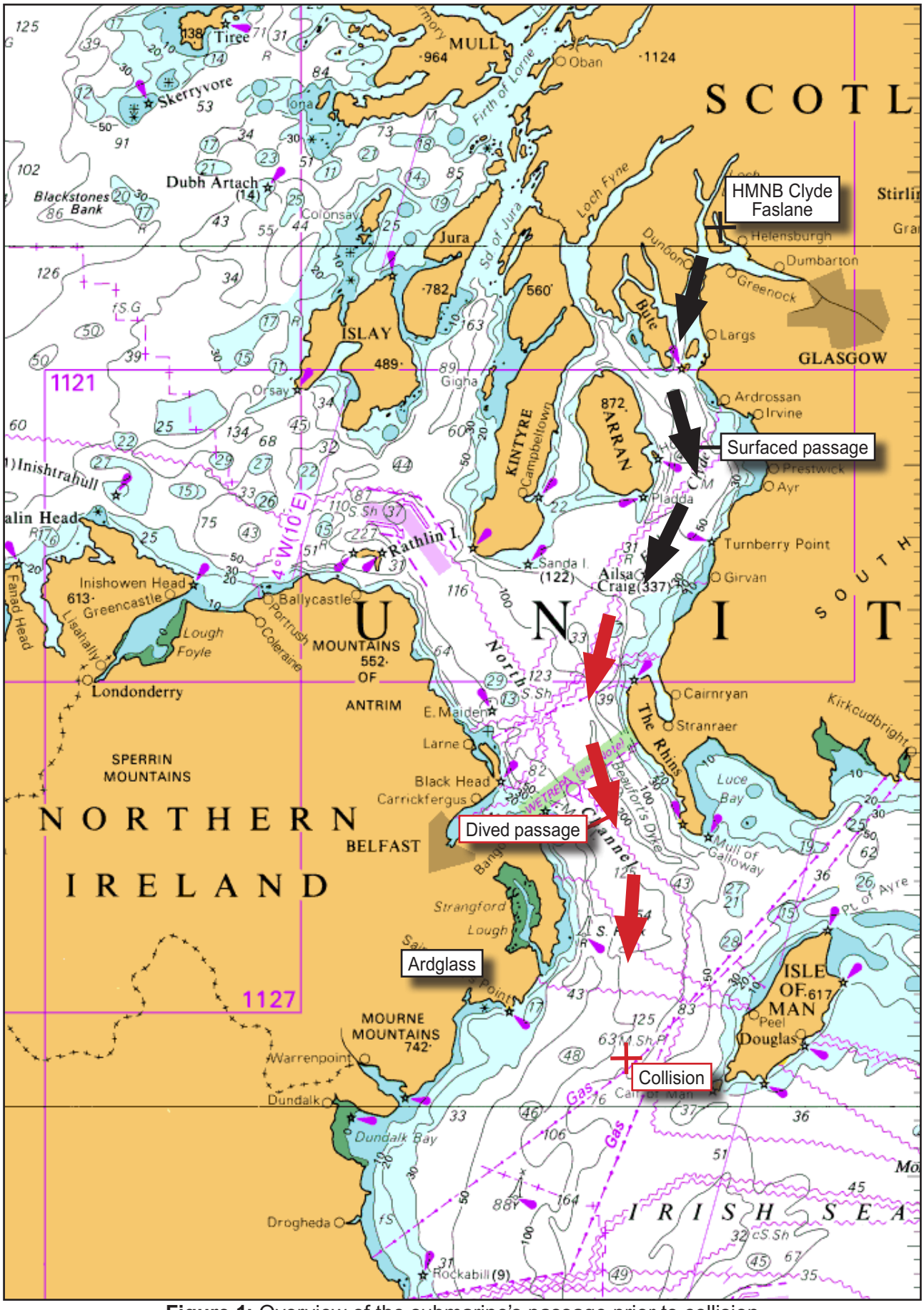

Figure 1: Overview of the submarine's passage prior to collision

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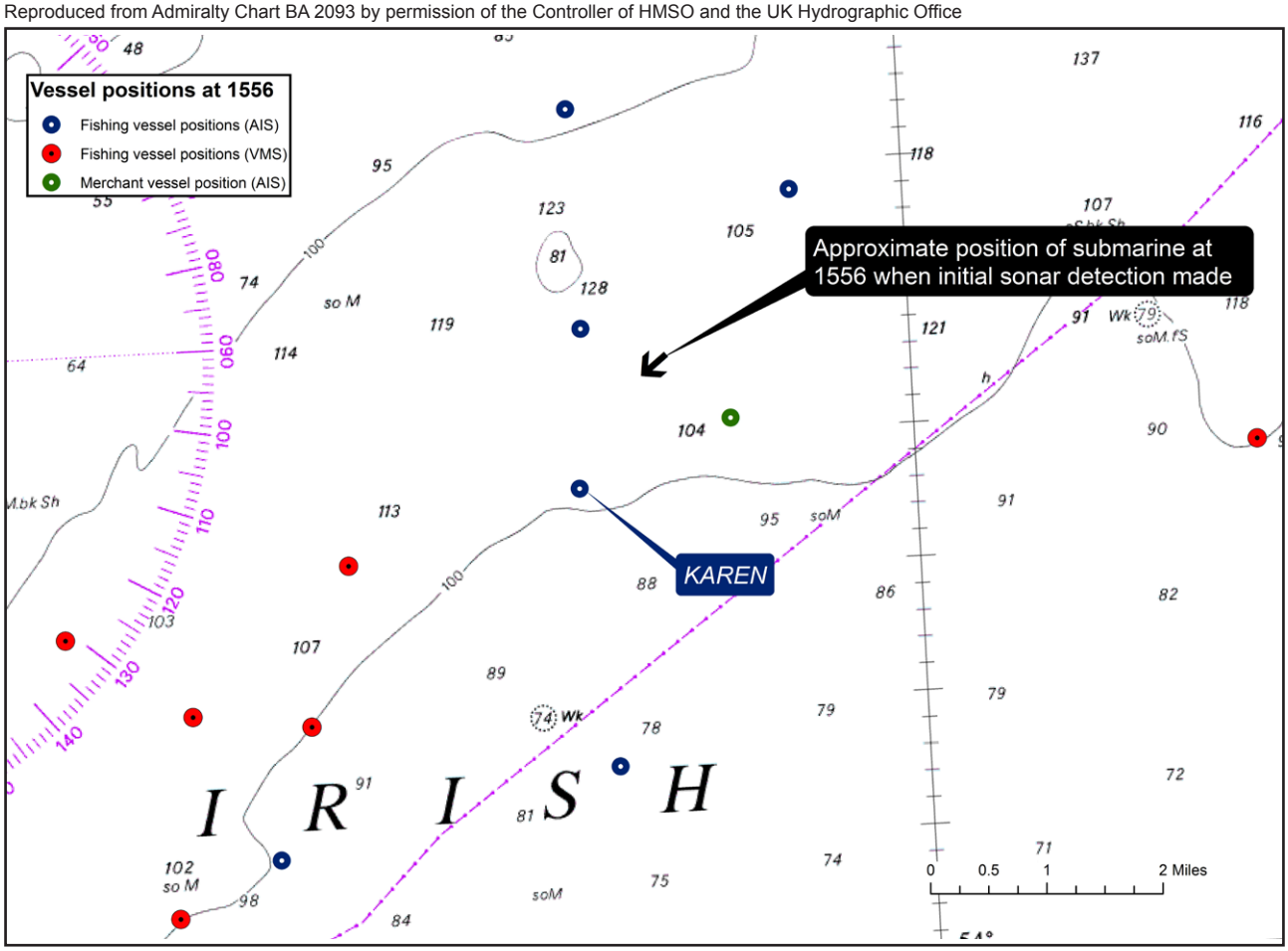

Figure 2: Plot showing the approximate position of the submarine and adjacent shipping at 1556, based on AIS and VMS data

1.2.2 The collision

At 1605, having steadied on a south-easterly heading, the submarine passed close to *Karen*'s stern and snagged its fishing gear. When the collision occurred, *Karen*'s crew heard an unusual noise and realised something was wrong as the trawl warps had unexpectedly tightened and the vessel started to be dragged backwards **(Figure 3)**. The skipper immediately disengaged the propeller and shouted to the crew to release the winch brakes; having done that, both warps started to run away freely. The starboard warp ran out completely but the port warp became fouled on its winch drum and again came taut. This caused *Karen* to heel to port and ship water over the stern as the vessel started submerging backwards under the downward pull on the port warp. Unable to release the tension on the port warp, one of the crewmen started preparing the liferaft for launch, while the others kept clear of the taut wire. After being dragged backwards at about 7kts for around 30 seconds, the port warp parted and *Karen* was released.

1.2.3 Post-collision

After the port warp parted, *Karen* slowed down, returned to upright and the water drained from the deck. With the fishing gear gone, the crew began to assess the situation on board; damage was evident to the port gallows, but the engine was still running and there was no evidence of internal flooding.

At about 1610, the chief petty officer in charge of the sonar team on board the submarine went to the control room to brief the command team that an unusual noise had been detected. Although only audible for a short duration, the noise was

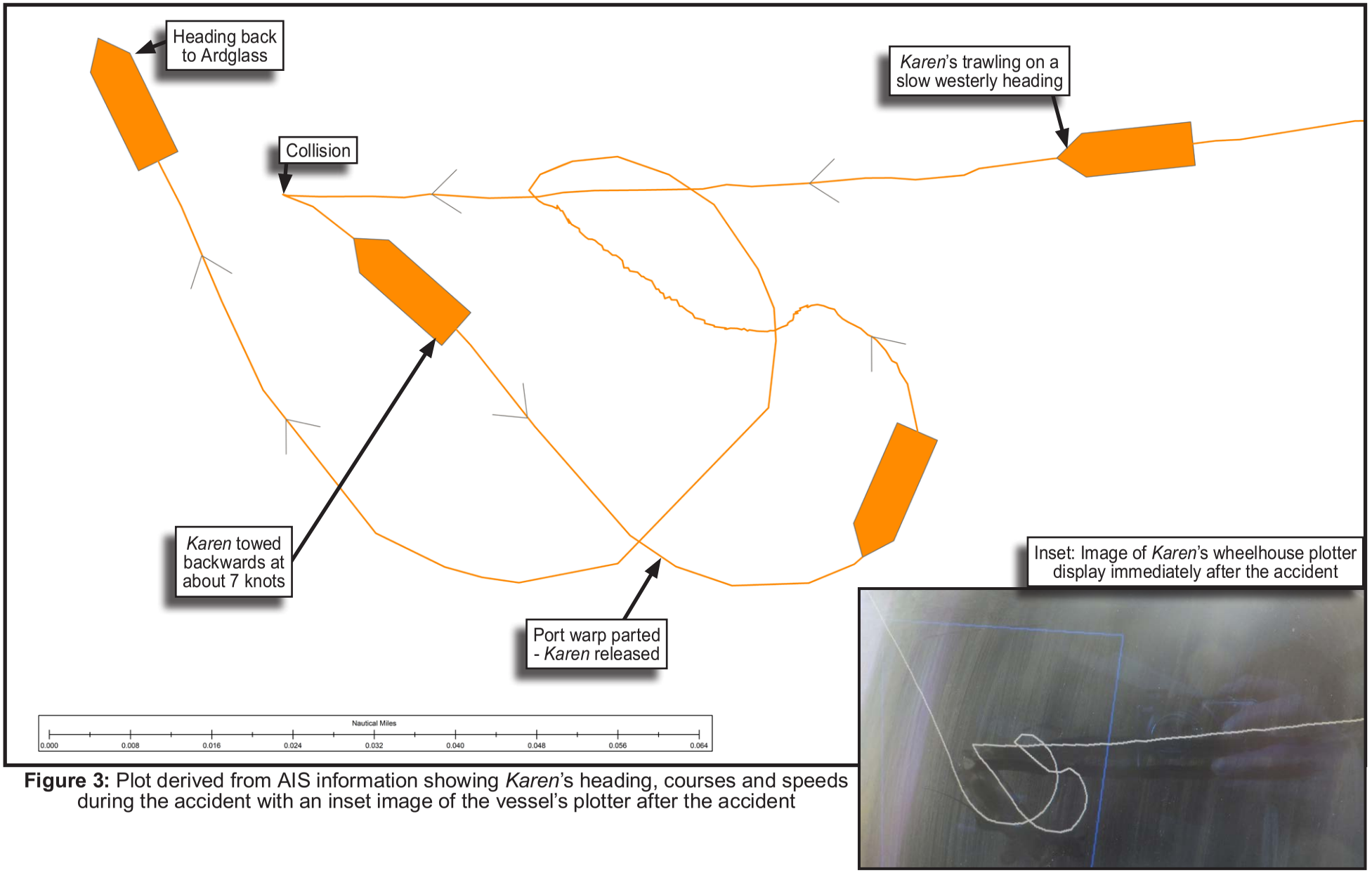

Figure 3: Plot derived from AIS information showing *Karen*'s heading, courses and speeds during the accident with an inset image of the vessel's plotter after the accident

detected on the hull vibration monitoring equipment (HVME)[5] and was also heard on one of the submarine's sonars. This issue was briefly discussed by the command team; it was not assessed as significant and was attributed to the loss of a casing tile[6]. The submarine continued on its dived passage south through the Irish Sea.

At 1615, *Karen*'s skipper called Belfast Coastguard and explained that his vessel had been uncontrollably towed backwards and that all his fishing gear was lost. He also advised the coastguard that his assessment was that the cause of the incident must have been a submarine. Having regained control of his vessel and completed his report to the coastguard, the skipper started to head *Karen* back to Ardglass **(Figure 3)**.

Aware that a military exercise[7] was taking place in training areas north and west of the UK, a watch officer from Belfast Coastguard telephoned the exercise's duty controller at HMNB Clyde at 1628 to report what had happened. The exercise's duty controller referred the coastguard to the Royal Navy's duty submarine controller at the Fleet Operations Division in Northwood, Middlesex. At 1638, the coastguard watch officer phoned the duty submarine controller to notify him of the incident and to ask if any submarines were operating in the area. The duty submarine controller responded by stating that no comment could be made regarding submarine operations.

At 1900, the submarine received a message from its Operating Authority reporting details of the incident including that *Karen*'s crew was safe; the message also stated that an assumption had been made ashore that the submarine was not involved. On receipt of the message, the submarine's Commanding Officer reviewed the situation and realised that he had been responsible for the snagging. The Commanding Officer then decided to continue the dived passage and no further action was taken on board the submarine.

Later that evening, *Karen* arrived back safely in Ardglass **(Figure 4)**.

On an undisclosed date, the submarine returned to HMNB Clyde. During the post-deployment debrief to senior officers, the Commanding Officer confirmed that he had been responsible for the snagging of *Karen* on 15 April 2015.

1.3 ENVIRONMENTAL CONDITIONS

The environmental conditions in the accident location were:

Sunrise:	0621
Sunset:	2024
Wind:	westerly, force 3
Weather:	clear, sunny
Sea state:	slight
Visibility:	good
Tidal stream:	265°, less than 0.5kt
Depth of water:	100m

[5] HVME – A system using a series of sensors to monitor and assess the submarine's own noise emissions.

[6] The outside of the submarine is covered in acoustic tiles, which can occasionally break free when the submarine is underway underwater.

[7] The exercise was Joint Warrior 151 (see Section 1.10.5).

Sonar conditions: no evidence has been presented to indicate that there was any significant environmental condition that could have affected the acoustic detection of surface vessels by the submarine's sonar equipment.

Image courtesy of Ross Boats Ltd

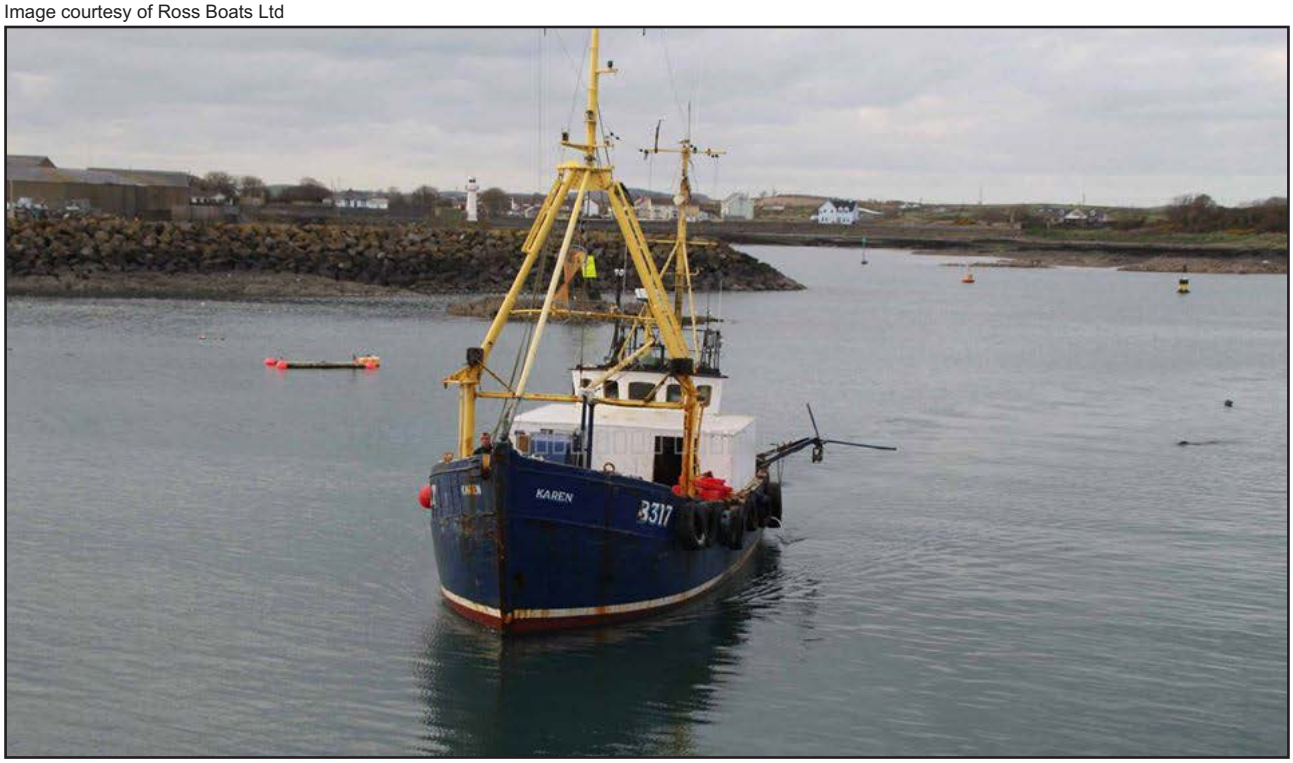

Figure 4: *Karen* returning to Ardglass – damage evident on port side

1.4 FISHING VESSEL *KAREN*

1.4.1 General description

Built in Denmark in 1975, *Karen* was a 19.23m stern trawler of wooden construction. The vessel was registered in Belfast, owned by Mr T Wills and Sons Limited and operated out of the fishing port of Ardglass, Northern Ireland.

Karen's Kelvin Marine 209kW main engine drove a single shaft with a 4-bladed propeller through a 1:3.75 ratio reduction gearbox. When trawling, the skipper adjusted the engine revolutions to achieve an optimum trawling speed of 2.8kts over the ground. Depending on the tidal effect, this would usually require an engine speed of between 800 and 900rpm, which equated to a shaft rpm range of 213 to 240.

Karen's navigation equipment included a radar, echo sounder, chart plotter, fish finder, a digital selective calling (DSC) capable very high frequency (VHF) radio, a Class A automatic identification system (AIS) transceiver and two global positioning system (GPS) receivers. *Karen* was also fitted with a float-free electronic position indicating radio beacon (EPIRB).

Karen was rigged with a single demersal[8] trawl used for catching prawns. The net was towed using two 14mm diameter steel wire warps operated from separate winch drums positioned on the fore deck. The ends of the warps were connected to the drums using thin pieces of rope. The warps ran from the drums, through the

[8] Demersal fishing catches species that live at or near to the seabed.

shelterdeck to gallows on each side of the wheelhouse then over the stern into the water **(Figure 5)**. The warp length was typically four times the depth of water; at the time of the accident, the total length of *Karen*'s tow, including the net, was 457m.

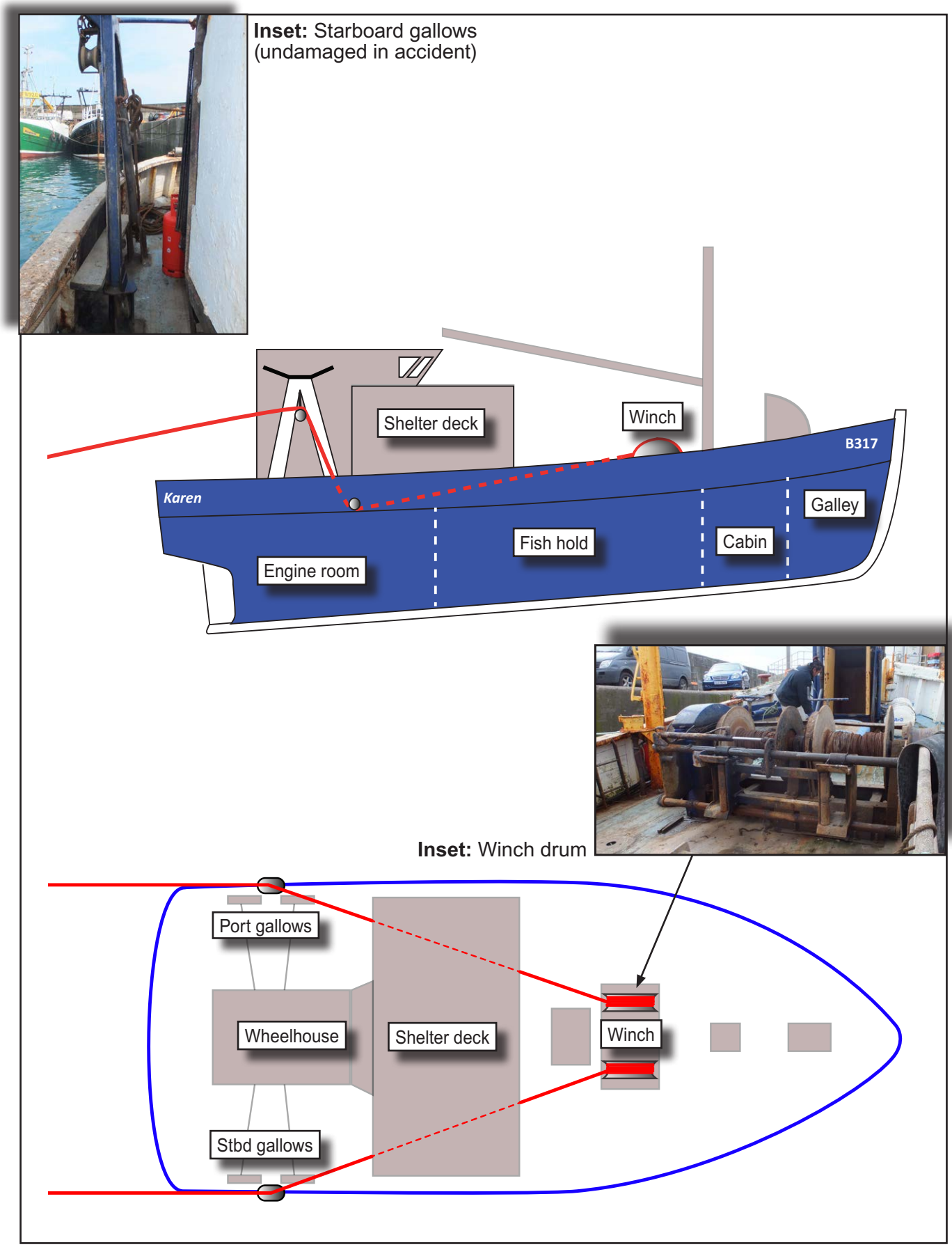

Figure 5: *Karen* – layout showing rigging of trawl warps

1.4.2 Crew

Karen was operated by a 4-man crew. The skipper was a 46-year-old UK national who held a Maritime and Coastguard Agency (MCA) Class 2 fishing vessel skipper's certificate of competency. He was a career fisherman with over 24 years' experience as a skipper, the last 5 of which had been on board *Karen*. The other three crewmen were Filipino nationals; they were all experienced fishermen and had completed the mandatory training required to work on UK registered fishing vessels.

1.5 DAMAGE

In addition to the loss of its net, trawl warps and doors, *Karen* suffered significant damage as a result of the accident, specifically:

- The port gallows structure was distorted and had collapsed onto the port after bulwark. The bulwark's top rail was cracked where the port gallows had collapsed onto it **(Figure 6)**.

- Deck planking around the port gallows' foundation plate was broken and damaged **(Figure 7)**.

- The internal transverse beam in the fish hold that supported the hydraulic winch bedplate was cracked **(Figure 8)**.

The Royal Navy stated that the submarine had been inspected on its return to Faslane and no damage had been found.

Image courtesy of the Maritime and Coastguard Agency

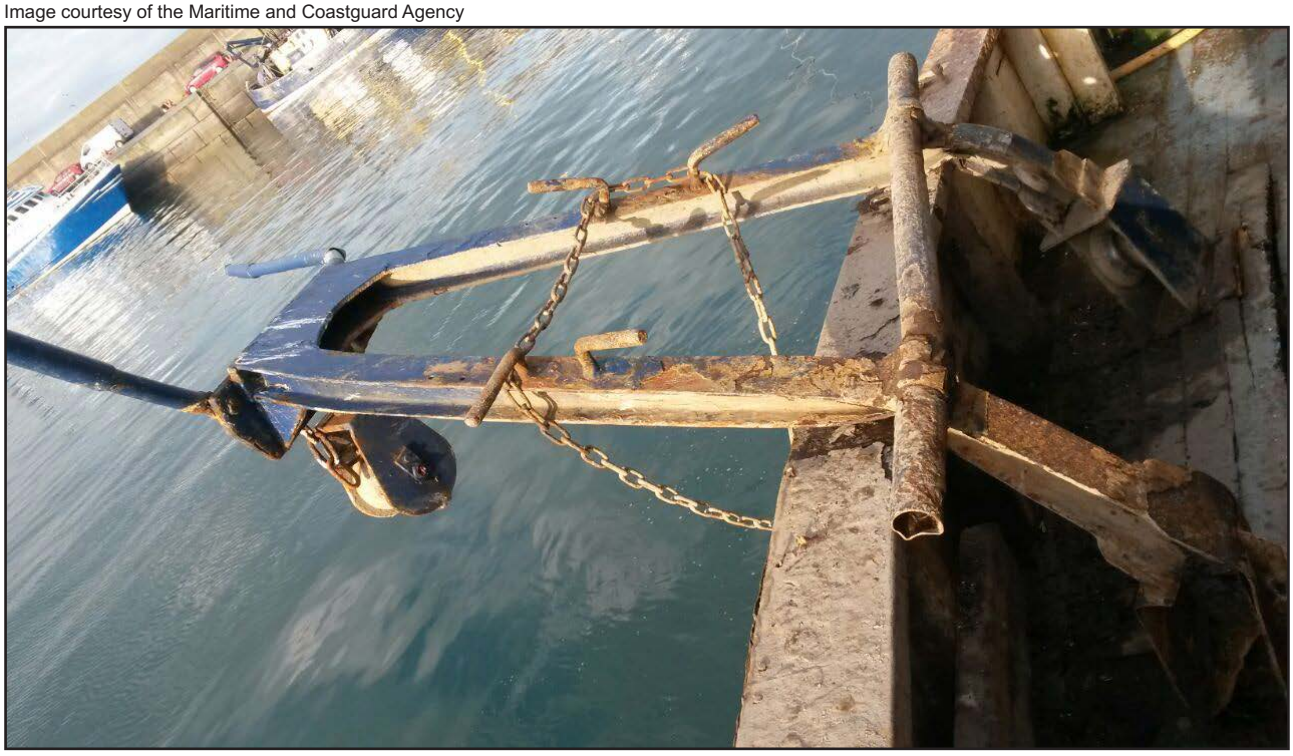

Figure 6: *Karen* – damage to port gallows and bulwark top edge

Figure 7: *Karen* – damage to deck planking around port gallows foundation plate

Image courtesy of Cummins Marine Surveys Ltd

Figure 8: *Karen* – crack in fish hold transverse beam used to support the hydraulic winch bedplate

1.6 RECOVERY AND EXAMINATION OF *KAREN*'S FISHING GEAR

Karen's net and one of its trawl doors were recovered off the seabed in the same fishing grounds by other trawlers in the weeks after the accident. The recovered net was identified as having originated from *Karen* based on its Northern Ireland Government identification tag[9]. MAIB inspectors examined the net and found extensive damage to the mesh on the starboard side **(Figure 9)**. The headline rope and grass rope were both damaged and broken and the cod end rope appeared to have been cut.

Samples of the recovered net and the broken end of the port trawl warp that had remained on board *Karen* after the accident **(Figure 10)** were sent to Materials Technology Limited (MTL) for laboratory examination. Key conclusions of the MTL examination report included:

- The port trawl warp showed evidence of failure due to tensile overload, and the applied failure load would have been in the region of 13 tonnes(t) **(Figure 11)**.
- Samples from the headline and grass ropes both showed evidence of tensile overload failure; their steel wire cores were also heavily corroded **(Figure 12)**.
- The cod end bag rope had been cleanly cut with a sharp single blade or cropper **(Figure 13)**.

[9] The Northern Ireland Government Department for Agriculture and Rural Development places identity tags on fishing nets than can be traced to its owner.

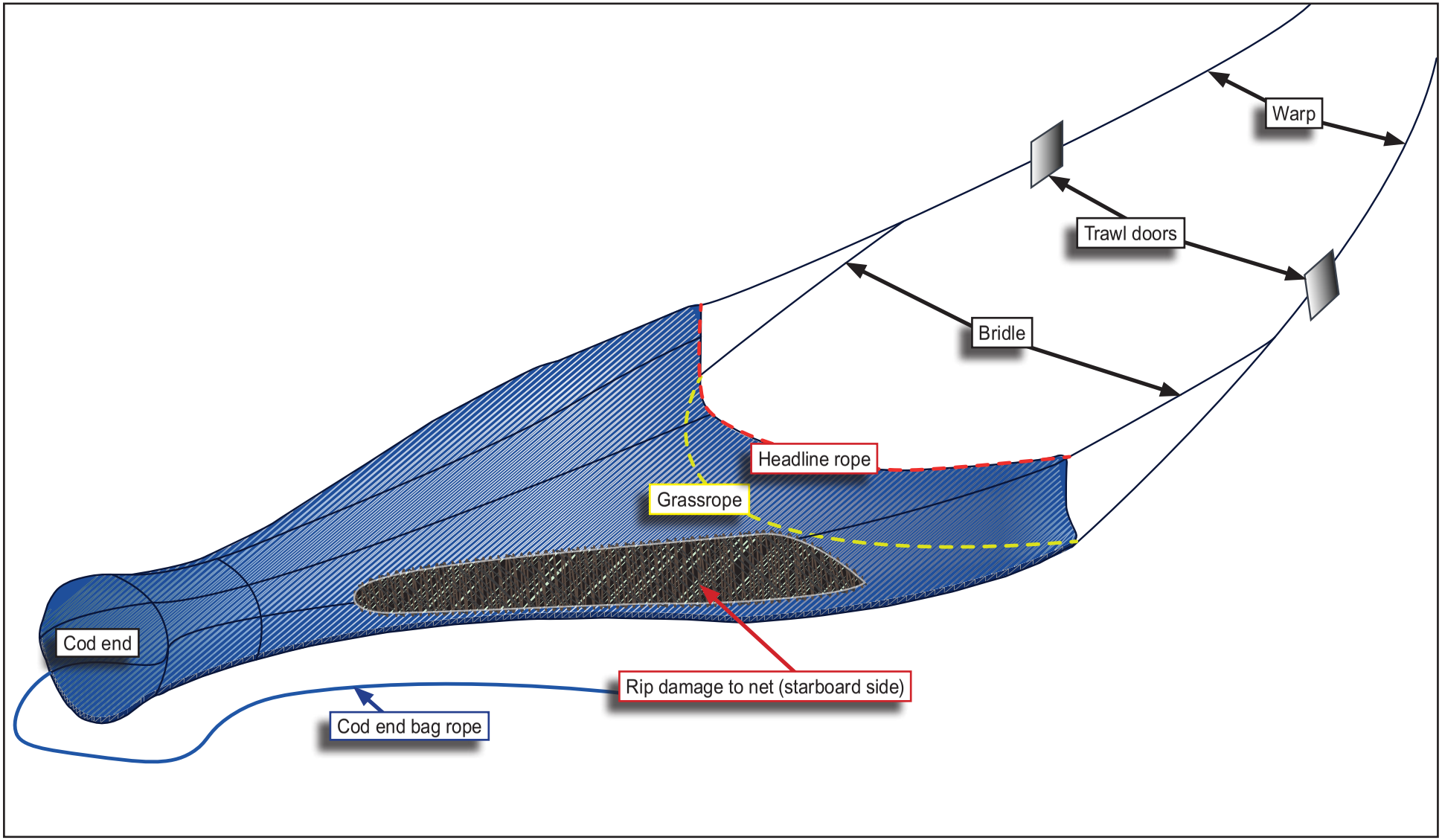

Figure 9: Diagram of fishing gear showing areas of damage and sections removed for further analysis

Figure 10: *Karen* – broken end of the port trawl warp that was left on board after the warp parted

Image courtesy of Materials Technology Ltd

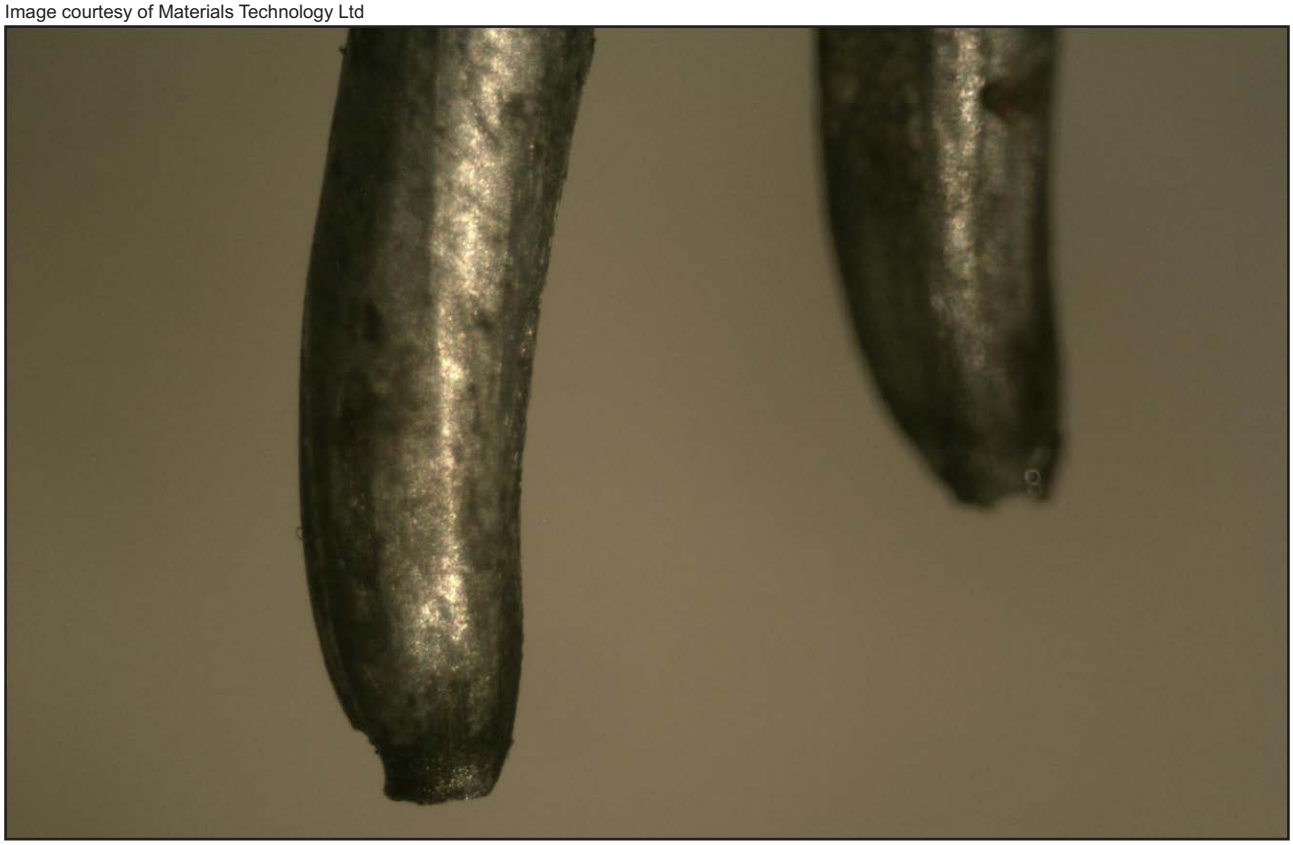

Figure 11: Close-up of strands of the port warp showing 'cup and cone' ductile failure indicative of overload failure

Image courtesy of Materials Technology Ltd

Figure 12: Starboard grass rope point of failure showing corroded central steel wire rope and external sisal core

Image courtesy of Materials Technology Ltd

Figure 13: Cod end bag rope showing spliced shackle and cut end

1.7 ROYAL NAVY SUBMARINES

1.7.1 The fleet

At the time of the accident, the Royal Navy was operating a fleet of 10 nuclear-powered submarines: 4 Vanguard class, 4 Trafalgar class and 2 Astute class submarines. Vanguard and Astute class submarines were based at HMNB Clyde in Faslane and the Trafalgar class submarines were based at HMNB Devonport in Plymouth, England.

The Vanguard class submarines, HMS *Vanguard*, HMS *Victorious*, HMS *Vigilant* and HMS *Vengeance* were 149.9m in length, had a displacement of 15,900t and were capable of speeds up to 25kts. These submarines carried the trident ballistic nuclear missile system and maintain the 'continuous at sea' strategic deterrent patrol.

The four Trafalgar class submarines, HMS *Talent*, HMS *Torbay*, HMS *Trenchant* and HMS *Triumph,* were 85.4m in length, had a displacement of 5,298t and were armed with torpedoes and land attack missiles.

The two Astute class submarines, HMS *Astute* and HMS *Ambush,* were 97m in length, had a displacement of 7,400t, were capable of speeds up to 30kts and, similar to the Trafalgar class, were armed with torpedoes and land attack missiles.

The Royal Navy disclosed neither the name nor the class of the submarine involved in this accident to the MAIB.

1.7.2 Operational command and control

The Royal Navy managed and operated its fleet from two sites: the 'Navy Command' Headquarters (HQ), at Whale Island in Portsmouth, and the Fleet Operations Division, at the Northwood HQ in Middlesex. The Fleet Operations Division was headed by the Commander Operations (COMOPS); a Royal Navy Rear Admiral with submarine command experience.

Within the Northwood HQ, command and control of submarines was exercised by two Operating Authorities[10]: Commander Task Force (CTF) 345, who exercised command of the Vanguard class strategic deterrent submarines; and CTF 311, who exercised command of all other UK submarines and NATO submarines operating in the Eastern Atlantic and UK waters.

Operating Authorities have responsibility for submarines' routing, waterspace management, communications, intelligence, logistics support and dealing with emergencies. Waterspace management is designed to deconflict the operations of submarines from other naval units by allocating them dedicated areas or routes. The Operating Authorities were continuously manned and had access to a wide variety of information sources necessary to support submarine operations; this included 'real time' maritime data such as AIS information on shipping.

Operational security is a critical factor in delivering submarine operations. It was a long-standing policy of the Ministry of Defence (MoD) not to comment publicly

[10] Given that the class of submarine involved in this accident has not been disclosed by the Royal Navy, it follows that the Operating Authority exercising command and control in this case has also not been determined. Nevertheless, the term 'Operating Authority' will be used in this report to refer to the submarine's shore-based command and control HQ.

about submarine operations. Commanding Officers of submarines also held orders in operational documentation that normally required them to conduct operations without being detected; one aspect of this would be to maintain radio silence[11].

1.7.3 Modes of operation

Submarines can operate in two modes:

- Surfaced: The submarine is fully buoyant with the fin and casing visual and an officer of the watch / lookout posted on the bridge.

- Dived:
  - Periscope depth: The submarine is fully submerged but at a shallow depth where periscopes and radar could be used.

  - Deep: Any depth below periscope depth.

When surfaced, submarines comply with the International Regulations for the Prevention of Collisions at Sea (COLREGs), including showing appropriate lights and shapes. There is no provision in the COLREGs for dived submarines; this means that responsibility for collision avoidance rests entirely with its commanding officer once a submarine has dived. When deep, submarines operate at a depth where there is no risk of collision with any merchant vessel that could be encountered; this is known as 'safe depth' **(Figure 14)**.

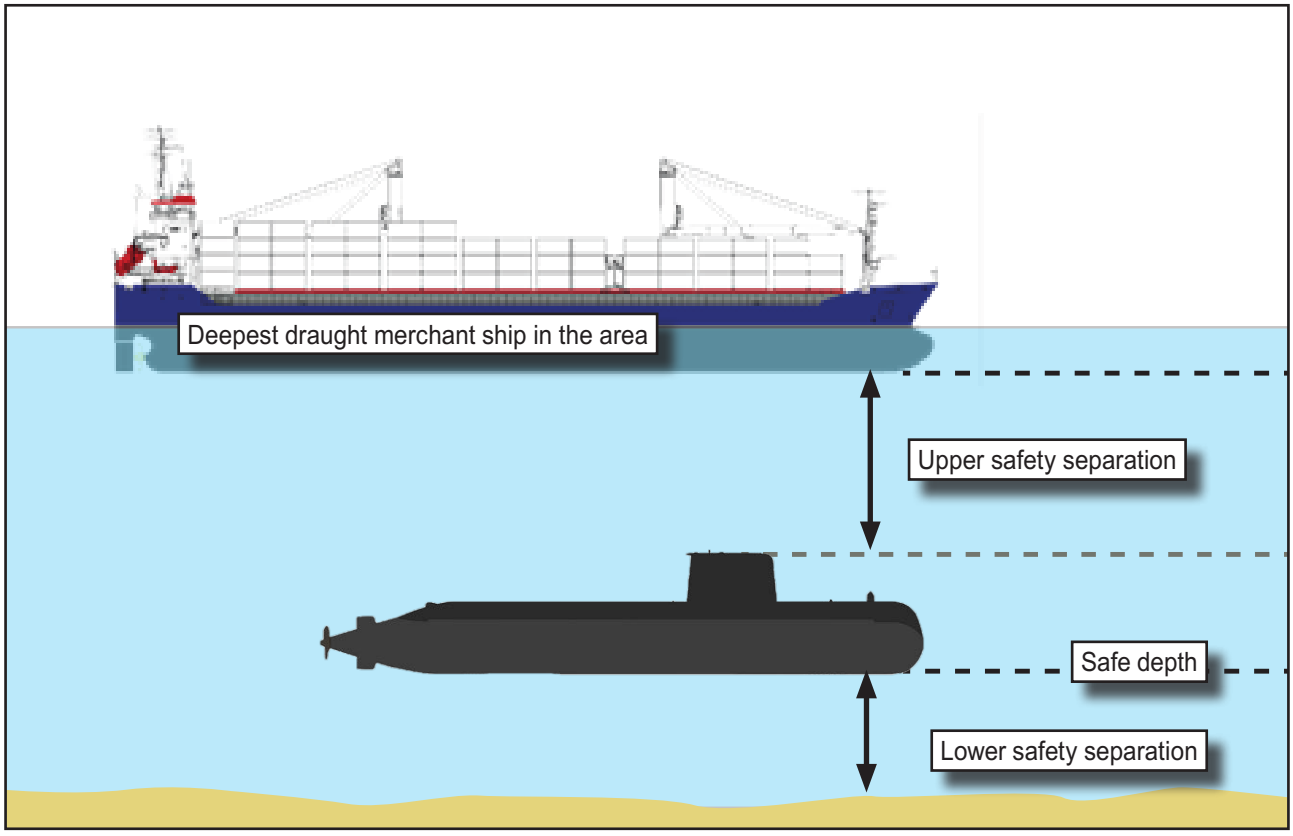

Figure 14: Illustration (not to scale) of a submarine at safe depth

[11] 'Radio silence' meaning receiving communications from shore but not transmitting any messages back by any means.

1.7.4 Navigation and communications

Royal Navy submarines are fitted with computerised, inertial navigation systems that are designed to deliver continuous, highly accurate positional information. Submarines are also equipped with a suite of communications equipment utilising long range, very low frequency (VLF) receivers for information broadcast by the Operating Authority as well as high frequency (HF), VHF and satellite equipment for other ship-to-shore and ship-to-ship exchanges. When submarines operate on the surface or at periscope depth, they can receive AIS information transmitted by surface vessels in the area.

1.8 MANAGEMENT OF SONAR CONTACTS

1.8.1 Contact detection and classification

A submarine's sonar equipment is used continuously to detect, analyse and assess shipping contacts; data received is also recorded for further analysis after the submarine has returned to its base. When a submarine is operating on the surface or at periscope depth, sonar information can be used in conjunction with visual, radar and AIS information to build a picture of shipping in the vicinity. When a submarine is deep, visual, radar and AIS information is not available and sonar becomes the only method for monitoring the movements of other vessels. At the time of the accident, the submarine was deep and using its sonar equipment in a 'passive' mode, listening for the sounds emanating from other vessels.

Sonar specialist crew members on board submarines are trained to analyse the detailed acoustic characteristics of passive contacts to determine, inter alia, a vessel's shaft rpm, propeller blade configuration and other discrete noises generated by machinery or equipment. Distinctive noises associated with fishing equipment can also be detected, such as nets and warps passing through the water or being dragged along the seabed; these are referred to as *trawl noise*.

The information detected by sonar operators is reported to the submarine's command team in the control room. The command team then assess the information provided to determine the type of vessel for each surface contact.

Where multiple surface contacts are present in close proximity, it is possible for an individual ship to remain undetected by a submarine when only passive sonar is in use. This occurs because the sonar operator may only hear the noisiest vessel when two or more are on a similar bearing; this phenomenon is known as *masking*.

1.8.2 Analysis of passive sonar contacts

Passive sonar is only capable of determining the bearing of another vessel; it does not show the vessel's range, course or speed. In order to determine the relative position and movement of passive sonar contacts, command teams monitor their bearing movement. In the same way as would be apparent to the officer of the watch on a ship observing visually, a steady bearing on a sonar contact can indicate a risk of collision.

The bearings of passive contacts are plotted by a computer and this data can be used by tactical system operators to estimate the range, course and speed of the ship being detected. This process is called target motion analysis (TMA) and an estimated position, course and speed of the other vessel is referred to as a *solution*.

The process of determining the range of a passive sonar contact can be significantly improved by the submarine altering course and/or speed as the subsequent change in bearing movement allows the command team to refine the solution, in particular the contact's range. Changing the submarine's course and/or speed to determine the range of passive contacts is called a *ranging manoeuvre*.

The TMA process can also be refined using the additional acoustic evidence available. For instance, if a passive sonar contact has the acoustic characteristic of a large merchant vessel, the submarine's command team can work to find solutions at speeds typical for such a vessel. Equally, if the sonar operators hear trawl noise, then the command team will classify the contact as a vessel engaged in fishing, and find TMA solutions at speeds typical for such a vessel. The workload of sonar and tactical system operators is a function of the number of contacts being detected and analysed.

Figure 15 illustrates the passive TMA process prior to the collision. The submarine's track, including the ranging manoeuvre, is shown in black and two possible TMA solutions are also shown. The more distant contact (shown in green) is a solution using a typical merchant vessel speed of 10kts, and the closer contact (shown in red) is a solution for a vessel speed of 2.8kts, representative of *Karen*'s actual relative movement.

1.8.3 Close quarters procedures

In the event of a deep submarine making a sonar detection of a new contact that could present a risk to the submarine, the command team would undertake a *close quarters procedure*. This was a rapid, predetermined set of reactions intended to avoid collision. The Royal Navy has not disclosed to the MAIB the nature of the close quarters procedures in use by its submarines or the detail of the circumstances in which such action would be taken.

1.9 PASSAGE PLANNING

1.9.1 Royal Navy guidance

The Admiralty Manual of Navigation Volume 1, *The Principles of Navigation*, Book of Reference (BR) 45(1) is the Royal Navy's primary reference for the planning and conduct of navigation. The conduct of coastal navigation is covered by Chapter 12; key extracts include:

> ***SECTION 1 – PLANNING COASTAL NAVIGATION***
>
> ***1210. Check Lists and Navplan Preparations***
>
> ***b. Appraisal.*** *After completing initial research, appraisal of the following items should be carried out as soon as possible thereafter…*

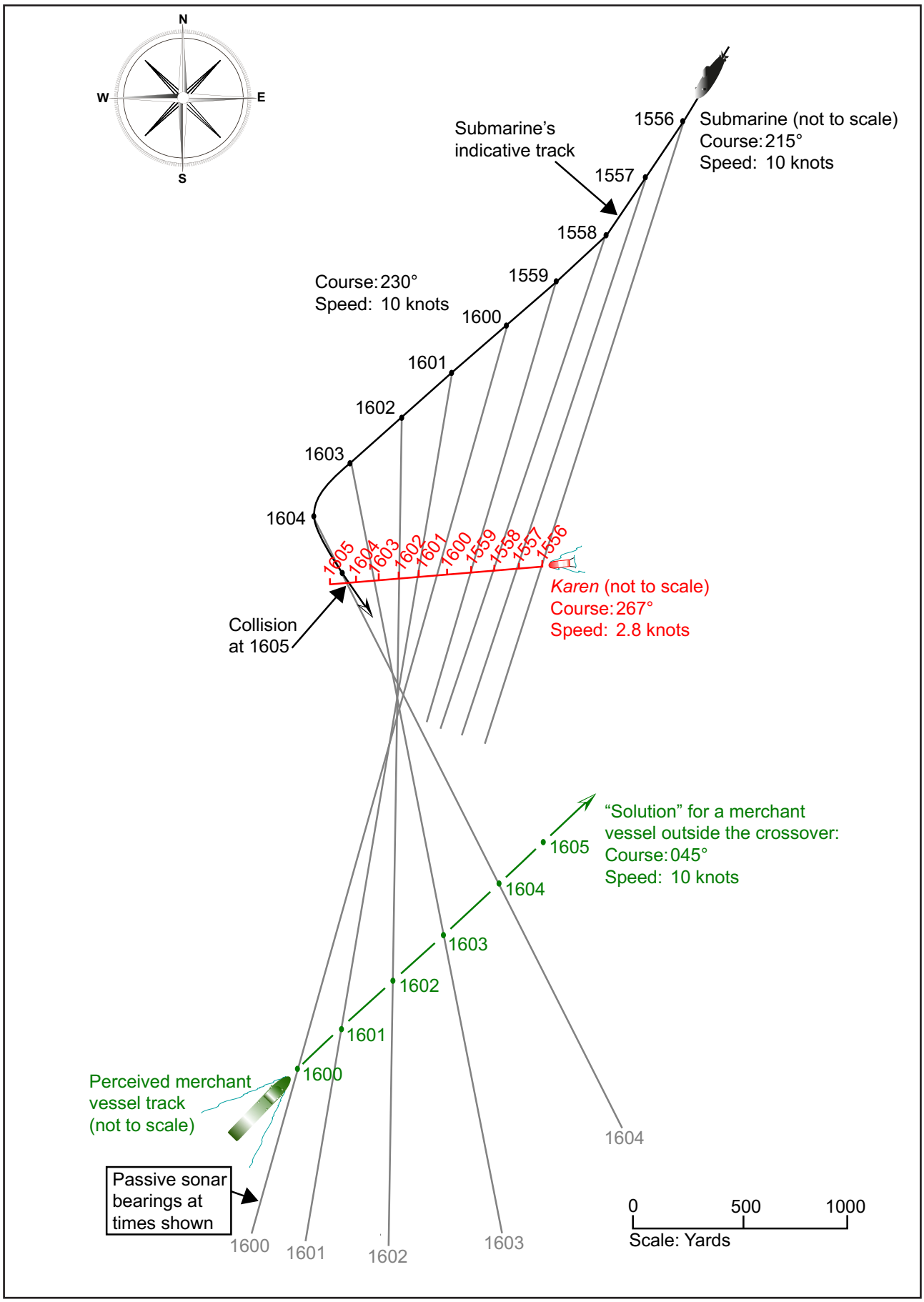

Figure 15: Illustration of TMA process showing potential solutions for vessels at 2.8kts and 10kts

- *ETD[12]s / ETA[13]s and refined speed of advance (SOA).*
- *TSS[14], shipping lanes, traffic density, likely concentrations of fishing vessels.*
- *Exercise areas.*
- *Any limitations of ship.*
- *Maritime Jurisdiction, Innocent Passage and Diplomatic Clearance.*
- *Intelligence requirements / planning.*
- *Cross check all available sources of navigation and other information.*

1211. Criteria for Route Selection

Fishing Vessels. *In Coastal Navigation, fishing vessels / fishing fleets may be encountered. Concentrations of fishing vessels should be avoided if possible.*

Additional guidance was available to submarine navigating officers for planning dived submarine navigation; this information was not released to the MAIB.

1.9.2 Fishing patterns

On the day of the accident, *Karen* was one of 61 fishing vessels operating in the fishing grounds between Ireland and the Isle of Man. At the time of the accident, this area was included in the European Union (EU) *Cod Recovery Zone*[15], active between 14 February and 30 April 2015. This regulation prevented any type of fishing for white fish and, as a result, all of the active trawlers in the area would have been fishing the seabed for prawns. Prawns can be caught all year round, but spring and summer provide a better harvest due to the longer daylight hours. This was relevant for vessels such as *Karen* that use a net, designed to catch prawns that have emerged from seabed burrows in daylight. Larger fishing vessels with heavier gear can work all hours as the trawls dig into the seabed and catch prawns in any light condition. This meant that the concentration of vessels engaged in fishing in the area was likely to reduce during darkness. In addition, between October and May, the prawn fishery is generally better in deeper water. Typically, this results in a situation where submarines and trawlers will both tend to operate in the same area during the winter and spring months.

When active at fishing grounds, trawlers are normally in a continuous process of shooting nets, trawling and then recovering the gear, thus the risk of collision for a submarine operating in the same area is ever-present.

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[12] Estimated time of departure.

[13] Estimated time of arrival.

[14] Traffic separation schemes.

[15] The Cod Recovery Zone in the Irish Sea was implemented by the UK Government in order to meet the requirements of the EU Council Regulations No. 1342/2008 and 57/2011.

1.10 SUBMARINE OPERATIONS IN THE VICINITY OF FISHING VESSELS

1.10.1 Guidance for submarine command teams

Guidance for UK submarine command teams was contained in the Royal Navy's BR0095, *Fishing Vessel Avoidance*; key extracts include:

> Annex 1A stated that *the safety of life is of paramount importance and over-rides all other considerations.*
>
> Para 0103(b) stated that *where practicable routine transits of coastal waters will be undertaken on the surface,* but that *essential dived transits through coastal waters are to be conducted at periscope depth (PD) at slow transit speeds and only for short periods…*
>
> Para 0104(5) specified a mandatory separation of at least 4000yds[16] from all vessels classified as possible fishing vessels, whether or not they are believed to be engaged in fishing.
>
> Para 0105(a) stated that *when shipping and navigation constraints arise, and it becomes impractical, for whatever reason, for a submarine below PD to maintain 4000 yards separation, it must return to PD in as short a time as possible.*

1.10.2 The Fishing Vessel Code of Practice

In 1993, The Royal Navy first published its unclassified *Code of Practice for Fishing Vessel Avoidance* (the FV Code) **(Annex A)**.

The FV Code had been accepted by the Fishing Industry Safety Group (FISG) and was last revised and updated in 2002. It stated that the FISG had acknowledged an *essential military requirement* to operate submarines dived in waters where UK vessels engaged in fishing may be operating. Similar to BR0095, the FV Code stated that, if a deep submarine was unable to maintain a mandatory separation of 4000yds from any vessel possibly engaged in fishing, it should return to periscope depth as soon as possible.

In the event of a collision between a submarine and a fishing vessel, the FV Code listed actions to be taken by the submarine; these included slowing down, returning to periscope depth, communicating with the fishing vessel, surfacing to render assistance and reporting the incident to its Operating Authority.

1.10.3 Submarine information broadcasts

The Royal Navy operated a warning system, referred to as SUBFACTS[17], intended to notify mariners of the presence of dived submarines operating in designated exercise areas **(Figure 16)**. SUBFACTS information was compiled by the duty submarine controller at the Fleet Operations Division in Northwood. It was then broadcast at 0620 UTC and 1820 UTC daily via the coastguard on VHF radio and also using the Navigational and Meteorological Warning Broadcast Service (NAVTEX).

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[16] Distances in this report relating to submarine operations are stated in yards, which is the unit of measurement used by UK submarines; 1 yard equals 0.9144m.

[17] Full details of the SUBFACTS system were promulgated in the Admiralty List of Radio Signals (ALRS) Volume 3 Part 1.

Image extracted from the Royal Navy Code of Practice for Fishing Vessel Avoidance **(Annex A)**

Figure 16: SUBFACTS area coverage diagram

At 0720 on 15 April 2015, the following SUBFACTS warning message was issued **(Figure 17)**:

SUBFACTS …warning (all times UTC).

1. Dived submarine operations in progress:

- *North Channel – North of Calf of Man and East of Tiree:*[18]
- *Between 150600 and 160700 APR.*

[18] The SUBFACTS area described in the broadcast message promulgated on the day of the accident was not in accordance with the pre-designated submarine exercise areas described in ALRS or MGN 12(F) (**Annex B** to this report).

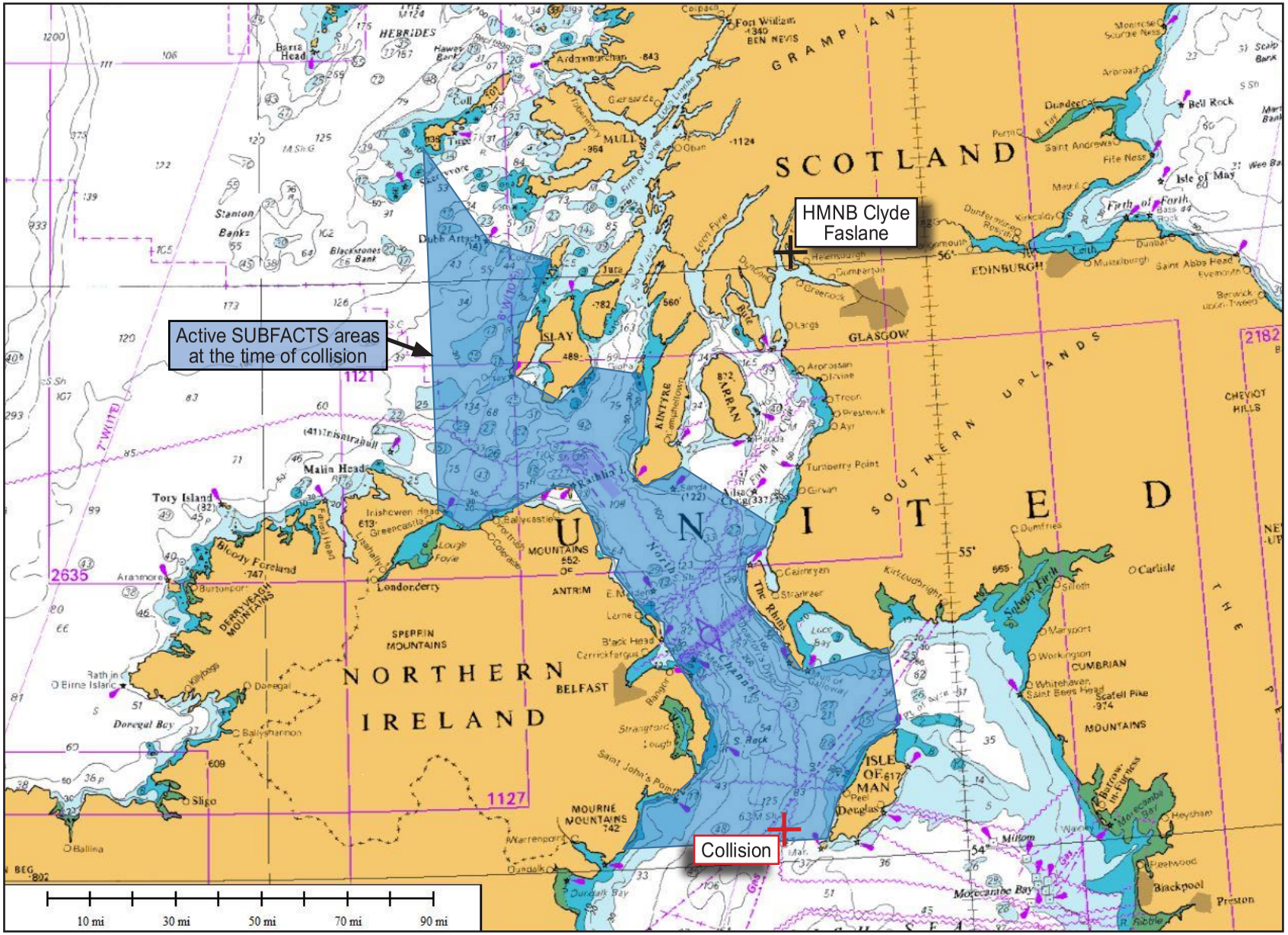

Figure 17: Active SUBFACTS areas at the time of the accident

The accident location was about 1 mile inside the southern boundary of this SUBFACTS promulgated area.

Similar messages were transmitted the day before the accident and later the same day, which warned of submarine activity in the same areas between 0700 on 14 April 2015 until 0800 on 16 April 2015.

1.10.4 Marine Guidance Note 12(F)

In 1997 the Marine Safety Agency (MSA)[19] published its Marine Guidance Note (MGN) 12(F), *Fishing vessels operating in submarine exercise areas* **(Annex B)**. The MGN described the measures implemented by the Royal Navy to minimise the risks to fishing vessels when operating in known submarine exercise areas. This included details of the exercise areas, the SUBFACTS broadcast arrangements and the responsibilities of the Fishing Vessel Safety Ship (FVSS) appointed during submarine exercises. MGN 12(F) also contained recommended actions to be taken by fishing vessels when operating within a known submarine exercise area. This advice included:

- Making use of the SUBFACTS broadcast.
- Ensuring a radio watch is kept on VHF channel 16.
- If stopped in the water, ensuring all electronic equipment such as fish finders and echo sounders, capable of generating pulses in the water, are operating.
- In the event of a total power failure and, therefore, a risk of not being detected by a submarine's passive sonar, the fishing vessel should contact the coastguard immediately and consider releasing fishing gear for later recovery.

The MGN also reminded fishing vessel skippers to ensure that they are showing the correct navigation lights and shapes in order to allow dived submarines at periscope depth to correctly identify them.

1.10.5 Military exercises

The military exercise taking place at the time of the accident was Exercise *Joint Warrior 151*. The MoD's Joint Tactical Exercise Planning Staff (JTEPS) plan and deliver this major land, sea and air training exercise that takes place twice a year, predominantly in areas to the north and west of Scotland. Before the exercise started, the Director of JTEPS published a letter **(Annex C)** setting out the exercise areas in use, including where dived submarine operations were planned to take place. The submarine exercise areas detailed in the JTEPS letter **(Annex C)** did not correlate with the areas published in MGN 12(F) and the areas it indicated as being active on 15 April 2015 were not included in the SUBFACTS broadcast for that day.

[19] MGN12(F) was published in 1997 by the Marine Safety Agency and, although this predates the formation of the Maritime and Coastguard Agency, this MGN remains in force as an MCA publication.

1.11 ELECTRONIC DATA SYSTEMS

1.11.1 Statutory requirements

EU Directive 2002/59/EU required all fishing vessels over 15m in length and registered with an EU state to be fitted with a Class A AIS transceiver. The system was required to be maintained in operation at all times and only switched off if considered necessary by the skipper in the interests of safety.

It was also a mandatory requirement for all EU fishing vessels greater than 12m in length to carry vessel monitoring system (VMS) units. The VMS used transmitters fitted to fishing vessels for the Northern Ireland and Scottish Governments to monitor fishing activity in the area. The VMS units transmit a fishing vessel's identification, location, movement and fishing status approximately every 2 hours. Unlike AIS, VMS data was not available in real-time to other vessels in the area.

1.11.2 Automatic identification system data from *Karen*

Key data points from *Karen*'s AIS transmissions are shown at **Table 1**.

Time (15 April 2015, UTC+1)	Heading	Course over ground (COG)	Speed over ground (SOG) (knots)
1605:33	268°	273.6°	3.1
1605:54	279°	264.1°	0.2
1606.11	310°	138.3°	5.9
1606:31	298°	122.4°	6.9
1607:03	208°	034.4°	1.6

Table 1: Tabular data from *Karen*'s AIS transmissions at the time of the accident

A plot showing *Karen*'s AIS track during the accident and an image of the wheelhouse plotter taken just after the accident is at **Figure 3**.

1.11.3 Data in the accident vicinity

AIS data for 30 minutes prior to the accident, in *Karen*'s vicinity, **(Figure 18)** shows:

- Forty fishing vessels, concentrated in the deeper water
- One ro-ro ferry
- Six other merchant vessels
- One fisheries research vessel

AIS data was also examined for times of 24 and 48 hours prior to the accident; this showed similar levels of activity.

VMS data identified an additional 21 fishing vessels that were underway in the area at the time but which had not been recorded by AIS.

Reproduced from Admiralty Chart BA 2093 by permission of the Controller of HMSO and the UK Hydrographic Office

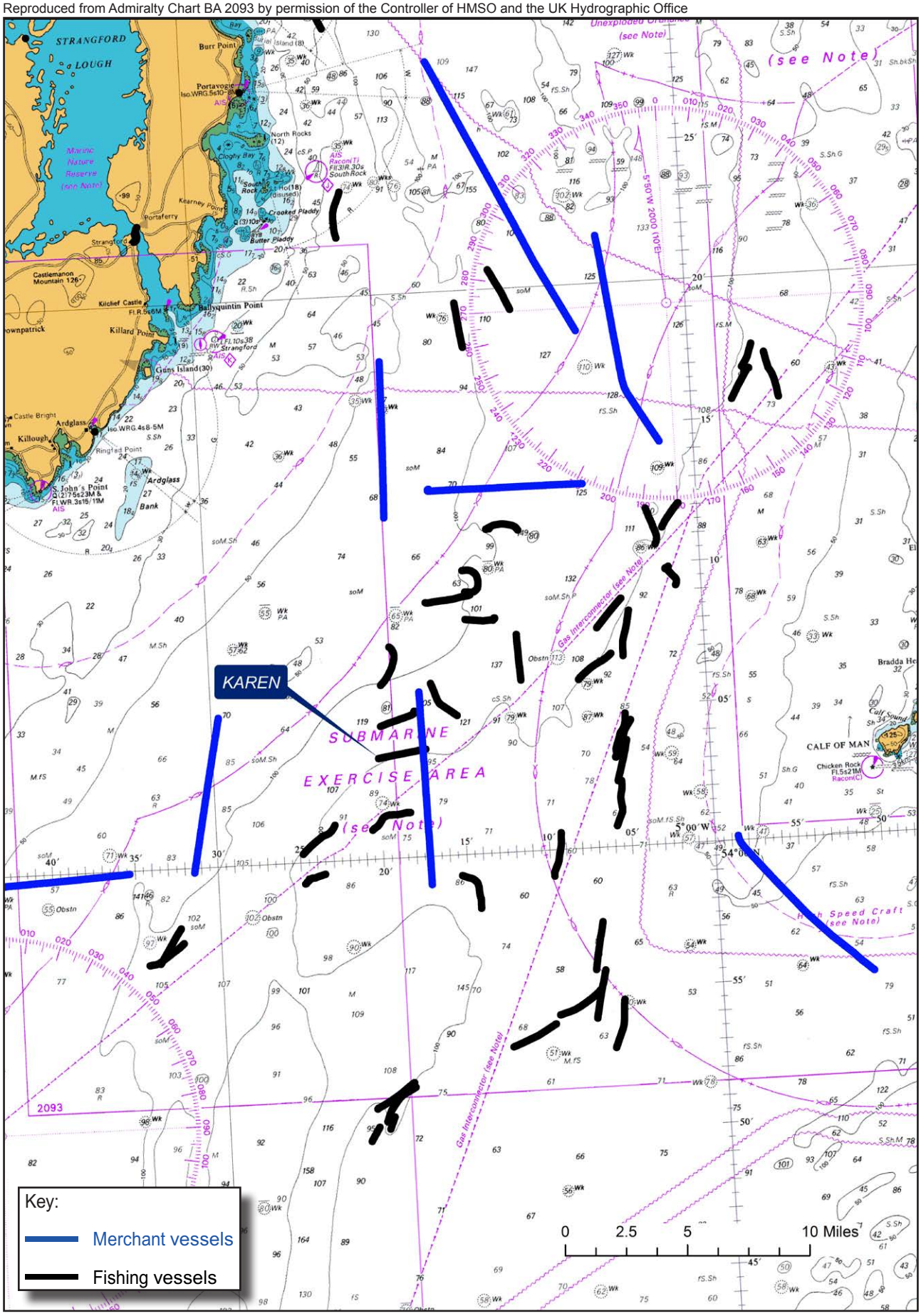

Figure 18: Plot of all AIS tracks in the area for 30 minutes prior to the accident

1.12 SAFETY INVESTIGATION AND PARLIAMENTARY NARRATIVE

1.12.1 Initial MAIB investigation

Having been notified of the accident by *Karen*'s owner, the MAIB initiated a preliminary assessment of the circumstances; this included the recovery of electronic evidence and an inspection of the vessel. It was apparent from this initial evidence collection that the vessel had been towed backwards and had suffered significant damage; this resulted in a decision to proceed with a full safety investigation.

On 20 April 2015, the MAIB informed the Navy Command HQ in Portsmouth about the investigation and asked if any submarines could have been responsible for the event. Navy Command advised the MAIB that there was no UK or NATO submarine operating within 50 nautical miles (nm) of the location at the time of the accident.

On 5 June 2015, the MAIB attended a meeting with the Fleet Operations Division at the Northwood HQ. At this meeting, MAIB inspectors presented a brief on the accident. This included the AIS evidence that showed *Karen*'s rapid transition from a slow westerly heading to being dragged backwards in a south-easterly direction **(Figure 3)**. In response to this brief, Fleet Operations explained that no submarines had reported snagging a fishing vessel. As a result, the MAIB was told that there was no possibility of a UK or NATO submarine being involved.

1.12.2 Parliamentary questions

In response to concerns raised by *Karen*'s owner, the MP for South Down, Northern Ireland, tabled a written Parliamentary question[20] to the Secretary of State for Defence on 5 June 2015 asking what reports had been received of submarine activity in the Irish Sea on 15 April 2015. The question was answered by the Minister of State for the Armed Forces on 10 June 2015 who stated that:

> *Following reports of damage to the fishing vessel KAREN on 15 April 2015, Ministers were advised of the Royal Navy's confidence that no UK submarine was responsible.*

On 13 July 2015, in response to a further Parliamentary question[21] from the MP for South Down, the Minister of State for the Armed Forces stated that:

> *…the Royal Navy takes its responsibilities very seriously. Since 1993, it has adhered to the comprehensive code of practice and conduct for operations in the vicinity of fishing vessels, which ensures not only the safety of our ships and submarines, but other vessels.*

1.12.3 MAIB initial draft accident investigation report

On 25 August 2015, the MAIB sent its draft investigation report to COMOPS for consultation with a closing date for comments of 9 September 2015. The MAIB draft report was prepared based on the evidence made available by the Royal Navy and the MoD. The draft report concluded that, in the absence of any other credible explanation, *Karen*'s trawl warp or net had become snagged by a submarine.

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[20] Written Parliamentary Question 1312 (Submarines: Irish Sea).

[21] Hansard, 13 July 2015, Daily Report, Column 579.

1.12.4 Parliamentary announcement and Westminster Hall debate

On 7 September 2015, a written statement[22] was put before Parliament by the Minister of State for the Armed Forces stating that, based on new information, a UK submarine had been responsible for the snagging of *Karen*'s nets. This statement also confirmed that the Royal Navy was co-operating with the MAIB's independent investigation. On the same day, officers from the Royal Navy visited the owner and skipper of *Karen* to deliver letters explaining that a submarine had been responsible for the incident.

A Westminster Hall debate followed on 16 September 2015[23] where the MPs for Dunfermline and West Fife, Strangford and South Down asked the Minister of State for the Armed Forces a series of questions about the incident. These questions included: what submarine activity was taking place on the day, why protocols were breached, the type of submarine, what action would be taken to restore trust and the arrangements for investigating the incident. In response to the MPs' questions, the Minister of State for the Armed Forces stated an expectation that all their questions would be covered by the MAIB's investigation report.

1.12.5 Further MAIB investigation

Following the announcement that a UK submarine had been responsible for the accident, the MAIB reopened its investigation. A second meeting was held at the Fleet Operations Division in Northwood on 21 September 2015, where the MAIB requested the following evidence in support of the investigation:

- Interviews with members of the submarine's command team.
- A meeting with senior submarine officers to gain insight into the organisational influences on the accident.
- A copy of the Royal Navy's own report into the accident.
- Electronic evidence, specifically the submarine's courses and speeds prior to the collision, as well as further detail regarding onboard decision-making.
- Full details of the actions taken by the Royal Navy since the accident.

The MAIB also requested this list of evidence in an email to COMOPS on 16 October 2015. The MAIB was refused access to the submarine's Commanding Officer and its crew. Instead, on 17 November 2015, COMOPS directed a review of the case (the Directed Review).

1.13 ROYAL NAVY DIRECTED REVIEW

The Royal Navy's Directed Review of the accident was concluded on 2 February 2016 and, on 12 February 2016, the MAIB received a declassified summary of this work, stating that the full report could not be disclosed for operational security reasons.

[22] Hansard, 7 September 2015, Volume 599, Column 2WS.

[23] Hansard, 16 September 2015, Column 362WH.

The summary report submitted to the MAIB noted that post-event analysis of the submarine's acoustic data recordings suggested that:

- The snagging would not have been visual on the internal sonar displays given the way the systems had been set up during the transit.
- The stopping of *Karen*'s propulsion was clearly heard, as was the release of the starboard trawl warp and the parting of the port warp.
- The noise detected by the HVME was probably the parting of the port warp.

The summary report also noted that:

- Guidance provided in BR0095 relied predominantly on the fact that a fishing vessel had been correctly identified.
- Guidance on actions to take in the event of a collision were predicated on the basis that the submarine was aware that an incident had occurred.
- Prior to the receipt of the signal from its Operating Authority, the submarine was not aware that it had been involved in a snagging.
- At no stage did the submarine surface to clear any wires, nets or any other entanglement.
- Where trawl noise was absent, almost every close quarters contact was classified as a merchant vessel.

Additionally, the summary report concluded that:

- The Commanding Officer's intention to proceed dived via the Irish Sea at a relatively high speed should have been challenged by the Operating Authority, but was not.
- The high speed of advance in coastal waters where fishing vessel activity tends to be at its highest goes against the guidance provided in the Royal Navy's BR0095, *Fishing Vessel Avoidance*.
- The high speed of advance was based on where the Commanding Officer wished to go, rather than where he had to go.
- The submarine's Operating Authority could have used AIS information to provide the Commanding Officer with regular updates of fishing vessel activity[24].
- The training provided by the Royal Navy probably led the sonar teams to think that trawl noise would always be heard from vessels engaged in fishing.
- It was narrow and over-simplistic to use the absence of trawl noise as evidence towards an assessment that a sonar contact was not a vessel engaged in fishing.

[24] AIS information would not be available to a deep submarine, see Section 1.8.1.

- As the submarine was deep and could not make a visual classification, *Karen*'s contact should have been treated as a fishing vessel.

- The submarine crew were operating near to their limit of capability.

- The Commanding Officer could have taken action to reduce workload by reducing the submarine's speed of approach and returning to periscope depth.

- The Operating Authority's post-incident signal, informing the submarine of the reported incident, should have required a positive response had the submarine been involved.

- There was no evidence of any equipment defect that would have prevented safe dived operations during the submarine's transit through the Irish Sea.

The Directed Review report listed the actions already taken by the Royal Navy and included a number of recommendations aimed at reducing the likelihood and potential consequences of collisions with fishing vessels in the future.

1.14 PREVIOUS OR SIMILAR ACCIDENTS

1.14.1 Collision between HMS *Trenchant* and *Antares*

At 0217 on 22 November 1990, the Royal Navy Trafalgar Class nuclear powered submarine, HMS *Trenchant,* collided with the trawl gear of the pelagic trawler *Antares* east of the Island of Arran, Scotland. The collision resulted in *Antares* capsizing and foundering with the loss of all four crew. The MAIB investigation[25] established that the collision was caused by a breakdown in the watchkeeping structure and standards on board the submarine. The submarine's command team had no clear appreciation of the surface contacts held on sonar prior to the collision, and the absence of trawl noise from *Antares* led to an incorrect assumption that the contact was not engaged in fishing.

After the collision, a sonar operator on board HMS *Trenchant* reported hearing an unusual noise, which was later assessed to probably have been noises associated with *Antares* sinking. This noise, allied with the disappearance of *Antares*' sonar contact, should have provided sufficient evidence on board for the command team of HMS *Trenchant* to appreciate what had happened. However, there was no proper analysis of these two pieces of information and, after surfacing to clear wires from its casing, the submarine dived and continued its training exercise.

Recommendations were made in the MAIB report that included: extending the existing notification scheme, submarines not on exercise should proceed on the surface, extending the minimum passing distance for a deep submarine to 4000yds and reviewing the guidance in place at the time. The outcome of the Royal Navy's review, undertaken as a result of these recommendations, was the creation of the FV Code as described in this report.

[25] MAIB Report dated 15 April 1992.

1.14.2 Collision between USS *Greeneville* and *Ehime Maru*

On 9 February 2001, the United States Navy submarine, USS *Greeneville,* collided with the Japanese fishing/training vessel *Ehime Maru*. USS *Greeneville* was hosting distinguished visitors for a day at sea and was demonstrating an emergency surfacing procedure when the collision occurred. The American National Transportation Safety Board (NTSB) report[26] concluded that the submarine's command team failed to perform adequate contact analysis, safety procedures were rushed and the sonar teams were overloaded. These factors led to a loss of situational awareness by the submarine's command team, leading to the collision. It is evident from the NTSB report that unrestricted access to witnesses was granted to investigators, facilitating an extensive and thorough investigation of the accident.

[26] NTSB Case Report DCA-01-MM-022.

SECTION 2 – ANALYSIS

2.1 AIM

The purpose of the analysis is to determine the causes and circumstances of the accident in order to make safety recommendations to prevent recurrence.

2.2 SUMMARY

Despite the Royal Navy's initial insistence that no UK or NATO submarine was within 50nm of the accident, the MAIB's initial draft investigation report concluded that *Karen* had been dragged backwards by a submarine. When the MoD later confirmed that a UK submarine had collided with *Karen*'s fishing gear, the MAIB's investigation was reopened.

The investigation focused on the circumstances that led to the collision and the actions taken afterwards. The scope of the investigation and the ability to determine all the factors that influenced the accident, particularly the decision-making on board the submarine and at the Operating Authority, was significantly constrained by the lack of access to the submarine and its crew.

Based largely on the information provided in the summary report of the Royal Navy's Directed Review, the cause of the collision and the contributing factors that led to it will be analysed in this section. The emergency response on board *Karen* and the submarine, and the actions taken by the Royal Navy after the accident, will also be discussed.

2.3 THE COLLISION

2.3.1 Misidentification of *Karen*

The submarine collided with *Karen*'s fishing gear because its sonar contact was assessed to be that of a small merchant vessel, and earlier the Commanding Officer had suspended the requirement for close quarters procedures, the effect of which was to normalise close passes with merchant vessel contacts. At the time of the collision there were 36 other vessels operating within a 10-mile radius of the submarine; most were fishing vessels and at least two[27] of those, including *Karen*, were within 4000yds **(Figure 19)**.

Karen was misidentified, along with the majority of other fishing vessels in the area, because the submarine's sonar operators did not detect or report hearing trawl noise. Given the number of vessels operating in the area, it is almost certain that the noise levels being generated would have been extremely high, with noise from one vessel masking the noise from another. Such a situation would make it impossible for the sonar operators to methodically identify and analyse each contact, in particular to identify discrete acoustic classification clues such as trawl noise.

The misidentification of *Karen* as a merchant vessel also led directly to the TMA process over-estimating the fishing vessel's speed and, therefore, its range **(Figure 15)**. The close pass with *Karen* shortly after the submarine had altered course to

[27] On **Figure 19**, three fishing vessels are shown within 4000 yards (2nm) of the accident location. The two positions (shown in blue) derived from AIS, including *Karen*, are timed at 1605. The position of the third fishing vessel (shown in red) also inside 4000yds of the accident location, was derived from VMS and timed at 1622 (see Section 1.11.1).

Reproduced from Admiralty Chart BA 2093 by permission of the Controller of HMSO and the UK Hydrographic Office

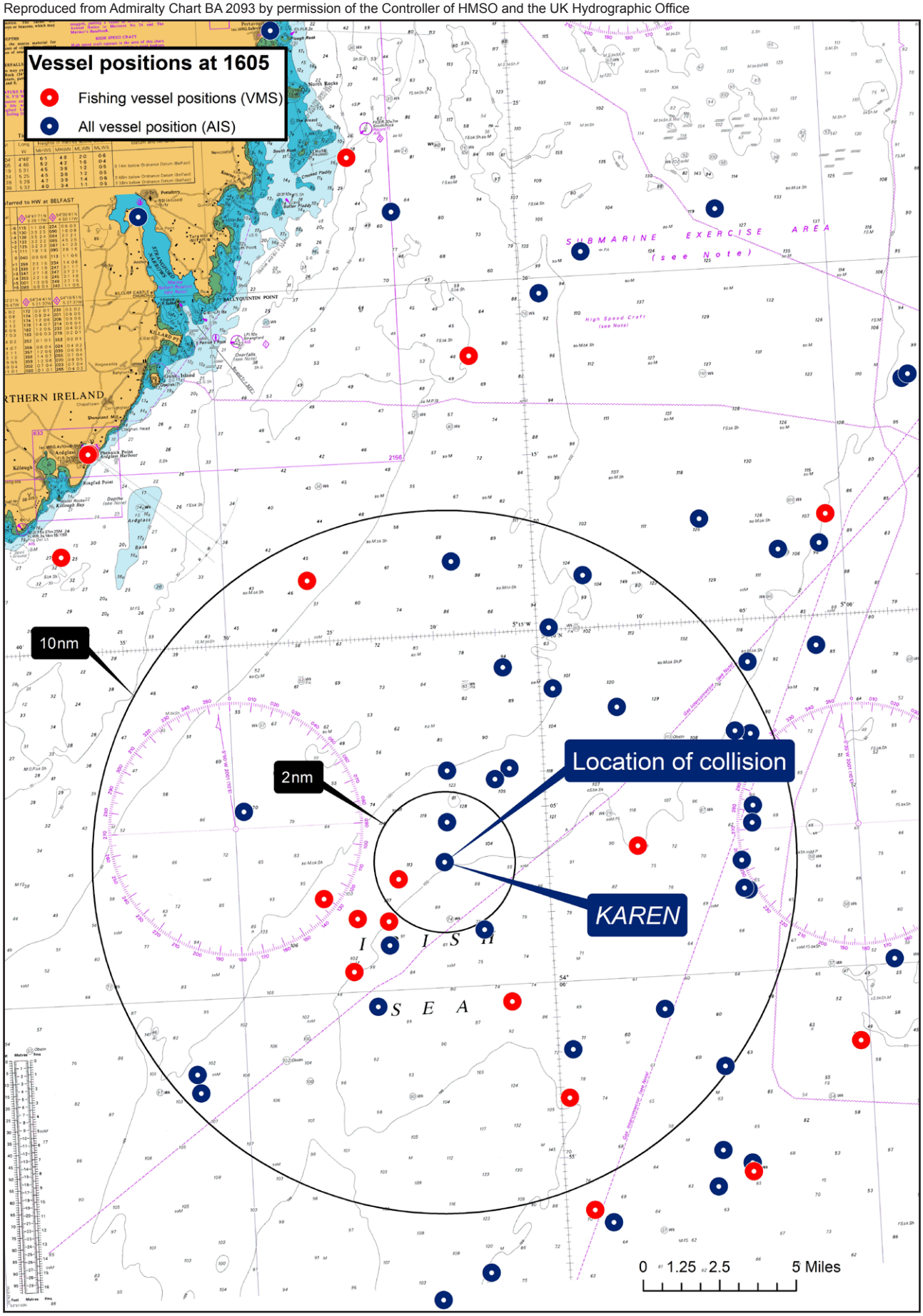

Figure 19: Plot of all vessels operating within 10nm of the accident location

port should have alerted the command team to the fact that they had made an error with their TMA. This could have prompted them to re-evaluate the situation leading to an appreciation of a slower, closer contact. Had this happened, it is possible that the command team would have realised that they had just passed very close to a fishing vessel. However, the misidentification of *Karen* meant that the command team's perception would have been that no risk of collision could exist between a submarine at safe depth and a merchant vessel. Thus, it is assessed that, once the threat posed by *Karen* had been discounted, the command team's attention rapidly diverted to analysis of other sonar contacts.

The difficulties experienced by the submarine were the product of its speed of advance while operating deep in a densely populated fishing ground. The sonar and command teams did not have sufficient time to evaluate and classify contacts or take the necessary collision avoidance actions. The Royal Navy's Directed Review concluded that the submarine was operating near to the limit of its capability. Given that all the submarine's systems were reported to be functioning properly, it was clearly apparent that the submarine's limit of capability had, in reality, been exceeded, with its sonar and command teams becoming cognitively overloaded, leading to degraded situational awareness and poor decision-making.

2.3.2 The mechanics of the collision

There was insufficient evidence to determine with certainty the exact nature of the collision. However, it is highly likely that the initial contact by the submarine was with *Karen*'s trawl warps.

Once the submarine's forceful pull was applied to the warps, the gear will have lifted off the seabed and, in order to apply a minimum 13t force, the trawl doors, or possibly the net, must have become snagged on the submarine. Additionally, the damage to the transverse beam in the fish hold, which the winch bedplate was bolted onto, can almost certainly be attributed to the excessive, albeit brief, load on the port warp. It has not been possible to determine how the cod end bag rope was cleanly cut, but there is no evidence to suggest that this was done by the submarine or its crew.

On board *Karen*, the starboard warp was able to run freely away because it had been attached to its winch drum using rope. However, the port warp became fouled on its winch probably because the drum's rapid rotation caused the warp to ride over itself and lock[28]. The port warp coming taut in this way, combined with the trawl doors or net being snagged on the submarine, would account for *Karen*'s uncontrolled sternway **(Table 1)**. It is, therefore, extremely fortunate that the port warp parted when it did as *Karen* had already been partially submerged by the downward pull of the submarine and would inevitably have capsized and then been dragged further underwater.

Although the Royal Navy reported that the submarine was undamaged in the accident, the snagging was a very significant hazard that could potentially have disabled the submarine had its rudder, hydroplane control surfaces or propulsion system become fouled. Given that the lost fishing gear was recovered in the same fishing grounds, then it probably dropped clear of the submarine when the port warp parted; nevertheless, the potential hazard to the submarine was very significant.

[28] Often referred to as a 'riding turn'.

2.4 EMERGENCY RESPONSE

2.4.1 *Karen*

When *Karen* was dragged backwards, the crew took appropriate actions to disengage propulsion and release the winch brakes freeing the gear. When the port warp fouled on its drum and again came taut, the next reaction was to prepare the liferaft for deployment; this was still happening when the port warp broke. About 10 minutes after the accident, when the skipper had regained control of the vessel, he reported the incident to the coastguard using VHF radio.

In such a rapidly deteriorating set of circumstances, there was little else the crew could have done. However, had the port warp not parted, *Karen* would have foundered, denying the crew sufficient time to initiate a controlled abandonment. This scenario would have placed their lives in immediate danger, and raising the alarm would have been a critical step in saving life. Had the vessel been pulled underwater, *Karen*'s EPIRB would have floated free, raising the alarm. Nevertheless, when the incident started, the skipper could have initiated a DSC alert using the emergency button on the vessel's VHF radio. This action takes approximately 5 seconds and would have alerted the coastguard immediately and, critically, would have included the distressed vessel's position, aiding any rescue effort. It is apparent, from other MAIB investigations, that there is a reluctance to use the DSC system for distress alerting. It is not an instinctive reaction and not routinely tested or practised, which probably results in a lack of confidence in the system during emergencies.

2.4.2 The submarine

Evidence that the collision had occurred was detected on board the submarine.

The unusual noise reported by the sonar chief petty officer was dismissed as insignificant, and post-deployment analysis showed that the collision had been detected by sonar but not observed on board. It is reasonable to conclude that, had these events been observed and connected with the simultaneous close pass, it would have been possible for the command team to have identified that a collision might have occurred. However, this did not happen because the command team had no expectation of danger; their perception of the situation was that no risk of collision existed with a merchant vessel.

It is fortunate that *Karen*'s crew were on deck and able to release the winch brakes within seconds of the accident. Had this not occurred, the force of the submarine's pull, applied through both warps, would have been much higher and could have resulted in more significant damage or foundering, as was the case in the *Antares* accident. The rapid nature of such accidents leads to the conclusion that, unless part of the fishing vessel's equipment fails, the consequences of a snagging for a fishing vessel are likely to be catastrophic. In such circumstances, it is of paramount importance that the submarine is able to recognise what has happened in order to render immediate assistance.

About 3 hours after the accident, when the Commanding Officer realised that his submarine had been in collision, a decision was taken to press ahead with the dived passage; the submarine was not checked externally for damage and the matter went unreported. From a safety point of view, it would have been more appropriate for the

submarine's involvement to have been reported. Such a report would have clarified any assumptions being made ashore and allowed the accident investigation to commence immediately. A message from the submarine could also have confirmed that the submarine and its crew were safe after being in collision.

2.5 PLANNING AND CONDUCT OF THE PASSAGE

2.5.1 Pre-deployment planning

The Admiralty Manual of Navigation provided advice on the requirement to make an appraisal of potential navigational hazards when planning a passage. A high concentration of fishing vessels in coastal waters presents a very significant risk to the safe operation of a dived submarine and fishing vessels, which should have been identified in this process.

This risk would have been identified if the submarine's crew had examined historical fishing patterns, including AIS information, as part of the passage planning process. However, the Royal Navy's Directed Review identified that neither the command team nor the Operating Authority made sufficient reference to AIS data during the appraisal process.

Having not identified the risk of encountering high concentrations of fishing vessels, the plan, as stated at the pre-deployment brief, was to transit the Irish Sea dived at a relatively high speed through anticipated light traffic levels. This decision was not challenged by the Operating Authority but should have been as identified in the Directed Review.

If the command team's preference was to proceed deep and fast, and not be forced into situations where compliance with BR0095 would mean slowing down or operating at periscope depth, then a plan should have been made to avoid busy fishing grounds. An alternative route should have been chosen or the Irish Sea passage could have been conducted at night when fewer fishing vessels were likely to have been encountered. Alternatively, the passage should have been planned at a speed consistent with operating continuously at periscope depth.

In the days prior to sailing and even after the departure from HMNB Clyde, the submarine and the Operating Authority could have taken detailed information about fishing vessel activity into account. AIS information for the 2 days preceding the accident showed similar levels of traffic density in the Irish Sea. Had this information been considered, it would have been evident that a high concentration of fishing vessels was likely to be encountered on the planned route. Options remained continuously available to adjust the plan; however, it is evident that at no stage prior to the Irish Sea passage was the risk to the submarine and the fishing vessels properly identified by the submarine's command team or the Operating Authority.

2.5.2 Conduct of the passage in the presence of fishing vessels

When the submarine commenced its dived passage south towards the Irish Sea, it started to encounter the denser concentration of surface vessels. Had knowledge of fishing patterns and AIS information been applied to this situation, it would have been readily apparent that the majority of these contacts were vessels engaged in fishing. Therefore, it is not credible for the command team to have assessed, as was identified by the Directed Review, that, where trawl noise was absent, almost every close contact was classified as a merchant vessel.

The Directed Review identified that it was narrow and over-simplistic to use the absence of trawl noise as evidence towards an assessment that a sonar contact was not a vessel engaged in fishing. This illustrates a confirmation bias towards applying a merchant ship classification to sonar contacts; in other words, the command team wanted the surface contacts to be merchant vessels because they would present no risk of collision.

Figure 20 shows the positions of all the 61 fishing vessels[29] in the area, based on AIS and VMS data, at or near to the time of the accident[30]; the circles shown around each contact are at 4000yds. It is apparent from this analysis that the area was impassable to a deep submarine operating in compliance with BR0095. It is also apparent that the submarine must have passed within 4000yds of several other fishing vessels both prior to and after the collision.

More appropriate action when the surface contact density increased would have been to assume that they were all vessels engaged in fishing unless absolutely proven otherwise. Had this happened and guidance on fishing vessel avoidance been applied, the submarine would not have pressed ahead; instead, its speed would have been reduced and it would have been returned to periscope depth. Once back at periscope depth, it would have been readily apparent - from visual and AIS information - that continuing the passage below periscope depth would be unsafe.

2.6 FISHING OPERATIONS IN SUBMARINE EXERCISE AREAS

The accident occurred within a designated submarine exercise area and, although the submarine was in transit, a SUBFACTS broadcast had warned of the presence of submarines on the day of the accident. The SUBFACTS system is intended to alert mariners to the potential presence of a submarine; it does not prohibit or restrict fishing. However, when a SUBFACTS warning is in place, fishing skippers should be guided by the advice in MGN12(F) **(Annex B)**. This advice is intended to ensure the best prospect of detection by a submarine.

At the time of the accident, AIS transmissions were being detected ashore from only 40 of the 61 fishing vessels operating in the area. It is possible that the 21 vessels only identified by VMS were operating an AIS, but their transmissions were not detected by shore-based VHF aerials; alternatively, the vessels were not fitted with an AIS system[31]. Nevertheless, this investigation has shown that AIS information is critical for submarines' situational awareness and, where fitted, AIS should be continuously transmitting to ensure this method of detection can be effectively utilised by submarines. MGN 12(F) was published before the development of AIS and would benefit from being updated to include this advice.

Additionally, the submarine was heading south out of the promulgated SUBFACTS area where no warning or notification system would have been in place. However, the FV Code applies to all areas where UK fishing vessels operate, thus it would be appropriate for fishing skippers to follow the guidance in MGN 12(F) at all times and not just when operating in designated exercise areas.

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[29] AIS contacts identified as merchant vessels have been removed from this analysis.

[30] On Figure 20, fishing vessel AIS positions (shown in blue) are at the time of the accident. Given that the VMS system only transmits a fishing vessel's position approximately every 2 hours, then the fishing vessel positions derived from VMS (shown in red) are at the time nearest to 1605 that a VMS transmission was made.

[31] A fishing vessel over 12m and below 15m in length would require a VMS but not an AIS system to be fitted (Section 1.11.1).

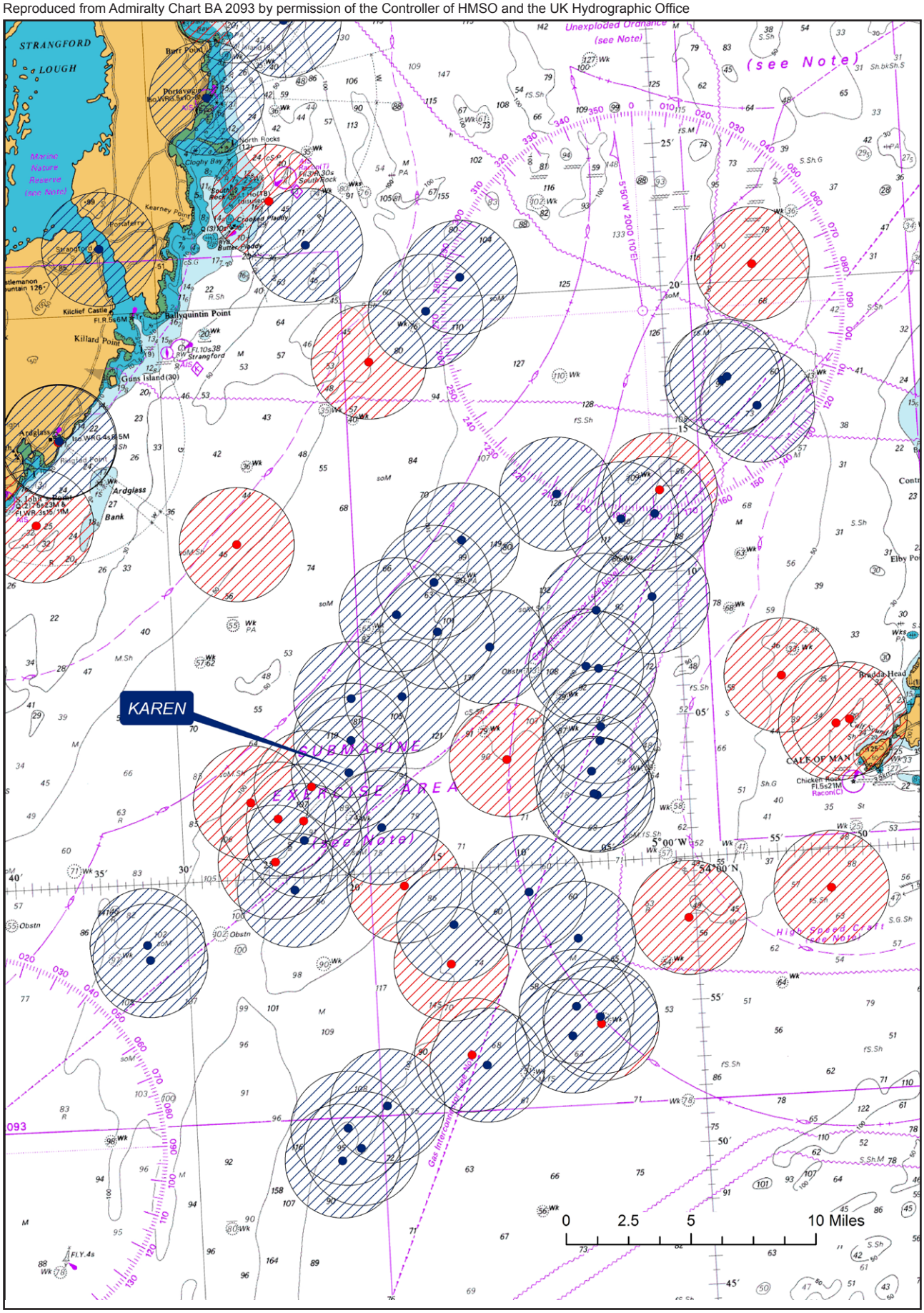

Figure 20: Plot of all fishing vessels in the area with 4000 yard separation circles

2.7 INVESTIGATION OF THE ACCIDENT

Learning lessons from accidents in a timely manner is key to both the prevention of recurrence and a strong safety culture. In this case, the MoD's policy of not commenting on submarine operations resulted in significant delays to the independent investigation of an accident that endangered the lives of four fishermen. Evidence provided by the Royal Navy was also insufficient to identify all the causal factors.

In response to the coastguard's initial enquiry, and in compliance with MoD policy, the duty submarine controller stated that no comment could be made regarding submarine operations. However, when the Royal Navy stated on 20 April 2015 that there was no UK or NATO submarine within 50nm of the accident location, the Operating Authority would have been aware that it was possible that a submarine might have been involved. Moreover, on 5 June 2015, when compelling evidence of submarine involvement was shared with the Royal Navy, it had a duty to establish, beyond doubt, whether a submarine was involved or not, rather than just repeating the denial.

When the presence of a UK submarine was admitted on 7 September 2015, nearly 5 months had passed since the accident, during which time perishable evidence, including witness recollections, would almost certainly have become contaminated or lost. Even after this admission, access was still denied to witnesses and other primary evidence sources required to progress the independent investigation. Instead, the MAIB had to await the outcome of the Royal Navy's Directed Review (Section 1.13) that was not made available until nearly 10 months after the accident. Although the declassified summary of this Review received by the MAIB described events leading up to the collision, it did not fully explain why it happened. Furthermore, it did not deal with why the lessons identified following the snagging of *Antares* were lost.

During this investigation, the Royal Navy has been slow to react and has actively controlled the release of evidence; this approach has impeded the MAIB's investigation. Additionally, from the information provided, the Royal Navy's own investigation did not appear to deal with the systemic issues underlying this collision and has done little to inspire confidence in its ability to react quickly and effectively to investigate and then take the actions necessary to prevent recurrence. Therefore, the Royal Navy should demonstrate that it has conducted a thorough investigation into this accident. This would ensure that the MPs' questions asked in the Westminster Hall debate were fully answered, provide assurance that lessons have been effectively managed and help rebuild trust with the fishing industry.

SECTION 3 – CONCLUSIONS

3.1 SAFETY ISSUES DIRECTLY CONTRIBUTING TO THE ACCIDENT THAT HAVE BEEN ADDRESSED OR RESULTED IN RECOMMENDATIONS

1. The collision happened because the submarine's command team believed *Karen* to be a merchant ship, so they did not perceive any risk of collision or need for avoiding action. [2.3.1]

2. The submarine's command team believed that *Karen* was a merchant ship primarily because no trawl noise had been heard on the same bearing. [2.3.1]

3. It is highly likely that the command team and sonar operators were cognitively overloaded due to: the density of shipping traffic; the associated noisy acoustic environment; and the unnecessarily high speed of advance. [2.3.1]

4. The circumstances of this collision were allowed to develop because the command team did not follow the standard procedures for fishing vessel avoidance set out in BR0095. Had these procedures been followed, the accident would have been avoided because the submarine would have been slowed down and returned to periscope depth when numerous vessels engaged in fishing were first encountered. [2.5.2]

5. The fishing vessel activity levels were predictable and the Irish Sea was impassable to a deep submarine operating in compliance with BR0095. This hazard should have been identified as a significant risk to the safety of both the submarine and fishing vessels during the development of the submarine's passage plan. [2.5.1]

6. If the submarine command team's priority was to achieve an undetected, deep, fast passage, then a high concentration of fishing vessels should have been avoided. [2.5.1]

3.2 SAFETY ISSUES NOT DIRECTLY CONTRIBUTING TO THE ACCIDENT THAT HAVE BEEN ADDRESSED OR RESULTED IN RECOMMENDATIONS

1. On board the submarine, evidence of the collision was either not observed or misinterpreted. This meant that the submarine's command team was unaware of the collision until about 3 hours later. As a result, the submarine did not render immediate assistance; action that would have been necessary to preserve life had *Karen* foundered. [2.4.2]

2. Had the submarine reported its involvement in the accident, the Operating Authority would have been reassured that the submarine was safe and the accident investigation would not have been delayed. [2.4.2]

3. Delays in establishing and admitting that a submarine was responsible, as well as the Royal Navy's restrictions on the release of evidence, impeded the independent safety investigation. Additionally, the evidence submitted was insufficient to determine all the causal factors of the accident. [2.7]

4. Although there was nothing that the crew of *Karen* could have done to avoid the accident, lessons can still be learnt; in particular:

   a Transmitting on AIS provides important information for submarines and their operating authorities ashore regarding fishing vessel activity in declared submarine exercise areas. [2.4.1]

   b As is apparent from other accidents and incidents, raising the alarm through the use of DSC is not a natural reaction. [2.4.1]

SECTION 4 – ACTION TAKEN

The **Royal Navy** has:

- Issued instructions to all submarines stating that guidance on fishing vessel avoidance is to be adhered to at all times. Direction has also been provided to submarine commanding officers as to when to report to their chain of command, irrespective of the operational situation.

- Reviewed and amended training given to submarine teams on the identification and analysis of sonar contacts, including use of trawl noise as a classification method.

- Submarine commanding officers have been ordered to review their pre-deployment briefing process to ensure that all potential hazards are identified and then acted upon if encountered.

SECTION 5 – RECOMMENDATIONS

The **Royal Navy** is recommended to:

2016/144 Review the procedures and training necessary to ensure that:

- Dived submarine operations in the vicinity of vessels engaged in fishing are conducted safely by complying with guidance on fishing vessel avoidance (BR0095).
- Collisions with fishing gear do not go undetected/unrecognised.

The Maritime and Coastguard Agency and the UK fishing industry should be consulted in this review; updated versions of the Fishing Vessel Code of Practice and Marine Guidance Note 12(F) should also be considered.

2016/145 Provide assurance to Defence Ministers and the fishing industry that the causes and circumstances of this accident have been thoroughly investigated and all necessary actions have been put in place to minimise the risk of recurrence.

Safety recommendations shall in no case create a presumption of blame or liability

Marine Accident Report

INVESTORS IN PEOPLE