Transportation Safety Board of Canada
Bureau de la sécurité des transports du Canada

MARINE INVESTIGATION REPORT M16C0016

Striking of ice and subsequent flooding

Fishing vessel *Saputi*
Davis Strait, Nunavut
21 February 2016

Canada

Transportation Safety Board of Canada
Place du Centre
200 Promenade du Portage, 4th floor
Gatineau QC K1A 1K8
819-994-3741
1-800-387-3557
www.tsb.gc.ca
communications@bst-tsb.gc.ca

Marine Investigation Report M16C0016

Cat. No. TU3-7/16-0016E-PDF
ISBN 978-0-660-08089-5

This report is available on the website of the
Transportation Safety Board of Canada at www.tsb.gc.ca

Le présent rapport est également disponible en français.

Marine Investigation Report M16C0016

Striking of ice and subsequent flooding
Fishing vessel *Saputi*
Davis Strait, Nunavut
21 February 2016

Summary

On 21 February 2016, the fishing vessel *Saputi,* with 30 people on board, was fishing turbot in the Davis Strait, 167 nautical miles east-northeast of Resolution Island, Nunavut, and 220 nautical miles west-southwest of Nuuk, Greenland. At 1935 Atlantic Standard Time, the vessel struck a piece of ice and was holed in the shell plating on the starboard side at the forward end of the cargo hold. After pumping operations failed to keep up with the ingress of water, the cargo hold was sealed, and it subsequently flooded. The vessel developed a severe list to port but proceeded under its own power to Nuuk, Greenland, arriving on 24 February. No injuries were reported.

Le présent rapport est également disponible en français.

Table of contents

1.0 Factual information

1.1 Particulars of the vessel

Table 1. Particulars of the vessel

Name of vessel	*Saputi*
International Maritime Organization (IMO) number	8516809
Port of registry	Iqaluit, Nunavut
Flag	Canada
Type	Fishing vessel, factory freezer stern trawler
Gross tonnage	2634
Length	67.1 m
Breadth	13 m
Class (including ice class)	✠1A1 ICE-1C Stern Trawler
Draft at time of occurrence (estimate)	Forward: 4.7 m Aft: 7.1 m
Built	1987, Langsten Slip & Båtbyggeri AS, Denmark
Lengthened	2012, PTS Ltd., Szczecin, Poland
Propulsion	1 diesel engine (3043 kW) driving 1 controllable-pitch propeller
Cargo	306 tonnes of packaged frozen fish (consisting of 121 tonnes of shrimp and 185 tonnes of turbot)
Crew	30
Registered owner	Qikiqtaaluk Fisheries Corporation, Iqaluit, Nunavut
Manager	Nataaqnaq Fisheries Inc., St. John's, Newfoundland and Labrador

1.2 Description of the vessel

The *Saputi* (Figure 1) is a factory freezer stern trawler of steel construction with the navigation bridge and crew accommodations located forward of amidships. The machinery space is located aft and shares a common bulkhead with the cargo hold. The refrigerated cargo hold has a volume of 1290 m^3 and is kept at a temperature of −34 °C using an ammonia refrigeration system. The fish processing factory is located above the cargo hold and the forward portion of the machinery space. Below the main deck, the vessel is subdivided into 5 compartments by 4 transverse watertight bulkheads (Appendix A). The vessel is fitted with a bow thruster with a single controllable-pitch propeller.

Figure 1. Fishing vessel *Saputi* (Source: Nataaqnaq Fisheries)

The bridge is equipped with the required navigational equipment, including a 3 cm wavelength radar and a 10 cm wavelength radar. Two searchlights are fitted on top of the bridge. The vessel is also equipped with a thermal imaging camera used to detect ice; however, this camera was not operational at the time of the occurrence.

The vessel's bilge pump is located in the engine room. It has a capacity of 42 m^3 per hour and a delivery head of 20 m. A ballast pump of the same capacity is located next to the bilge pump, and either pump can be used in the bilge system. Through a manifold, either pump can be connected to 2 independent suctions in the cargo hold, one at the extreme forward end and one at the extreme after end, and both are just to starboard of the centreline. The suction lines run from the manifold to a well below the deck of the cargo hold; water enters the well through an opening in the cargo hold deck measuring 53 cm by 61 cm. This opening is covered completely by a perforated metal strainer with holes measuring 6 mm in diameter. In addition to the fitted bilge and ballast pumps, the vessel also carries 2 electric submersible auxiliary pumps. The first auxiliary pump has a capacity of 300 L per minute (18 m^3 per hour) and, according to the manufacturer's specifications, is able to pump solids up to 38 mm in diameter. The second auxiliary pump has a capacity of 270 L per minute (16.2 m^3 per hour) and, according to the manufacturer's specifications, is able to pump solids up to 35 mm in diameter.

Although the arrangement of the bilge pumping system fitted on board the *Saputi* meets the regulatory requirements,[1] these systems on their own are not designed to be able to handle the entry of extreme amounts of seawater.

1.2.1 Vessel construction

The *Saputi* was built in 1987 under the supervision of Det Norske Veritas (DNV) and has been maintained in class with the class notation ✠ 1A1 ICE-1C Stern Trawler. This class notation indicates that the vessel may operate in channels prepared by icebreakers and in open waters where light ice conditions and smaller ice floes of a thickness of 0.4 m are anticipated. These rules are considered to meet the Canadian regulations[2] for type D vessels.

To obtain the ICE-1C class notation as an ice-strengthened vessel, DNV requires that the vessel be constructed with normal strength NV grade A steel shell plating. [3] The thickness of this plating can vary depending on its location on the hull. The *Saputi*'s ice belt (the section of the vessel's hull above and below the waterline that is prone to ice impact) is 30 mm thick. For ice-strengthened hulls such as that of the *Saputi*, DNV rules also define the ideal size and spacing of stiffeners in order to improve their resistance to the forces that would result from an ice impact.

Before the occurrence, ultrasonic testing of the vessel's shell plating was last completed in April 2015 in Szczecin, Poland. The testing found no decrease in the thickness of the plate from when it was originally installed.

1.2.2 Vessel operation

The *Saputi* primarily fishes shrimp and turbot in Canadian waters in an area that ranges from the east coast of Newfoundland and Labrador to the Davis Strait. At the time of the occurrence, the vessel was fishing in North Atlantic Fisheries Organization (NAFO) fishing Division 0B (Appendix B). The vessel is equipped to tow 2 trawls at once (Appendix C). To do this, the vessel is fitted with 3 towing warps: the 2 outboard warps are connected to the trawl doors, and the centre warp runs through a block suspended on the centreline above the ramp at the stern of the vessel, connected to a clump[4] that is attached to the inboard side of both trawls.

To deploy or shoot the trawl, the vessel operates at a speed of 4.9 to 5.4 knots and the trawls, trawl doors, and centre clump are released over the stern. The 3 warps are then run out until the desired warp length for the depth of water has been reached. The warp length is then

---

1 *Large Fishing Vessel Inspection Regulations* (C.R.C., c. 1435), Section 14.

2 *Arctic Shipping Pollution Prevention Regulations*, Schedule V, Construction Standards for Types A, B, C, D, and E Ships.

3 "NV" indicates the steel grade that corresponds to DNV society rules, and "A" indicates the grade within these rules.

4 A clump is a heavy weight, part of the twin trawl arrangement, which is designed to drag along the bottom between both trawls.

fixed by applying the brake on the winches, and the vessel's speed is reduced to a towing speed of 2.9 to 3.1 knots. Any reduction in this towing speed would allow the trawls or trawl doors to become caught on the bottom.

1.3 History of the voyage

On 29 January 2016, the *Saputi* departed Bay Roberts, Newfoundland and Labrador, and headed northeast to fish shrimp in shrimp fishing area 6 (Appendix D). On 05 February, the vessel headed north toward Davis Strait to fish turbot in NAFO Division 0B.[5] The vessel arrived on the fishing grounds east of Baffin Island on 07 February and began fishing turbot along the ice edge.

On 21 February at 1830,[6] the master was alone on the bridge and began to shoot the trawls, proceeding to the southeast at a speed of 5 knots. At the time, visibility was good, in twilight conditions with a full moon overhead. The two searchlights were on, and both radars were in operation.

At 1840, the master observed a single piece of ice fine to port[7] at a distance of 3 nautical miles (nm) on radar, and confirmed the target visually. The piece of ice was estimated to be 5 m in length, 4 m wide at its widest and 0.5 m in height above the surface, and it appeared to be composed of smaller pieces of ice pushed together and frozen into one larger piece. It was drifting to the south-southeast.

Approximately 15 minutes later, the master began the tow, reducing the vessel's speed to 3 knots and continuing on a southeast course.

As the vessel approached the piece of ice, the master did not assess the ice to be of any danger to the vessel. At 1930, the master slowly altered to port to maintain the intended track of the vessel along the depth contour, and to avoid the ice by leaving it on the starboard side.

As the vessel turned, it heeled to port due to force on the warps.[8] At 1935, the piece of ice was abeam of the vessel to starboard at a distance of 5 m. The vessel continued to heel to port as a result of the turn. A swell from the southeast lifted the vessel and, as the vessel fell off the swell, it made contact with the piece of ice. The impact caused a loud bang, and a vibration was felt. The master proceeded to the starboard bridge wing and saw several pieces of ice smaller than the original piece of ice floating away from the vessel. No pieces caused the master concern; the master continued on with the tow.

---

5 Northwest Atlantic Fisheries Organization fishing area.

6 All times are Atlantic Standard Time (Coordinated Universal Time minus 4 hours), unless otherwise noted.

7 In nautical terminology, "fine" means close or near; the expression "fine to port" means near the vessel's heading, but slightly to port.

8 As the vessel turns, the strain on the warps increases as the weight of the trawl resists this movement. The strain or pulling force acts upon the vessel at the blocks that the warps pass through, hanging above the trawl deck. The pulling force acting at this location on the vessel causes the vessel to incline or list toward the direction of the turn.

At 2030, the engineer on watch (EOW) was alerted by the high bilge alarm in the cargo hold. The EOW started the bilge pump with the aft cargo hold bilge suction open. After the bilge pump ran for several minutes, the EOW removed the bilge strainer cover to find water at pressure, indicating that it was not a false alarm and that there was water in the cargo hold. At 2035, the EOW advised the master that the vessel was taking on water in the cargo hold. The master immediately began to recover the 2 trawls.

At 2040, the master mustered the chief mate and the rest of the crew, and instructed them to move the frozen cargo in the hold to allow access to the area where the water seemed to be coming in (at the extreme forward end of the cargo hold on the starboard side) to enable a better assessment of the damage. At 2100, the master advised the fleet manager that the vessel was taking on water in the cargo hold and that the situation was being assessed.

At 2110, the EOW transferred fuel to port and aft in an attempt to cause the vessel to list to port and raise the damaged area above the waterline. However, the vessel could not be listed enough to accomplish this. At 2115, the 2 trawls were recovered. At 2133, the master called Northern Canada Vessel Traffic Services (NORDREG) by satellite telephone to advise that the vessel had struck ice and that there was an undetermined amount of water ingress in the cargo hold; the vessel was not declaring an emergency, but would continue to assess the damage sustained. NORDREG advised that it would communicate the details of the situation to the Joint Rescue Coordination Centre (JRCC) Halifax, Nova Scotia, and JRCC Greenland.

The master instructed the crew to prepare the rescue boat to investigate the area of the damage. The crew launched the rescue boat, but was unable to see any damage from the boat; it was then taken back on board. The crew then wrapped a mattress in plastic and weighted it with chain to sink it below the surface of the water on the outside of the vessel, with the intention of placing it over the damaged area to slow the ingress of water. As the crew was unable to get the mattress in position over the damage, this process was abandoned.

At 2220, the crew had cleared the cargo from the damaged area and removed the panelling and insulation from the side of the cargo hold. The exposed area revealed a crack running vertically along a hull frame, upward from the deck of the cargo hold, and measuring approximately 1.5 m in length and 1 cm in width at its widest. There was a significant volume of water entering the vessel through the crack, but at that point, there was no water in the forward bilge well of the cargo hold. The engineers set up and started both auxiliary pumps to assist the vessel's bilge pump with controlling the water ingress.

At 2305, the Danish naval vessel *HDMS Knud Rasmussen* departed Greenland to provide assistance to the *Saputi*, with an estimated time of arrival (ETA) of 18 hours.

The crew attempted to slow the water ingress by applying a patch on the inside of the crack. The patch was composed of a sheet of rubber, a piece of wood, and a steel plate. A small hydraulic bottle jack was placed inside the frame and used to press the patch against the crack. This significantly slowed the water ingress through the upper section of the crack. The crew then removed more insulation around the lower section of the crack to attempt applying a second patch. This increased the water ingress dramatically. The second patch was applied but was less successful because the impact had pushed the shell plating forward of the crack inward approximately 3 cm, preventing a tight seal.

At 0120 on 22 February, the vessel was located 140 nm east of Baffin Island and 220 nm west-southwest of Nuuk, Greenland (Appendix E). Due to the quantity and concentration of ice along the coast of Baffin Island, the master proceeded northeast toward Nuuk at 8 knots.

At 0251, the master advised JRCC Halifax that the vessel was unable to keep up with the ingress of water using the pumps on board, and requested additional pumps. The cargo in the hold was beginning to float and clog the suctions of the auxiliary pumps. The crew then created wells around the suctions, placing one pump in a perforated fish basket that kept the debris out of the suction. The crew used a metal chute to direct the water from the crack in the hull into a large fish vat, and placed an auxiliary pump in the vat.

The vessel had developed a port list that caused the master to be concerned about its stability. The EOW transferred fuel to the starboard side, reducing but not eliminating the port list. The vessel was 210 nm west-southwest of Nuuk and proceeding at 5 knots. Winds were northwest at 20 knots with a slight swell, and there was moderate snow and ice-free waters. JRCC Halifax tasked a Hercules aircraft out of Greenwood, Nova Scotia, to deliver pumps to the vessel.

At 0258, the shifting cargo in the hold damaged 1 auxiliary pump, reducing the pumping capacity on board. Only the vessel's main bilge pump and 1 auxiliary pump were functioning at that time to dewater the vessel.

The master mustered the crew members a second time and advised them that the situation was worsening. In preparation for the possibility of abandoning the vessel, the master instructed the crew to get an immersion suit from the storage bin on the bridge and keep it close at all times.

The water level in the cargo hold had increased to the point that it was approaching the refrigeration coils mounted on the cargo hold's deckhead. If the water came into contact with the coils, there was a possibility that the coils would break and that ammonia would be released into the cargo hold. The master instructed the engineers to shut down the refrigeration system to prevent this from happening. Once the system was shut down, the engineers reclaimed the ammonia in the coils and put it in the ammonia storage tank outside the cargo hold to further reduce the possibility of an ammonia leak in the cargo hold.

At 0749, the vessel's main bilge pump lost suction, likely due to the suction line from the aft cargo hold bilge well becoming clogged with debris or freezing over because of the cold temperature. Only 1 auxiliary pump was functioning at that time to dewater the vessel. Before the loss of the vessel's main bilge pump, the crew had tried using both the forward bilge suction and the ballast pump to dewater the vessel. However, the ballast pump was shut down as it did not increase the amount of water displaced. The crew were using only the bilge pump from the aft suction when the main bilge pump lost suction.

At 0830, the Hercules aircraft arrived at the *Saputi* and dropped the first of 4 gasoline-powered search and rescue (SAR) pumps to the vessel. At 0855, 2 SAR pumps were on board the *Saputi*, and the crew was preparing the pumps for operation. The *Saputi* had a 25-degree list to port.

At 0930, all 4 pumps were on board, and the Hercules aircraft was standing by overhead. Two of the pumps were in operation and removing a large volume of water from the cargo hold.

At 1023, the crew had 3 SAR pumps running, and the water level in the cargo hold was receding. However, the pumps soon began to experience problems.

At 1118, the crew members in the cargo hold advised the master that they were having issues with all 4 SAR pumps. Among other issues, the pumps regularly lost suction because the strainers were clogging with debris that was floating in the cargo hold and of the rise and fall of the surface of the water in the cargo hold as the vessel rolled (refer to section 1.9 of this report).

The operation of the pumps' gasoline engines in the cargo hold and factory rapidly created an accumulation of exhaust fumes where the crew worked. Several hatches were opened to ventilate the space, and the crew worked in shifts to keep the pumps operating in the hold. Several crew members experienced headaches and nausea due to the exhaust fumes.

At 1219, the crew was able to get 2 pumps operating at full capacity. Although the strainers had become clogged with pieces of paper, cardboard, and fish, the crew was building wells around the pump suctions to keep the further debris away from the strainers. The 2 pumps were controlling the ingress of water and lowering the water level in the cargo hold. The list was also reduced to 10 to 15°.

At 1250, the winds were northwest at 25 knots, the seas were at 3 to 4 m, and the vessel was proceeding toward Nuuk at 6.7 knots. The *Saputi* was heeled 25° to port. At 1400, the *HDMS Knud Rasmussen* arrived at the *Saputi*'s position. The *HDMS Knud Rasmussen*'s zodiac transferred 3 of its crew members to the *Saputi* so that they could assess the situation and help stop the ingress. Once on board, they immediately went to the cargo hold and suggested that pumps be brought from their vessel. The Danish crew used rags and expansion spray foam to plug any opening around the temporary patches to further slow the ingress of water.

Two gasoline-powered pumps and 2 electric submersible pumps were transferred from the *HDMS Knud Rasmussen* and immediately put into operation. The Danish crew also made large strainers out of perforated metal (Figure 2). The submersible pumps were placed inside these strainers to prevent the debris from clogging the pumps. With the 4 pumps running, the water level receded. At 1445, the vessel was 150 nm from Nuuk, the wind remained northwest at 25 knots, the seas increased to 4 to 5 m, and the vessel's list to port held at 12 to 16°.

Figure 2. Improvised metal strainer (Source: Nataaqnaq Fisheries)

At 1550, the water level in the cargo hold had been reduced considerably, and the extreme rolling of the vessel had been reduced. The vessel's speed was increased to 10 knots. At 1700, the master reduced speed to 6 knots to allow a weather system to pass through and the weather conditions near the Greenland coast to improve ahead of the vessel's arrival.

At 2048, one of the gasoline-powered pumps provided by the *HDMS Knud Rasmussen* failed. At approximately 2200, the power panel supplying the 2 electric submersible pumps malfunctioned, and the submersible pumps could no longer be operated, leaving only 1 gasoline-powered pump to dewater the vessel. This single pump was not able to keep up with the ingress, and the water level in the cargo hold began to rise again.

At approximately 2300, a new power source for the electric submersible pumps was created, and both pumps were put back into operation, once again lowering the water level in the cargo hold. The weather had deteriorated with the wind northwest at 35 knots, the seas at 4 to 5 m from the south, and a visibility of less than 1 nm in snow. The vessel's speed was reduced to 4 knots to reduce pitching.

On 23 February, at 0000, weather conditions remained unchanged, and the water level in the cargo hold continued to lower through the operation of the SAR pumps. The vessel was 115 nm from Nuuk and proceeding at a speed of 4.5 knots.

At 0410, the master was called to the bridge. The water level in the cargo hold, which had been steadily dropping, began to increase. At that point, the volume of water entering the vessel exceeded the capacity of the pumps. At 0510, the water level in the cargo hold had increased significantly, and the cargo was moving freely in the cargo hold. The moving cargo was further hindering pumping operations as the suctions were becoming clogged with debris.

At 0555, the situation had deteriorated drastically; the weather conditions had continued to worsen, water had continued to flood the cargo hold faster than the pumps could pump it out, and the vessel was listing to port at an angle of 40°. To reduce the port list, the master decided to jettison the fishing equipment on the port side. The port trawl warp (14 metric tons [MT]), the port trawl door (5.4 MT), the centre warp (19 MT), and the clump (7.4 MT), which was attached to the centre warp, were all run overboard. As a result, the vessel's port list was reduced to 30°.

The master of the *Saputi* and the team leader of the *HDMS Knud Rasmussen* discussed the situation and agreed that the pumping operations in the cargo hold were not able to control the ingress of water. All pumping operations were stopped, and all efforts focused on making the cargo hold as watertight as possible to prevent the flooding of other compartments. All cargo hold hatches and doors were closed and dogged,[9] and, where possible, were further secured using jack posts from the hatch to the deckhead above (Figure 3). The crew also applied chain hoists to ensure that hatches were tightly sealed and that the increasing water pressure would not pop the hatches open as the cargo hold flooded (Figure 4).

[9] In nautical terminology, the term "dogged" means secured by dogs, simple handles or devices used to tightly secure a door or a hatch.

Figure 3. Jack posts used to secure hatches (Source: Nataaqnaq Fisheries)

Figure 4. Chain hoist used to secure hatch (Source: Nataaqnaq Fisheries)

The master decided to evacuate all crew not essential to the operation of the vessel to the *HDMS Knud Rasmussen*. The master mustered the crew members on the bridge to advise them of this decision. The master also requested that all crew members don their immersion suits and keep them on until advised otherwise given the seriousness of the situation. The master of the *HDMS Knud Rasmussen* planned to use the zodiac to transfer 7 crew members at a time. The first and second groups of 7 to be evacuated were identified and went to the change room on the trawl deck to await the transfer. After the weather conditions worsened, the crew of the *HDMS Knud Rasmussen* reduced the planned number of persons to be evacuated at a time to 5.

At 0700, the zodiac came alongside on the starboard side, and 4 of the *Saputi*'s crew were successfully transferred to the zodiac. However, because the zodiac had sustained damage during the transfer, it was returned to the *HDMS Knud Rasmussen*, and the crew took it out of service to fix it. Twenty-six crew members from the *Saputi* and 3 crew members from the *HDMS Knud Rasmussen* remained on board the *Saputi*.

At 0735, the cargo hold was completely sealed. All hatches were checked every 15 minutes to ensure that no leaking from the cargo hold had occurred.

At 0805, a crew member discovered that a small hatch, leading to the forward end of the cargo hold on the starboard side, was open. Before closing and sealing the hatch, the crew measured the distance from the cargo hold deckhead to the water surface and found it to be 2.44 m.

The master then contacted the vessel's fleet manager ashore, requesting that he contact a naval architect familiar with the vessel and have the naval architect complete calculations to determine the vessel's condition with the cargo hold flooded and 350 MT of product on board.

At 0830, a SAR helicopter located in Kangerlussuaq, Greenland, was tasked by JRCC Greenland to proceed to the *Saputi* and evacuate the remaining crew to the *HDMS Knud Rasmussen*. The winds were from the northwest at 45 to 50 knots with a moderate swell from the southeast and poor visibility in snow.

The naval architect completed the calculations requested by the fleet manager and advised that the vessel could remain afloat and stable with the cargo hold flooded. The fleet manager immediately relayed this information to the master. The fleet manager also advised the master that the information had been confirmed by a second independent naval architect who was familiar with the vessel and the situation on board.

At 0948, the SAR helicopter from Greenland aborted the mission due to icing, before reaching the *Saputi*, and returned to Nuuk.

At approximately 1000, the vessel heeled to port in excess of 45°.[10] The vessel rolled back to starboard and then quickly heeled to port again in excess of 45°. This process occurred several times over the following 6 to 8 minutes. By then, the vessel was listing to port at an angle of 40° and rolling out to 45°. The trawl deck hatch to the factory that was used earlier to ventilate the exhaust fumes from the pumps was still open. With the southeasterly swell now larger than the seas from the northwest, the master slowly turned the vessel to starboard, putting the bow into the swell to prevent a large swell from breaking over the stern and flooding the factory through the open hatch.

The vessel continued to turn to starboard until it reached a course of 180°. The wind was now on the starboard side of the superstructure, further heeling the vessel. The large swells from the southeast were striking the bridge windows on the port side and water was beginning to flood the trawl deck. The master put the rudder hard to port and pushed the telegraph to full ahead; this manoeuvre cleared water from the decks. The vessel continued to turn to port until it reached a course of 330°. At that time, the rolling of the vessel reduced and the vessel's port list stabilized at 40°.

The vessel slowly turned to starboard, settling on a heading of 045° toward Nuuk. The southeasterly swells reduced to 4 to 5 m. With a strong wind and a big sea from the northwest now on the port side, the vessel listed to starboard between 20° and 22°. The master jettisoned the starboard trawl warp (14 MT) and starboard trawl door (5.4 MT). The EOW transferred fuel from the starboard side, which had been at full capacity to reduce the previous port list, back to the port side. The vessel then returned to a near upright position.

At approximately 1100, a large swell from the southeast struck the *Saputi* on the starboard side and heeled the vessel to port in excess of 45°. The vessel rolled back and settled with a new list to port of 35 to 40°. All fuel transfer operations were stopped.

---

10 Heel and list readings are taken from an inclinometer on the bridge, with a maximum range of 45° to port and starboard. Any inclination past 45° cannot be accurately determined using the inclinometer.

At 1130, the hatch on the trawl deck leading to the factory was secured in order to prepare for the possibility of increased sea conditions in the area of the shallow bank off the Greenland coast. The swell increased as the vessel crossed onto the bank, resulting in an increase in the rolling of the vessel for a certain amount of time, but the vessel soon stabilized with a 45° list to port.

At 1750, the *Saputi* entered the fjord leading to Nuuk. In the sheltered waters of the fjord, 4 *Saputi* crew members and the 3 *HDMS Knud Rasmussen* crew members on board the *Saputi* were transferred to the *HDMS Knud Rasmussen*. At that point, 22 crew members remained on board the *Saputi*. The vessel continued up the fjord with a 40-degree list to port, and secured at Nuuk on 24 February at 0023.

1.4 Damage to the vessel

The vessel sustained a vertical crack in the shell plating on the starboard side within the strengthened ice belt between frames 78 and 79, at the forward end of the cargo hold. The crack measured 3000 mm; it originated approximately 3300 mm above the keel and ran upward. The shell plating between frames 75 and 80 was indented. The indentation had a maximum depth of 300 mm and measured 3200 mm wide by 3000 mm high. As a result, numerous frames were indented, and several stringers were indented, deflected, and cracked in way of the dent (Appendix F, Appendix G).

The transverse bulkhead forming the forward end of the cargo hold at frame 80 was also indented but not breached. At the estimated forward draft of 4.7 m, the centre of the crack would have been 1.4 m below the surface of the water outside of the vessel at the time of impact.

1.5 Post-occurrence examination

After the occurrence, a sample of the *Saputi*'s shell plating was tested,[11] and the following was found:

- the chemical composition of the sample met the requirements of the NV A specification;
- the tensile properties of the sample met the requirements of the NV A specification; and
- although it was 30 mm thick, the sample exceeded the minimum requirements of the NV A specification for a plate thickness of 50 mm or greater in terms of its impact energy properties (there is no minimum requirement for the 30 mm plate).

The sample was divided into segments, and each segment was tested at various temperatures to obtain impact energy results. Several of the results showed that the impact energy required to fracture the steel was substantially lower than that of the other sample

11 TSB Engineering Laboratory Report LP157/2016, available upon request.

segments tested at the same temperature.[12] However, such results are not uncharacteristic for any steel plate, and are not indicative of a fault or defect in the plate.

1.6 Personnel certification and experience

The master held a valid Fishing Master, First Class certificate issued in 2012. The master had sailed on fishing vessels in various capacities since 1980, and on factory freezer stern trawlers since the late 1980s. He joined the company that owns the *Saputi* in 2006 and, at the time of the occurrence, had sailed as master on the *Saputi* since 2009. As the vessel was operated in ice and northern waters for more than half of the fishing season, the master had significant experience navigating in ice.

1.7 Vessel certification

The *Saputi* was certified and equipped in accordance with existing regulations. The vessel was built and maintained in class with Det Norske Veritas - Germanischer Lloyd (DNV-GL). The vessel's classification certificate was valid (expiring 31 July 2016) and the most recent annual classification society survey had been carried out on 21 October 2015, at which time it was recommended that the vessel be retained within class.

The *Saputi* did not operate under a safety management system (SMS), nor was one required for this class of vessel.

1.8 Environmental conditions

At the time of impact with the piece of ice, the vessel was navigating in twilight in 3/10 to 4/10 ice coverage, 2/10 medium first-year ice (70 to 120 cm), and 2/10 thin first-year ice (30 to 70 cm) in strips 20 m wide, consisting primarily of small bits of ice with some larger pieces (Appendix H). Icebergs were visible on the horizon. The weather was clear and the visibility was good, estimated at 8 nm. The air temperature was −7°C, and the wind was light and variable. There was a moderate swell from the southeast.

1.9 Search and rescue provided pumps

It is the mandate of the Canadian Armed Forces to provide aeronautical search and rescue services while also supporting the Canadian Coast Guard in providing maritime SAR. Royal Canadian Air Force (RCAF) squadrons responsible for SAR have at their disposal a minimum of 3 air-droppable marine pump kits for use in response to maritime incidents. These marine pump kits are inspected every 180 days. As part of this process, pumps are run to confirm they are operational and in good working order, and other kit components are checked. The single type of pump that the RCAF employs is of a size and weight that can fit on board SAR aircraft and be easily handled by flight aircrew, as well as recovered by the crew on the distressed vessel and put to use. The pump is intended to perform in a variety of

---

12 Ibid. (see Table 1, Particulars of the vessel).

situations and the choice to use a single type of pump minimizes the financial, personnel-related, and logistical pressures that may be associated with the acquisition, maintenance, and training on multiple pumping systems.

SAR resources delivered 2 sets of pumps to the *Saputi*. The RCAF resources delivered one set of pumps, while the Danish SAR provided the other.

The pumps that came from the Canadian aircraft were powered by a gasoline engine and equipped with a non-collapsible suction hose measuring 7.6 cm in diameter and 4.8 m in length. A metal strainer was attached to the intake end of the hose, and there was a camlock-type fitting at the pump end. A discharge hose of light synthetic rubber construction measuring 7.6 cm in diameter and 6.1 m in length was also provided. This hose also had a camlock-type fitting at the pump end.

The pumps were delivered to a remote area less than 6 hours after the *Saputi* had requested them. Given the compact and robust characteristics of the pumps provided by Canadian SAR resources, they can be dropped from aircraft, greatly decreasing the wait time for vessels in distress.

The pumps were initially set up in the enclosed cargo hold, but the discharge hose kinked repeatedly when the crew tried to extend it to the deck above. The pumps were then moved to the enclosed factory on the main deck, immediately above the cargo hold. The suction hose was not long enough to allow the pumps to be set up on the open deck, and there was no means of connecting multiple lengths of hose. The operation of the gasoline engines in the enclosed space of the factory rapidly created a buildup of exhaust fumes in areas where the crew was required to work. Because the pumps could not discharge to the deck above due to kinking, they were being discharged onto the factory deck, where the vessel's own factory pumps were required to discharge the water overboard.

The pumps provided by the Canadian aircraft regularly lost suction because the strainers became clogged with debris that was floating in the cargo hold and the rise and fall of the water's surface in the cargo hold as the vessel rolled. The pump engines also stalled when the vessel's deck was at an angle due to the vessel's list. Positioned on the main deck, approximately 2 m above the water in the cargo hold, the pumps and suction hoses became difficult to prime using the attached hand pump. The crew spent considerable time trying to keep these pumps running in a challenging situation.

The 4 pumps delivered by the *HDMS Knud Rasmussen* were able to overcome many of the challenges experienced with the Canadian SAR pumps. Of these pumps, 2 were electric submersible pumps that were not affected by the vessel's list and did not generate exhaust gases. The other 2 pumps were gasoline-powered and equipped with a suction hose of approximately 7 m in length. Since the length of the hose allowed the pumps to be set up on the open trawl deck, all of the issues with the exhaust fumes were avoided. The gasoline-powered pumps were mounted on gimbaled platforms that kept the pump level on the inclined deck, preventing the engine from stalling. The gasoline-powered pumps still became clogged with the debris floating in the cargo hold; however, they could be restarted much faster and easier than the other gasoline-powered pumps each time they had to be shut down and cleared of debris. The fast and easy priming was due to a priming system that used the pump's engine and a v-belt to engage and drive the priming impeller rather than a hand-suction pump.

1.10 Arctic Ice Regime Shipping System

The *Arctic Shipping Pollution Prevention Regulations* govern access of vessels to the Arctic, through the Zone/Date System. The Arctic is divided into 16 shipping safety control zones, and access to each zone has been established based on historical data related to the probable ice conditions at different times of the year and the capabilities of the various vessel types to operate in ice.

The *Saputi* was operating in shipping safety control zone 15[13] and is a Type D[14] vessel based on its DNV ice classification. According to the Zone/Date System table,[15] Type D vessels are allowed to access zone 15 between 05 July and 10 November each year.

Because this simple system does not address the reality that ice conditions vary significantly from year to year, the Arctic Ice Regime Shipping System (AIRSS)[16] was developed as a flexible and safe system to permit vessels to navigate in the Arctic when ice conditions allow for it. AIRSS takes into account the risks different ice conditions pose to the structures of different vessels. Voyages that do not fall within the Zone/Date System must use AIRSS to obtain access to the Arctic.

Any vessel using AIRSS must have an ice navigator on board. To be considered an ice navigator, a person must be qualified to act as a master or person in charge of the deck watch and have served in that capacity while the vessel was operating in ice conditions for a total period of 50 days (30 of which must have been in Arctic waters).[17] Both the master and chief mate had sufficient qualifications and experience operating in ice conditions to act as the ice navigator.

To apply the AIRSS, it is necessary to obtain the current ice conditions for all points along the intended route. For each different ice condition or ice regime found along the route, an ice numeral (IN) is determined using the characteristics of the ice regime and the capabilities of the vessel through a mathematical calculation. If all INs are 0 or greater, an Ice Regime Routing Message in the specified format (with the vessel particulars, routing details, and ice navigator's name) is sent to NORDREG, and the vessel may proceed on the intended voyage. If the IN for any ice regime along the route is negative, access is not permitted. The master must consider an alternative route with less challenging ice conditions or wait for any

---

13 Shipping Safety Control Zones Order, Schedules 1 and 2.

14 *Arctic Shipping Pollution Prevention Regulations*, Schedule V, Construction Standards for Types A, B, C, D, and E Ships.

15 Ibid., Schedule VIII: Zone/Date System table.

16 Transport Canada, TP 12259, *Arctic Ice Regime Shipping System (AIRSS) Standards*.

17 *Arctic Shipping Pollution Prevention Regulations* (C.R.C., c. 353), subsection 26(3).

improvement in ice conditions that would result in INs that are 0 or greater. If INs remain negative, proceeding with the assistance of an icebreaker is an option.

On 06 February, the *Saputi* sent the required Ice Regime Routing Message to NORDREG. No IN was indicated in the message; however, the information provided in the message would have resulted in an IN of +12.

1.11 Assessment of floating ice

Determination of the type of ice encountered by the navigator indicates the hardness of the ice and its potential to cause damage to the vessel. The detection of ice by a vessel's crew is primarily achieved using standard marine radar and visual observation.

Various manufacturers produce specialized ice radars that display an image that is clearer than that of a standard marine radar and free of clutter, which assists the navigator in detecting ice.

Although there are currently no commercially available radars that can differentiate between types of ice based on hardness or salt content, research in the area of dual-polarized marine radar is ongoing.[18] The dual-polarized marine radar has the ability to differentiate glacier and multi-year ice from surrounding first-year ice. Furthermore, the Canadian Coast Guard, in partnership with Transport Canada (TC) and others, is carrying out research and development concerning an ice hazard radar system that displays high-resolution images of the ice and provides a clear contrast between the dangerous multi-year ice and other sea ice.[19]

Thermal imaging cameras (such as FLIR) are also used to detect floating ice. As these cameras use infrared radiation of the ice to create an image, they are effective in darkness and restricted visibility. Although there is some evidence that the image displayed by thermal imaging cameras differs between ice types, the cameras are primarily intended for ice detection and cannot be relied upon for assessment.

In this occurrence, the master of the *Saputi* had access to a standard marine radar to detect the presence of ice. As this radar does not distinguish between ice types, the master carried out that task by performing visual assessments.

Visual assessment of ice to determine its type and age must consider the following characteristics:

- The colour of the ice

---

18 Petroleum Research Newfoundland and Labrador, "Development of Improved Ice Management Capabilities for Operations in Arctic and Harsh Environments," November 2014, available at http://pr-ac.ca/files/files/PRNL%20Ice%20Management%20Program%20-%20November%202014.pdf (last accessed 16 March 2017).

19 Barbara J. O'Connell, Canadian Coast Guard, "Ice Hazard Radar", available at http://www.ccg-gcc.gc.ca/e0014402 (last accessed 24 October 2016).

- How high the ice sits out of the water
- The appearance of the ice surface
- The qualities of the ice circumference

First-year ice is sea ice that has formed within 1 winter season. Its thickness ranges between 30 cm and 2 m. As it contains a high amount of salt, first-year ice is softer than glacier ice and poses less of a hazard to an ice-strengthened vessel. Second-year ice has survived through 1 summer season and, as it is thicker than first-year ice, sits higher out of the water. Multi-year ice has survived through at least 2 summer seasons. Both second-year and multi-year ice can be referred to as "old ice" and are usually thicker than first-year ice. As ice ages, the salt leaches out of it, causing it to harden; thus, old ice is denser and harder than first-year ice. Therefore, contact with old ice is to be avoided wherever possible.[20]

These different types of ice all have visual characteristics that may be discernable to a navigator navigating in ice-infested waters, for example:

- Old ice is smoother than first-year ice.
- Multi-year ice has a more irregular, undulating appearance, due to the hummocks, ice ponds and valleys from the previous years' melting.
- When viewed from the side, first-year ice has a greenish hue, while multi-year ice is more bluish in colour.[21]
- First-year ice floes may be more angular and present sharper edges.

Glacier ice forms on land and is made of fresh water. The lack of salt makes this ice extremely hard and dangerous to vessels. There are 2 types of glacier ice that are commonly encountered:

- Bergy bits are pieces of glacier ice that generally show 1 m to less than 5 m above sea level, with a length of 5 m to less than 15 m. They normally occupy an area of 100 to 300 square metres (m^2).
- Growlers are pieces of glacier ice that are smaller than bergy bits and float less than 1 m above the sea surface. They usually appear to be white but may also be transparent or blue-green in colour. Extending less than 1 m above the sea surface and normally occupying an area of about 20 m^2, growlers are difficult to distinguish when surrounded by sea ice or in high sea state.[22]

1.12 Subdivision of the vessel

A vessel is subdivided into watertight compartments by decks and bulkheads. Where there is a greater level of subdivision, the vessel is more resistant to sinking in the event of

---

20 Canadian Coast Guard, *Ice Navigation in Canadian Waters*, Section 3.2.3: Ice Properties.

21 Captain Duke Snider FNI, *Polar Ship Operations: A Practical Guide* (London: The Nautical Institute, 2012), page 69.

22 Canadian Ice Service – Environment Canada, *Manual of Standard Procedures for Observing and Reporting Ice Conditions* (MANICE), Section 1.5.3.

damage. However, the activities for which a vessel is used and the way it is operated may limit the amount of subdivision possible.

The *Large Fishing Vessel Inspection Regulations* require every fishing vessel to have at least 3 suitably spaced transverse watertight bulkheads: 1 collision bulkhead in the forward section of the vessel, and 2 bulkheads aft of the collision bulkhead located at positions suitable to the design of the vessel.[23]

The *Saputi* had 4 transverse watertight bulkheads: a collision bulkhead forward of fuel oil tank 2 at frame 87, a second bulkhead separating the forward end of the cargo hold and fuel oil tank 2 at frame 80, a third bulkhead separating the aft end of the cargo hold and the engine room at frame 38, and a fourth bulkhead forming the aft end of the engine room at frame 10.

There is no design requirement for a fishing vessel to remain afloat or stable with any one compartment flooded as a result of damage. However, Canadian regulations[24] require that vessels, other than fishing vessels, be constructed so as to provide sufficient intact stability to withstand the final flooding of any one of the main compartments into which the vessel is subdivided.

Fishing vessels that carry fish in bulk are required to have watertight subdivisions in the cargo hold. However, as frozen packaged fish is not considered bulk, no such subdivision is required for vessels that carry fish in that form.

1.13 Damage control planning

The International Maritime Organization's (IMO) *International Convention for the Safety of Life at Sea* (SOLAS) requires passenger and dry cargo vessels to develop a damage control plan and booklet.[25] The *Saputi* did not carry a damage control plan or booklet, nor are these required for a fishing vessel.

The objective of damage control planning is to provide vessel personnel with clear information on the vessel's watertight subdivision and the effective maintenance of watertight boundaries in the event of flooding. This includes precautions to take to prevent the progressive flooding of undamaged spaces by ensuring the closure of any openings in the watertight boundaries.

Damage control plans and booklets may also indicate, through a colour-coded system, the likelihood of the vessel's survival with 1 or more of the watertight compartments flooded (Appendix I). Advice regarding the causes of any list, the effects of jettisoning deck cargo and liquid transfer options to manage a list, and information regarding the creation of

---

23 *Large Fishing Vessel Inspection Regulations* (C.R.C., c. 1435), subsection 19(1).

24 *Hull Construction Regulations* (C.R.C., c. 1431), subsection 12(1).

25 International Maritime Organization, *International Convention for the Safety of Life at Sea (SOLAS)*, 1974, as amended, Chapter II-1, Part B-4, Regulation 19 – Damage control information.

additional free surfaces through pumping operations to control water ingress may also be included. A damage control plan is not intended to replace the good judgment of the master but to ensure that the master considers all aspects of the situation.

In addition to a damage control plan and booklet, vessels may also carry essential damage-control materials that are available on short notice such as items to construct a patch, bracing and jacks for securing a patch or bracing a watertight door or hatch, plugs and wedges for smaller holes, and cutting and construction tools.

1.14 Post-damage stability information

A large fishing vessel is required[26] to undergo an inclining experiment to determine its stability under many different conditions, such as lightship, port departure, arrival at the fishing grounds, half-loaded condition, full load condition, and worst operating condition affecting stability. A booklet detailing the stability conditions of the vessel must be on board the vessel for the master's use. The purpose of this booklet is to provide the master quickly with key details of the vessel's stability, such as metacentric height and freeboard in common vessel conditions, without the necessity for any manual calculations.

Passenger vessels carry a document on board detailing the vessel's stability in a damaged condition in addition to normal operating conditions.[27] Again, this provides the master with key details of the vessel's stability in situations where a compartment has been damaged and flooded, without requiring any manual calculations in an emergency. There is no requirement for a fishing vessel to have such a document on board. Although the *Saputi* had a stability booklet for normal operating conditions, it did not have a document related to its stability in a damaged condition.

1.15 Immersion suits

Marine immersion suits protect a person immersed in cold water by reducing thermal shock upon entry, delaying the onset of hypothermia, and providing flotation to minimize the risk of drowning. In Canada, immersion suits are approved by TC according to the Canadian General Standards Board's (CGSB) standard[28] that includes rigorous testing for characteristics such as thermal performance, hand dexterity, skid resistance, and mobility out of the water.

The effectiveness of an immersion suit in preventing hypothermia, however, depends on how well it fits the wearer to prevent the ingress of water.

Abandonment suits come in several sizes and are designed for rapid donning by uninitiated persons, often in adverse conditions, with minimal risk that they will be improperly worn.

---

26 *Large Fishing Vessel Inspection Regulations* (C.R.C., c. 1435), section 9.

27 *Hull Construction Regulations* (C.R.C., c. 1431), subsection 12(6).

28 Canadian General Standards Board, National Standard of Canada, Immersion Suit Systems, CAN/CGSB-65.16-2005, section 8.5.

Universal size immersion suits "are designed with a 'One size fits most' approach, [making them] suitable for uncontrolled distribution in emergency situations".[29] The universal suit is designed to fit persons ranging in height from 150 to 200 cm and with a body mass ranging from 50 to 150 kg. [30] Small and jumbo suits are designed, respectively, for individuals who are below and above these height and weight limits.

In this occurrence, the *Saputi*'s immersion suits were sent to the manufacturer's representative for annual testing in the days before the vessel sailed. Following this testing, 22 of the vessel's suits were replaced by an equal number of new suits from a different manufacturer. The new suits arrived on board immediately before the vessel's departure. The new suits ordered in jumbo and universal sizes fit larger height and weight ranges than the previous ones (Table 2). The replacement suits were ordered based on the size names; i.e., a jumbo size to replace a jumbo size. The *Saputi* carried 35 approved[31] immersion suits, 16 of which were jumbo in size.

Table 2. Comparison of immersion suit sizes

Immersion suit	Universal size		Jumbo size	
	Height	Weight	Height	Weight
Original suits	168 to 185 cm	54 to 113 kg	180 to 198 cm	<145 kg
New suits	150 to 191 cm	50 to 150 kg	>191 cm	>100 kg

On board the *Saputi*, crew members practiced the donning of immersion suits to ensure proper donning and fit during abandonment drills at the beginning of each voyage. The emergency drill logbook indicated that regular drills had been carried out over the previous year, the last being conducted during the previous voyage on 05 January 2016. However, no emergency drill was conducted before or during the occurrence voyage.

Under the *Large Fishing Vessel Inspection Regulations*, fishing vessels of more than 24.4 m in length or of a gross tonnage of more than 150 making voyages beyond the limits of home-trade Class IV voyages, such as the *Saputi*, are required to carry 1 approved immersion suit for each person on board.[32] There is no reference in the regulations to the fit of the immersion suit.

The *Fire and Boat Drills Regulations,* which apply to fishing vessels of a gross tonnage of more than 150 such as the *Saputi*, require the master of a vessel to ensure that crew members are capable of donning the immersion suits or marine anti-exposure suits that are carried on the

29 Ibid., section 4.1.2.3.

30 Ibid.

31 Transport Canada Approval No. T.C.315.070.001.

32 *Large Fishing Vessel Inspection Regulations* (C.R.C., c. 1435), paragraph 24(7)(a.1).

vessel.[33] However, there is no specific reference in those regulations regarding the fit of the immersion suit.

The *Regulations Amending the Small Fishing Vessel Inspection Regulations,* which will come into force on 13 July 2017, require fishing vessels of not more than 24.4 m in length and with a maximum gross tonnage of 150 making certain voyages to carry an immersion suit of an appropriate size for each person on board.

The *Torremolinos International Convention for the Safety of Fishing Vessels,*[34] which Canada has not ratified, applies to fishing vessels of 24 m in length and over, such as the *Saputi*. Where an immersion suit is required under this convention, it must be an "approved immersion suit, of an appropriate size."[35]

In addition to thermal protection and flotation, TC approval ensures a minimum level of mobility which allows the wearer to carry out basic emergency duties. Manufacturers design several models of immersion suit with a variety of features which increase the mobility of the wearer beyond these minimum limits, allowing them to carry on with their regular routine while wearing the suit. These features may include form fitted feet for greater mobility and slip resistance and removable gloves for improved hand dexterity and can be found on immersion suits from various manufactures.

In this occurrence, abandonment was believed to be imminent due to the vessel's severe list. To prepare for immersion in case the vessel capsized, the crew members donned their immersion suits more than 18 hours before the vessel arrived in port. After donning the suits, some crew members continued to carry out their duties such as navigating the vessel, keeping the engine running, and ensuring that the flooding was contained to the cargo hold. However, the attached mitts, slippery feet and general looseness of the suits hindered the completion of these tasks, which resulted in the crew partially unzipping the suits, removing their arms from the sleeves and tying the sleeves around their waist. This helped with the completion of tasks requiring hand dexterity but did not alleviate the risks of slipping and tripping.

1.16 Cargo securing

Once the catch had been processed, packaged, and frozen in the factory, the boxes were sent to the refrigerated cargo hold. To ensure proper refrigeration, the cargo hold deck was completely covered with wooden pallets to create an air space between the deck and the frozen product. To store the boxes, one complete layer was laid on top of the pallets, packed tightly to the sides of the cargo hold. This arrangement prevented the boxes from moving

---

33 *Fire and Boat Drills Regulations* (SOR/2010-83), section 26.

34 International Maritime Organization, *International Regulations for the Safety of Fishing Vessels, Cape Town Agreement of 2012 on the Implementation of the Provisions of the 1993 Protocol relating to the Torremolinos International Convention for the Safety of Fishing Vessels, 1977* (Cape Town Agreement), Regulation 9.

35 Ibid.

horizontally in any direction. Once a layer was complete, another layer was started on top of the previous layer, and the process was repeated until the cargo hold was filled to capacity. This process maximized the cargo-carrying capacity of the vessel, prevented the shifting of the cargo, and allowed the vessel to maintain a manageable list and trim during loading. The vessel also carried bagged shrimp that was stored in a similar manner; a standard pallet-stacking method was used for subsequent layers to ensure stability and prevent shifting due to the movement of the vessel.

The vessel's general arrangement indicates pen boards that divide the cargo hold into 27 smaller sections. The use of pen boards is often required in the stowage of certain cargo prone to shifting, such as bulk fish. Although the vessel at one time used pen boards to segregate different cargo, the cargo was no longer stored in that way, and no pen boards were on board at the time of the occurrence.

1.17 Previous occurrences

Previous investigations by the Transportation Safety Board of Canada (TSB) have revealed similar safety issues related to ice damage, flooding, and the subsequent sinking of large factory freezer trawlers.

In March 2000, the *BCM Atlantic*[36] struck a piece of ice on the shrimp fishing grounds off Labrador. The vessel was holed in the vicinity of the bulkhead separating the machinery space and the cargo hold. The bilge pumps were unable to keep up with the ingress of water in the machinery and cargo hold. The crew abandoned the vessel into liferafts, were recovered by another fishing vessel 3 hours later, and suffered no injuries. The vessel sank 4 hours after striking the ice.

In June 1990, the *Northern Osprey*[37] was operating on the shrimp fishing grounds off Labrador when it sustained undetected damage to the shell plating in the vicinity of the bulkhead separating a fuel tank and the cargo hold. Fuel oil entered the cargo hold. Attempts to pump the fuel out using the bilge system failed, likely due to frozen suction lines in the refrigerated cargo hold. Access covers to a pipe tunnel in both the cargo hold and engine room were removed to allow the fuel to drain and be pumped from the engine room. These access covers were never replaced, removing the watertight subdivision. When water later entered the cargo hold, it was able to progressively flood the engine space through the pipe tunnel, and the vessel sank. The crew abandoned the vessel into liferafts and were recovered by another fishing vessel 1 hour later with no injuries.

The TSB has also previously investigated an occurrence that revealed similar safety issues related to immersion suits and the ingress of water.

---

36 TSB Marine Investigation Report M00N0009.

37 TSB Marine Investigation Report M90M4020.

In February 2004, the commercial fishing vessel *Hope Bay*[38] suddenly listed to starboard and capsized while transiting Queen Charlotte Sound, British Columbia. The 4 persons on board abandoned the vessel by jumping into the sea; however, only 3 of them were wearing immersion suits. Search and rescue personnel rescued 1 person wearing an immersion suit and recovered the bodies of 3 others. The 2 casualties recovered in immersion suits were found with their suits filled with cold water. The immersion suit worn by the survivor was effective at limiting the ingress of cold water.

1.18 TSB Watchlist

The Watchlist identifies the key safety issues that need to be addressed to make Canada's transportation system even safer.

Commercial fishing safety is a 2016 Watchlist issue.

Commercial fishing safety has been a Watchlist issue since 2010. In Canada, even though the numbers of registered fishermen and active fishing vessels have declined overall since 2006, the average number of fatalities has remained constant at 10 per year. The Board remains concerned about vessel stability, the use and availability of lifesaving appliances on board, and unsafe operating practices. Although regulations that apply to fishing vessels less than 24.4 m in length (the *Fishing Vessel Safety Regulations* phase 1) have been published and will likely lower some of the risks associated with outstanding safety deficiencies, there remain gaps with respect to stability assessments and associated guidance, as well as the carriage of emergency position indicating radio beacons (EPIRB) and immersion suits on these vessels. For phase 3 of the regulations, which will apply to large fishing vessels over 24.4 m in length, no work has commenced.

Commercial fishing safety will remain on the Watchlist until

- new regulations are implemented for commercial fishing vessels of all sizes;
- user-friendly guidelines regarding vessel stability are developed and implemented to reduce unsafe practices;
- there is evidence of behavioural changes among fishermen regarding the use of personal flotation devices, EPIRBs, and survival suits, as well as of on-board safety drills and risk assessments being carried out; and
- there is concerted and coordinated action by federal and provincial authorities, leaders within the fishing community, and fishermen themselves to put in place strong regional initiatives and develop a sound safety culture in the fishing community.

The Watchlist highlights the need for concerted and coordinated action by federal and provincial authorities and by leaders in the fishing community to improve the safety culture in fishing operations, recognizing the interaction of safety deficiencies.

1.19 TSB laboratory reports

The TSB completed the following laboratory report in support of this investigation:

[38] TSB Marine Investigation Report M04W0034.

- LP157/2016 –Examination of Ship Plate

2.0 Analysis

2.1 Factors leading to the flooding

Before the flooding of the cargo hold, the *Saputi* was towing 2 trawls. When towing trawls, the vessel must maintain a slow and constant speed to prevent the trawls from fouling the bottom and to ensure that they operate as designed. The master detected a single piece of ice ahead and assessed it to be non-threatening to the vessel. Despite the use of all available equipment and a sound visual assessment process, the non-threatening ice visible to the master concealed a growler, or a piece of multi-year ice. The master elected to alter course to port just enough to avoid the ice. This minor alteration was also meant to ensure that the vessel's speed would not be reduced through a large turn. The turning of the vessel caused it to heel to port. As the vessel was passing the ice, a swell from the southeast lifted the vessel and it made contact with the piece of ice as it fell off the swell. Although the heel to port allowed the ice to contact the vessel lower than if the vessel had been upright at the time of impact, the impact was still within the strengthened ice belt area. The vessel's hull was damaged, resulting in an uncontrolled ingress of water in the refrigerated cargo hold.

The vessel was constructed and maintained with an ice classification appropriate for the conditions. Testing of the vessel's hull plating also indicated that the vessel was structurally sound before the impact, and that the properties of the steel in the plating met or exceeded the requirements for this grade of steel. The vessel complied with all regulatory requirements of the Arctic Ice Regime Shipping System (AIRSS), and the master was experienced in ice navigation, including the assessment of ice.

Despite many concentrated efforts, the crew was unable to stem the ingress of water or fully stabilize the vessel. Temporary patches positioned on the interior of the cargo hold by the crew were effective at reducing the ingress of water for a time. However, during the voyage to Nuuk in severe weather, the ingress of water increased dramatically. This increase was likely caused by a shifting of the temporary patches, the growing of the initial crack or increased pressure on the crack from heavy weather, or a combination of all 3 factors.

Although the vessel was equipped with significant pumping capacity and additional pumping capacity was provided by search and rescue (SAR) resources, the mixing of the cargo with the water clogged the pump suctions and prevented them from working at full capacity. The cargo hold continued to flood, and the vessel took a significant list to port that could not be corrected by the transfer of liquids or other means.

With no damage control plan or designated equipment, the crew members used their personal experience with the vessel, creativity, and available materials to slow the ingress of water. They then isolated the cargo hold from the rest of the surrounding spaces to prevent the complete flooding of the vessel. The vessel continued toward port under its own power and arrived 3 days after striking the ice with no injuries to the crew on board.

2.2 Assessment of floating ice

The assessment of ice and determination of ice types encountered is critical to navigators because certain ice types can cause damage to the vessel. In the area of the occurrence, navigators may use ice-strengthened vessels and expect to strike some ice during a voyage. However, they use available technology, such as radar and FLIR, to detect ice, as well as visual assessments to help them determine which pieces of ice must be avoided.

In this occurrence, the master had significant experience operating in ice conditions. The master detected the piece of ice using marine radar and visual observation, despite the thermal imaging camera not working at the time. The master was familiar with the characteristics of the various types of floating ice and, through visual observation, assessed the piece of ice as non-threatening based on its colour and appearance, and how high it sat out of the water. As the ice appeared to be first-year ice, consisting of smaller pieces frozen together into one floe, the master determined that it was unlikely to cause any damage to the vessel.

However, based on the damage caused to the vessel, the smaller, non-threatening first-year ice pieces were likely covering a harder piece of multi-year ice or a growler. Although proper techniques in the detection and assessment of floating ice may be used, ice that is hazardous to a vessel may be surrounded by thin ice and therefore be concealed from detection. Navigators need to be cautious when assessing floating ice and use every available means to ensure that the ice has been properly identified.

If ice that is hazardous to a vessel is surrounded by thin ice or concealed by a light snow covering, navigators may not perceive it as a threat, which puts them at risk of damaging their vessels.

2.3 Subdivision

Canadian regulations[39] require that certain types of vessels be constructed with sufficient subdivision to withstand the flooding of any one of the main compartments into which they are subdivided. However, this requirement does not apply to fishing vessels.

Fishing vessels operating in ice-infested waters face the additional risk of hull damage from contact with ice. In this occurrence, the *Saputi* sustained hull damage following contact with ice that led to the flooding of the cargo hold, the largest space on board. The cargo hold extends more than half the overall length and over the entire breadth of the vessel, and is located in the forward part of the vessel; it also extends below the waterline. Due to the size and location of the cargo hold, if ice damage occurs to a fishing vessel, it will likely occur to the cargo hold.

The *Saputi* and any other fishing vessels operating in ice-infested waters are not required by regulation to remain afloat in a damaged condition when the cargo hold is flooded. In this

---

39 *Hull Construction Regulations*, subsection 12(1).

occurrence, the *Saputi* was able to withstand the complete flooding of the cargo hold, remain afloat, and proceed to port. However, the *Saputi's* capacity to do so was not a factor considered in the design or construction of the vessel, but was merely coincidental.

Therefore, if fishing vessels operating in ice-infested waters are not designed and constructed to withstand the complete flooding of any one of the main compartments, there is a risk that vessels will not be able to remain afloat if they lose their watertight integrity.

2.4 Damage control planning

Despite the safeguards in place, including having an ice-strengthened vessel, complying with AIRSS standards, having a qualified ice navigator on board, and navigating at a speed that would reduce the damage caused by an impact with ice, damage can and does happen to vessels in ice-infested waters. In addition, there is a lack of subdivision requirements on fishing vessels to enable vessels to withstand the flooding of any main compartment. As such, having a damage control plan on board is important to ensure that the actions taken by crew members are informed, efficient and effective to mitigate any damage and avoid loss of life.

In this occurrence, the crew members of the *Saputi* used their creativity and experience to react to the flooding of the compartment as the situation unfolded. They were able to stem the ingress of water and manage it for a time, using pumps and temporary patches. Due to their actions, the crew had enough time to consult with a naval architect to make calculations to ensure that the vessel could remain upright if the compartment flooded entirely, which it did.

However, damage control planning in advance would have been beneficial to the master and crew. Damage control planning provides readily available and concrete information regarding the vessel's watertight compartments and the means of ensuring the closure of openings in the watertight boundaries to maximize stability and survivability and to prevent flooding of the adjoining spaces.

The following are issues encountered by the *Saputi* crew that may have been addressed through damage control planning:

- A hatch from the cargo hold to the factory above was left open when the cargo hold was closed, allowing a path for progressive flooding. Damage control planning would include a complete list of all openings to be closed in the event of flooding.
- The master and crew were unaware of the vessel's ability to remain afloat and stable with the cargo hold completely flooded; they had to consult with a naval architect ashore to determine that fact. Damage control planning would quickly provide details on the vessel's stability with flooded compartments, allowing for earlier and more effective arrangements for abandonment, if necessary, to prevent loss of life.

Furthermore, the crew of the *Saputi* improvised, and used available materials not specifically intended for damage control. Owners and operators that have a damage control plan may acquire specific equipment and materials to respond more efficiently to damage that may occur.

Finally, the area of the occurrence may be very remote, as it was in this case, with few, if any, other vessels operating nearby. After the crew's request, it took nearly 6 hours for an aircraft to deliver the needed pumps to the *Saputi*. As assistance from SAR resources may be delayed due to distance or availability, it is important that crew be prepared to respond autonomously to damage to the vessel.

Thus, if fishing vessels operating in ice-infested waters do not carry a damage control plan and booklet on board, the master and crew may be inadequately prepared in an emergency situation where there is ingress of water, and may be unable to keep the vessel afloat until the arrival of rescue resources.

2.5 *Search and rescue pumps*

It is critical that the equipment provided to a vessel in distress by SAR resources perform adequately to address the emergency situation effectively.

In this occurrence, the gasoline-powered pumps provided by Canadian SAR resources in response to the incident did not perform efficiently, and the crew spent considerable time trying to keep them running in a challenging situation. The effectiveness of the pumps provided by Canadian SAR resources was limited due to the inability to extend the length of suction hose, the efficiency of priming, the difficulty in operating on an inclined deck, and the method of preventing debris from clogging the suction. While these pumps may perform satisfactorily in other situations, in this occurrence, the size of the vessel, severe list, and mixing of the cargo and flood water in the hold hindered the operation of the pumps.

Although the debris floating in the flooded cargo hold would have proven difficult for any dewatering pump, the other issues, such as the exhaust fumes due to the gasoline engines running in enclosed spaces, the short suction and discharge hoses, the stalling of engines on the inclined decks, and the difficult priming of the pump and suction line were not experienced when the crew used the pumps provided by the Danish SAR vessel.

The equipment provided by Canadian SAR resources must be compact and robust to allow for its rapid deployment from the air. However, the survivability of vessel and crew is maximized when the equipment provided by SAR resources is effective for the size and condition of the vessel in need of assistance.

If equipment provided by SAR resources is not adaptable to a vessel's size or condition, the maximum benefit of that equipment is not realized, and there is a risk that the assistance to the vessel and its crew will be ineffective.

2.6 *Immersion suits*

The effectiveness of an immersion suit in the prevention of hypothermia depends on how well it fits to limit loss of body heat and how effectively it prevents the ingress of water.

In this occurrence, when the crew members had to don immersion suits, most selected the jumbo size, which is the size they were accustomed to wearing on previous voyages. Once they put on the jumbo suits, it became evident that these suits, which had been purchased new and brought on board just before the occurrence voyage, were larger than the previous ones. Although the master and crew performed regular boat and fire drills where the crew donned immersion suits to ensure proper fit, there was no drill performed before this particular voyage, and the difference in fit was not detected.

Although the vessel carried 35 immersion suits, in excess of the required 1 suit per person with a crew of 30 on board, there was no evidence of a process or method to ensure that there was a properly fitting suit for each member of the crew. For example, there was only 1 size small suit on board. If more than 1 crew member required a small suit, someone would have had to wear a larger suit, significantly reducing its effectiveness as a safety device.

In addition, almost half of the 35 suits (46%) on board were jumbo in size, designed for individuals taller than 1.91 m and weighing more than 100 kg. When the last 2 crew members went to find the universal size suits that they would normally wear, they found only jumbo suits remaining, likely because several crew members had changed to the universal size when the jumbo suits were found to be too large.

While the *Torremolinos International Convention for the Safety of Fishing Vessels* and the soon-to-be-in-force *Regulations Amending the Small Fishing Vessel Inspection Regulations* address the fit of immersion suits, the current *Large Fishing Vessel Inspection Regulations*, which apply to the *Saputi*, do not.

If a vessel operator does not have a specific process to ensure that properly fitting immersion suits are available for all members of the crew on each voyage, and if regulations do not address the fit of immersion suits, there is a risk that an improperly fitting immersion suit will fail to protect the wearer from the effects of cold water immersion.

2.7 Cargo securing

In all normal operating conditions, the method of loading the refrigerated cargo hold 1 layer at a time, as was done in this occurrence, prevents the shifting of cargo. Another method that is often recommended for the stowage of cargo prone to shifting, such as bulk fish, is to use pen boards to divide the cargo hold into smaller sections.

On the *Saputi*, pen boards were indicated on the general arrangement, and had been used in the past. However, they were no longer used. Instead, the crew used an interlocking pattern to store the boxes, which prevented the boxes from shifting while the vessel was underway under normal operating conditions. Under those conditions, the addition of pen boards would have provided little additional stability or resistance to shifting.

However, as the cargo hold flooded during the occurrence, the shrimp began to float, thereby disrupting the interlocking pattern of the boxes. As the mixture of cargo and water was free to move without restriction across the hold, a large free surface effect was created.

In this occurrence, the means of securing and segregating the cargo was no longer effective once the cargo hold flooded. In addition to the free movement of cargo negatively affecting the stability of the vessel, the effectiveness of the vessel's pumping system was compromised. Fishing vessels operating in ice-infested waters are at risk of ice damage and subsequent flooding. The size and positioning of the cargo hold further increases the risk of flooding in this space.

If crew members of fishing vessels that operate in ice-infested waters do not consider the possible effects of flooding when stowing cargo, there is a risk that the securing mechanism may become ineffective and that the cargo could interfere with the pumping systems on board when flooding occurs, increasing the difficulty of managing the emergency situation.

3.0 Findings

3.1 Findings as to causes and contributing factors

1. As the *Saputi* turned to port to pass a piece of ice, a swell from the southeast lifted the vessel and, as the vessel fell off the swell, it made contact with the piece of ice.

2. The vessel's hull was damaged, resulting in an uncontrolled ingress of water in the refrigerated cargo hold.

3. Despite the use of the vessel's pumps as well as those provided by assisting search and rescue resources, the crew was unable to stem the ingress of water as the mixing of the cargo with the water clogged the pump suctions and prevented them from working at full capacity.

4. The cargo hold continued to flood, and the vessel took a significant list to port that could not be corrected by the transfer of liquids or other means.

5. The crew was able to seal the cargo hold, and the vessel continued to port under its own power.

3.2 Findings as to risk

1. If ice that is hazardous to a vessel is surrounded by thin ice or concealed by a light snow covering, navigators may not perceive it as a threat, which puts them at risk of damaging their vessels.

2. If fishing vessels operating in ice-infested waters are not designed and constructed to withstand the complete flooding of any one of the main compartments, there is a risk that vessels will not be able to remain afloat if they lose their watertight integrity.

3. If fishing vessels operating in ice-infested waters do not carry a damage control plan and booklet on board, the master and crew may be inadequately prepared in an emergency situation where there is ingress of water, and may be unable to keep the vessel afloat until the arrival of rescue resources.

4. If equipment provided by search and rescue resources is not adaptable to a vessel's size or condition, the maximum benefit of that equipment is not realized, and there is a risk that the assistance to the vessel and its crew will be ineffective.

5. If a vessel operator does not have a specific process to ensure that properly fitting immersion suits are available for all members of the crew on each voyage, and if regulations do not address the fit of immersion suits, there is a risk that an improperly fitting immersion suit will fail to protect the wearer from the effects of cold water immersion.

6. If crew members of fishing vessels that operate in ice-infested waters do not consider the possible effects of flooding when stowing cargo, there is a risk that the securing mechanism may become ineffective, increasing the difficulty of managing the emergency situation.

3.3 Other findings

1. While all Transport Canada-approved immersion suits provide a guaranteed level of protection against immersion in cold water, each manufacturer provides a variety of design features. Some of those features greatly enhance the suit's abilities, such as those that contribute to a high level of mobility. There are many situations in which crews must don a suit to be prepared for the possibility of immersion while still being able to carry out other duties. As such, in addition to Transport Canada approval, the features and limitations of a particular suit are an important consideration for vessel owners and operators.

4.0 Safety action

4.1 Safety action taken

4.1.1 Qikiqtaaluk Fisheries

Following the occurrence, the company sent all the immersion suits on board the *Saputi* to be inspected by an authorized service technician. Several suits were condemned and replaced. Several suits were exchanged with suits of a different design, enhancing the wearer's level of mobility while ensuring that everyone on board has access to a properly fitting immersion suit.

4.1.2 Transportation Safety Board of Canada

On 15 September 2016, the Transportation Safety Board of Canada issued:

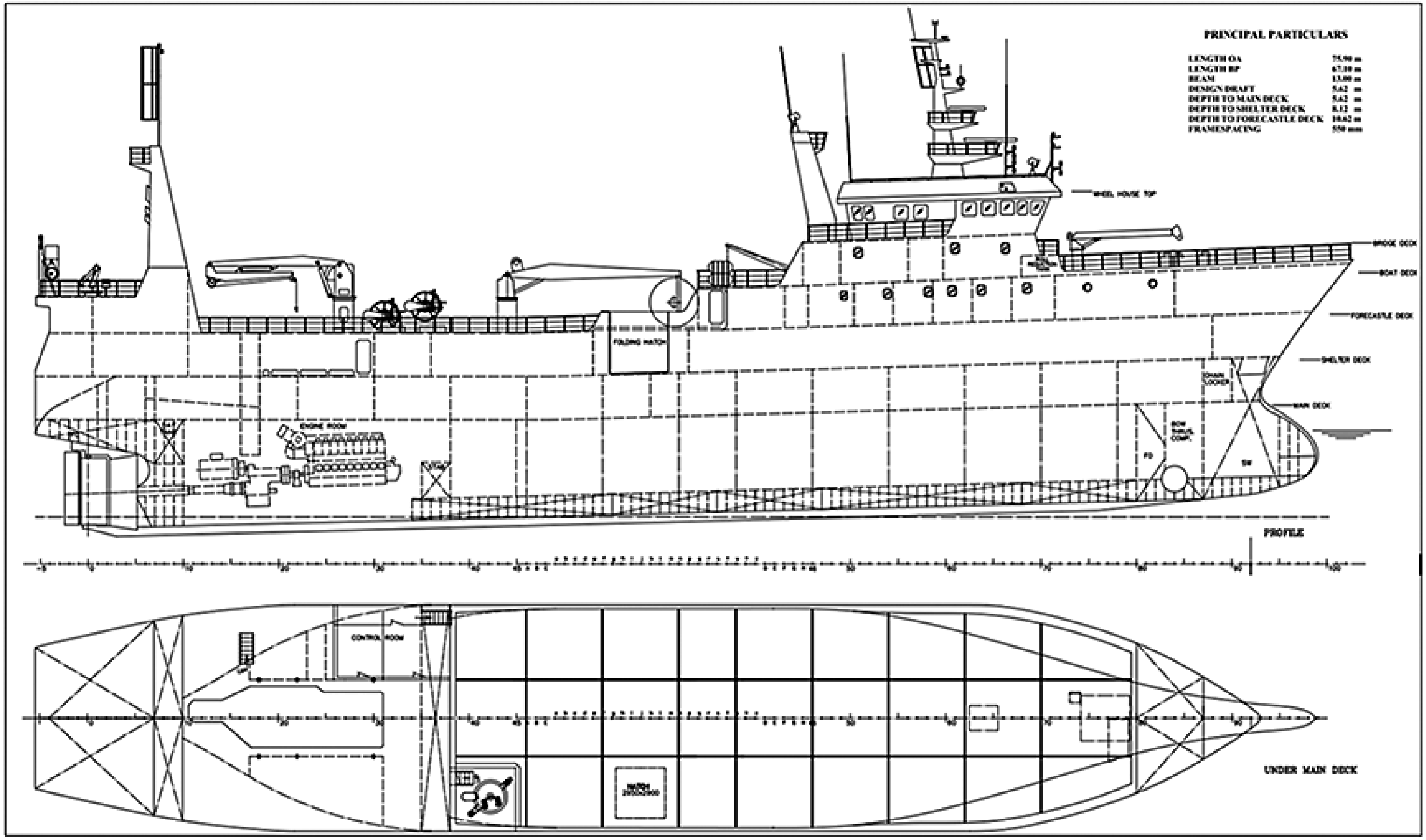
- Marine Safety Information Letter (MSI 06/16 – Behavior of cargo in a flooded cargo hold) to the vessel managers advising them of the unsafe conditions that affected the vessel's stability and pumping systems once the cargo hold was flooded.
- Marine Safety Information Letter (MSI 07/16 – Allocation and sizing of immersion suits) to the vessel managers advising them of the unsafe conditions that affected the sizing and fit of immersion suits provided on board.
- Marine Safety Information Letter (MSI 08/16 – Operating capability of pumps provided by Canadian Search and Rescue resources) to the Department of National Defence advising them of the unsafe conditions that affected the auxiliary pumps provided to dewater the vessel.

This report concludes the Transportation Safety Board's investigation into this occurrence. The Board authorized the release of this report on 29 March 2017. It was officially released on 06 April 2017.

Visit the Transportation Safety Board's website (www.tsb.gc.ca) for information about the TSB and its products and services. You will also find the Watchlist, which identifies the transportation safety issues that pose the greatest risk to Canadians. In each case, the TSB has found that actions taken to date are inadequate, and that industry and regulators need to take additional concrete measures to eliminate the risks.

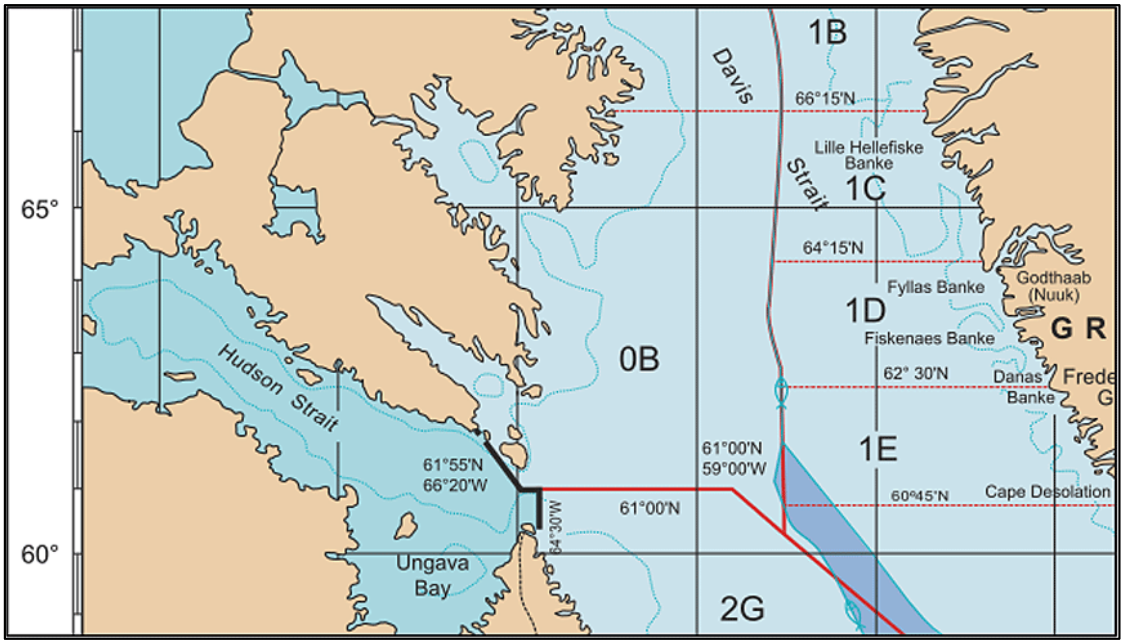
Appendices

Appendix A – General arrangement



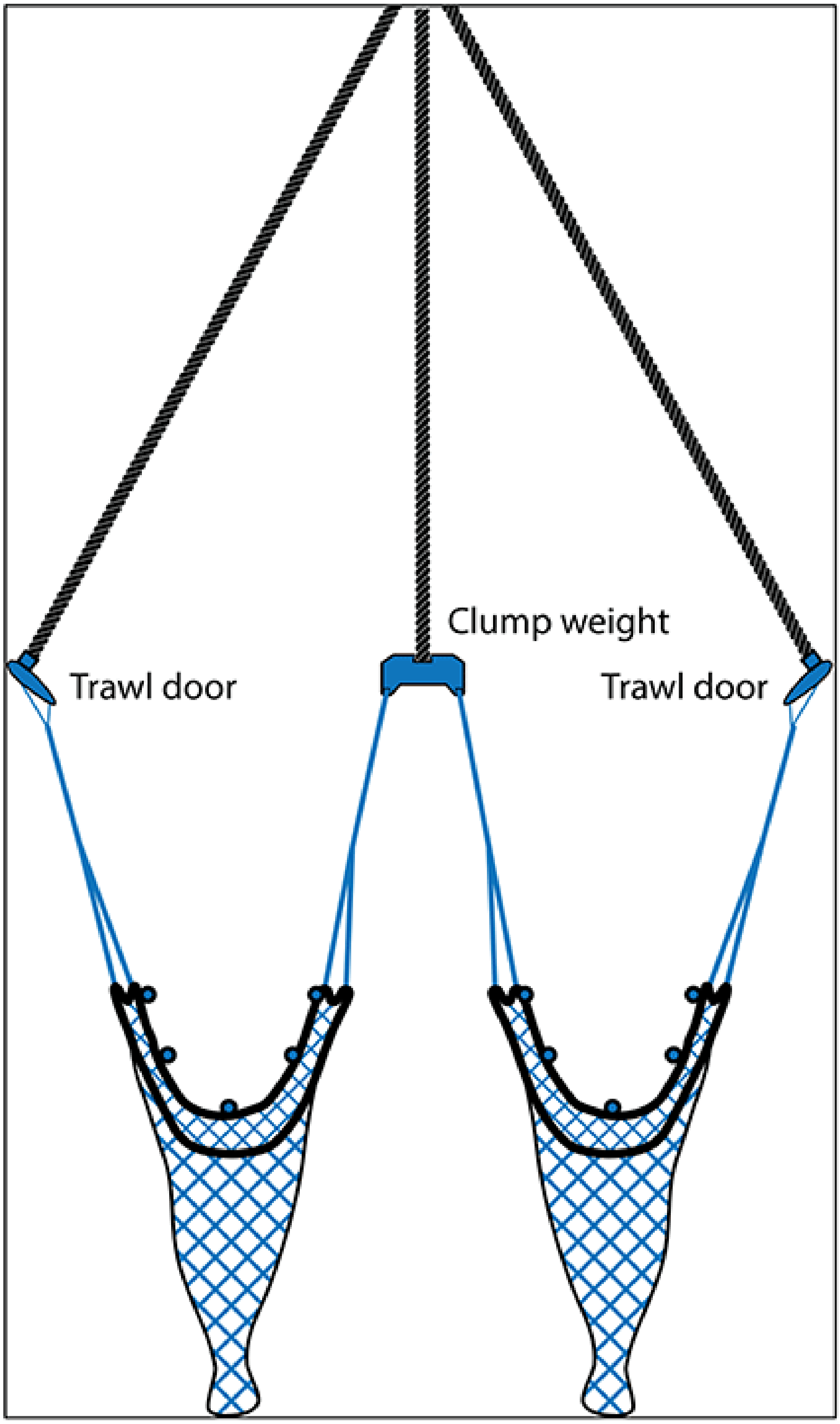
Source: Nataaqnaq Fisheries (cropped by the TSB)

Appendix B – Northwest Atlantic Fisheries Organization (NAFO) fishing area map including Division 0B

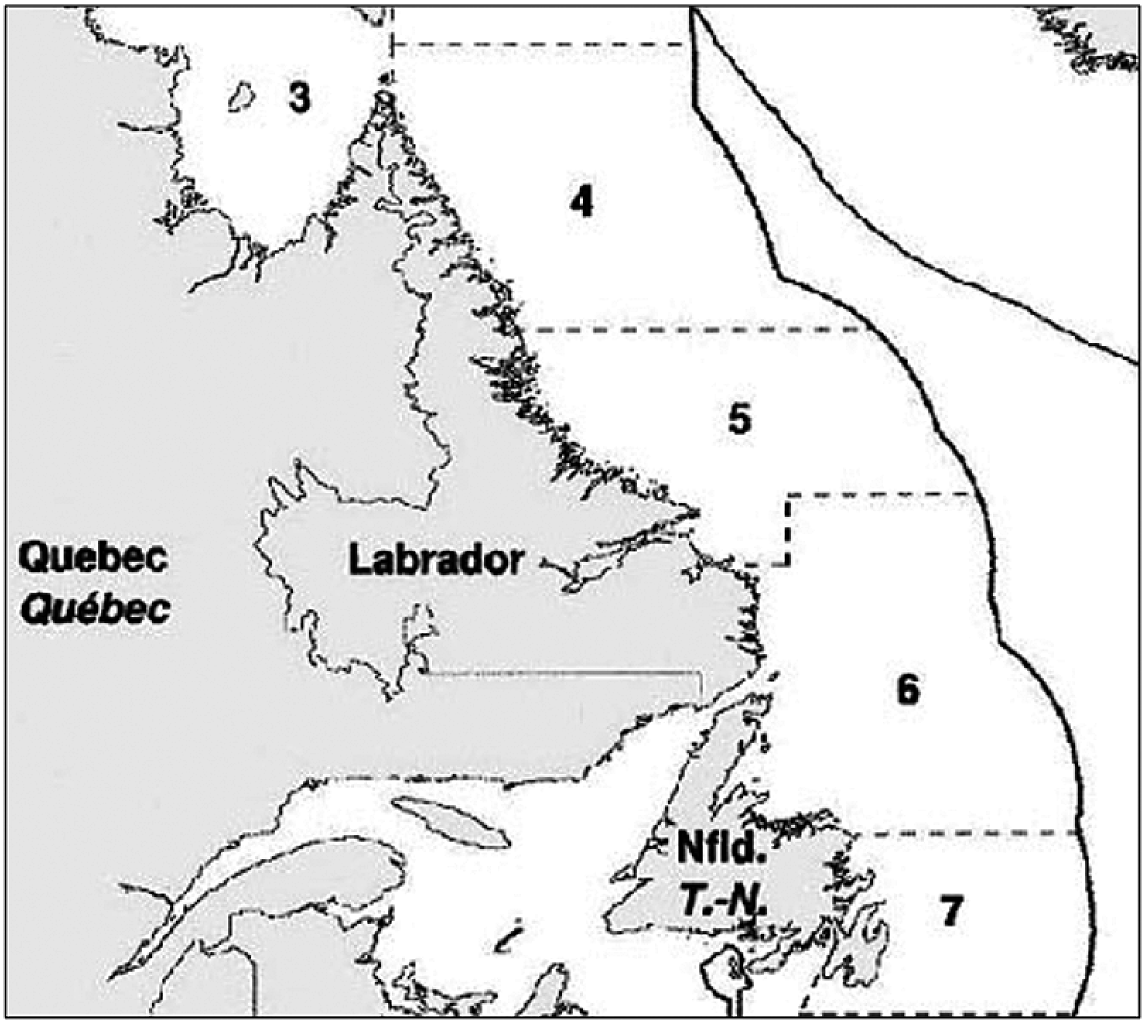


Source: Fisheries and Oceans Canada; available at http://www.dfo-mpo.gc.ca/international/media/images/NAFOmap-carteOPANOlg-eng.jpg (last accessed on 30 March 2017).

Appendix C – Twin trawl arrangement

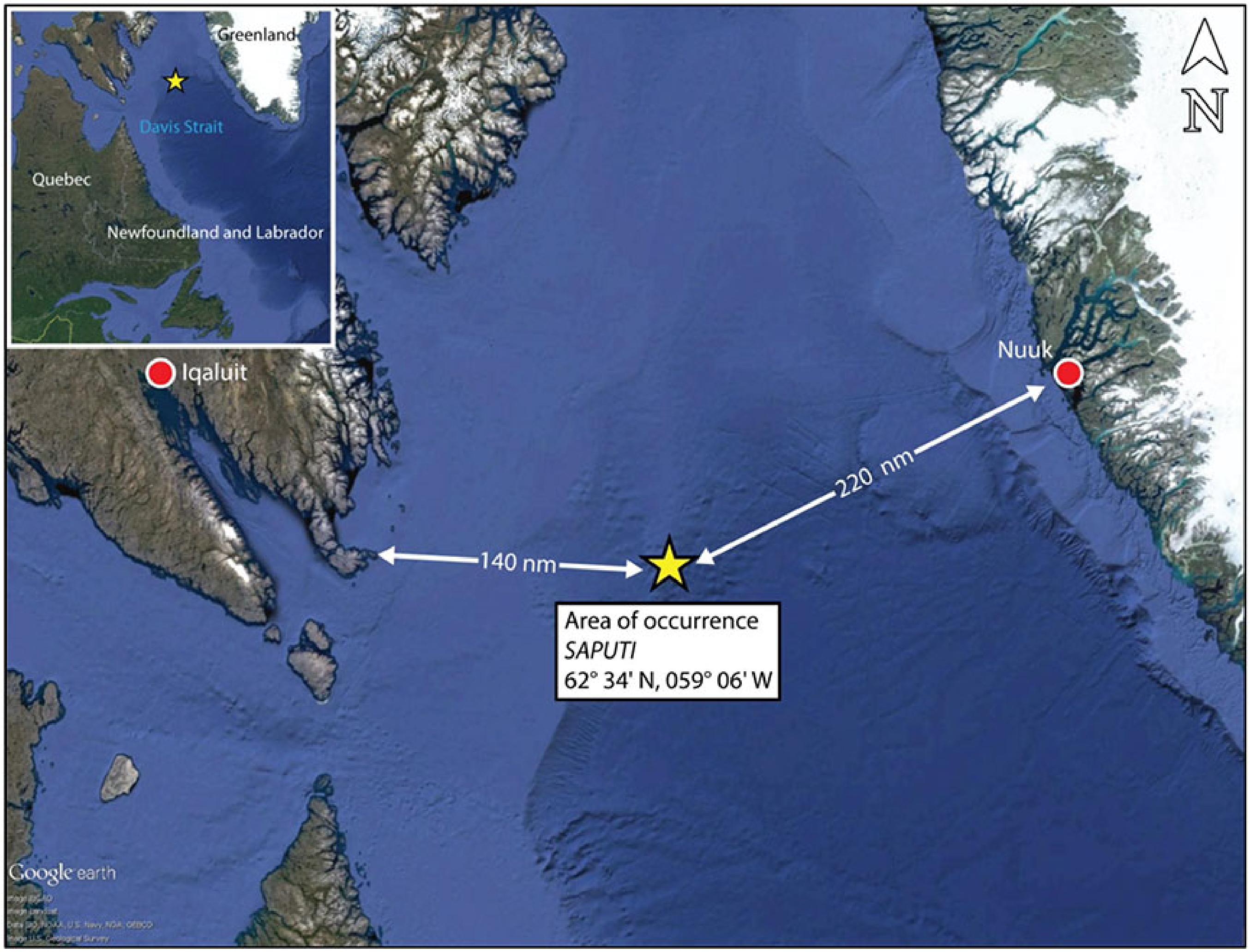


Appendix D – Northern shrimp fishing areas



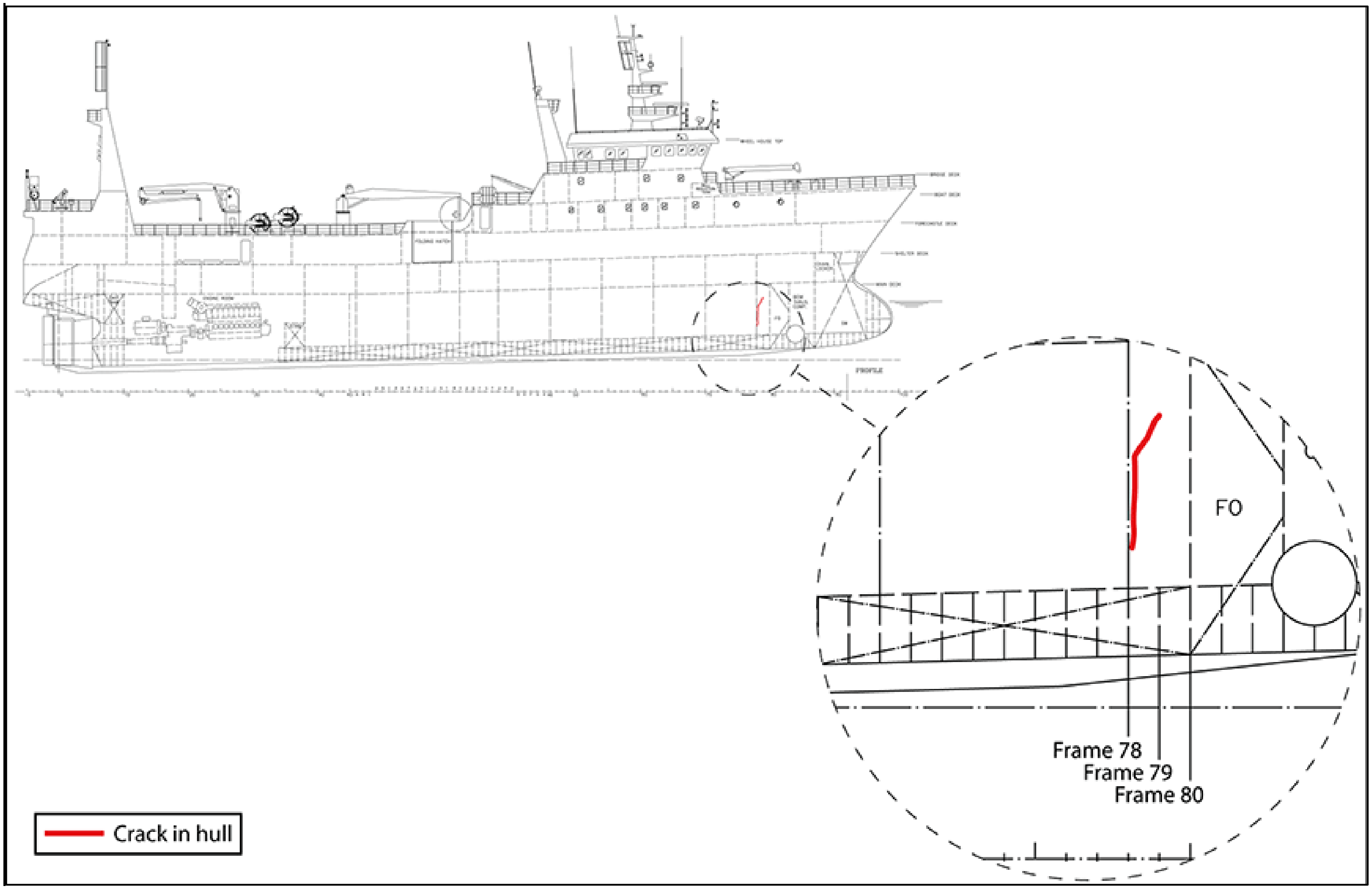
Source: Fisheries and Oceans Canada, available at www.dfo-mpo.gc.ca/fm-gp/peches-fisheries/ifmp-gmp/shrimp-crevette/shrimp-crevette-2007-eng.htm (last accessed on 30 March 2017).

Appendix E – Area of the occurrence



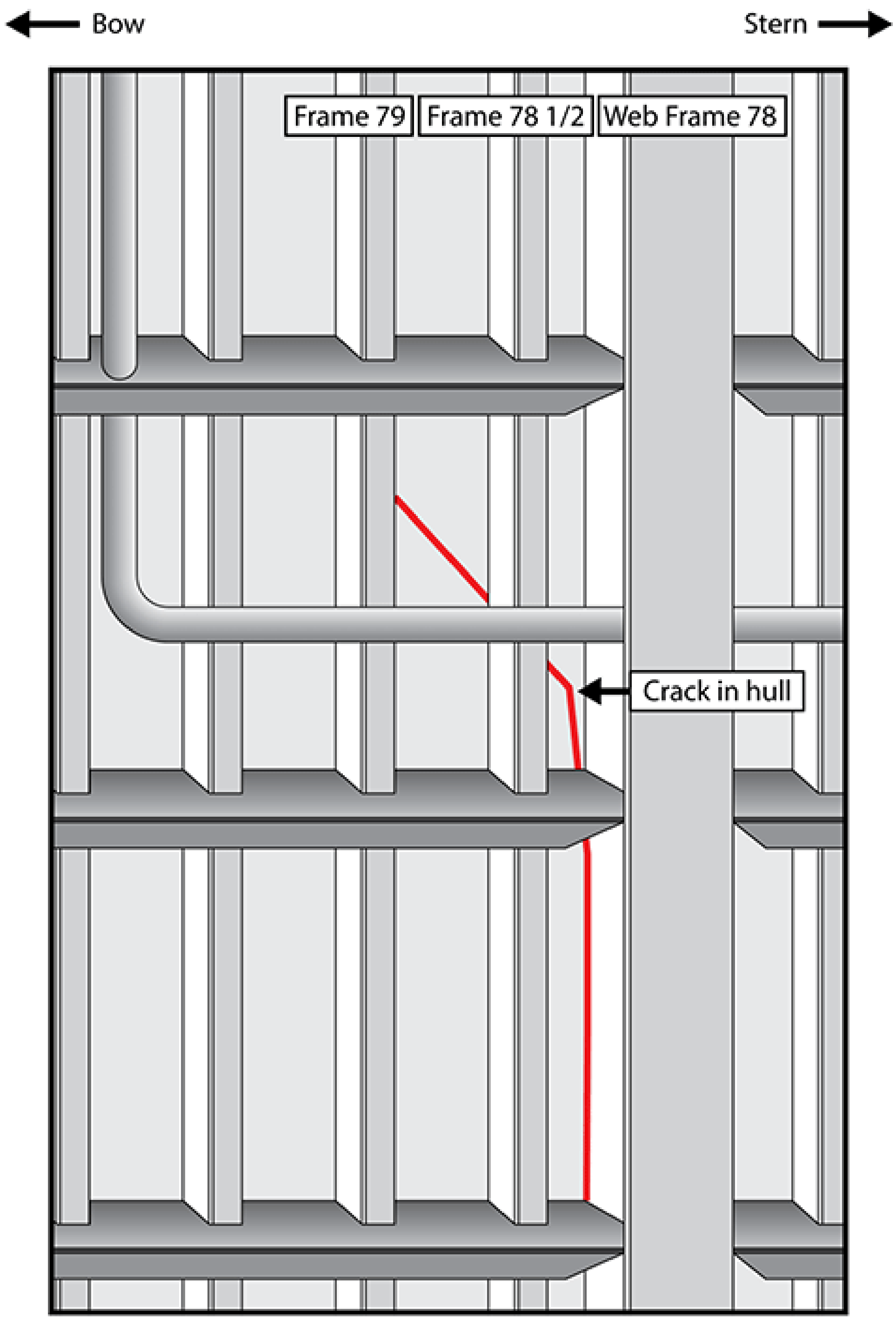
Source: Google Earth, with TSB annotations

Appendix F – Sketch of damage – exterior

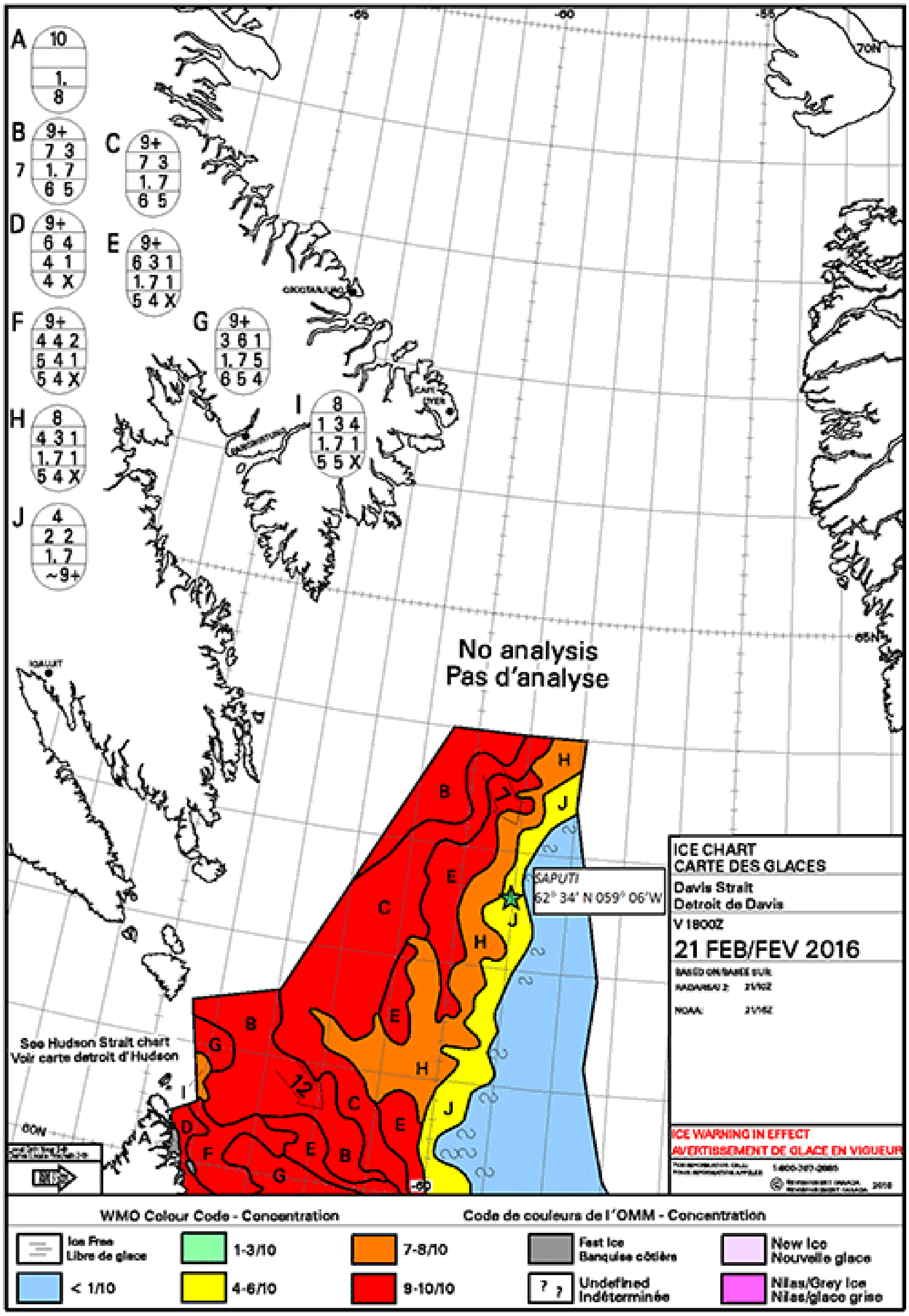


Source: Nataaqnaq Fisheries, with TSB annotations

Appendix G – Sketch of damage – interior



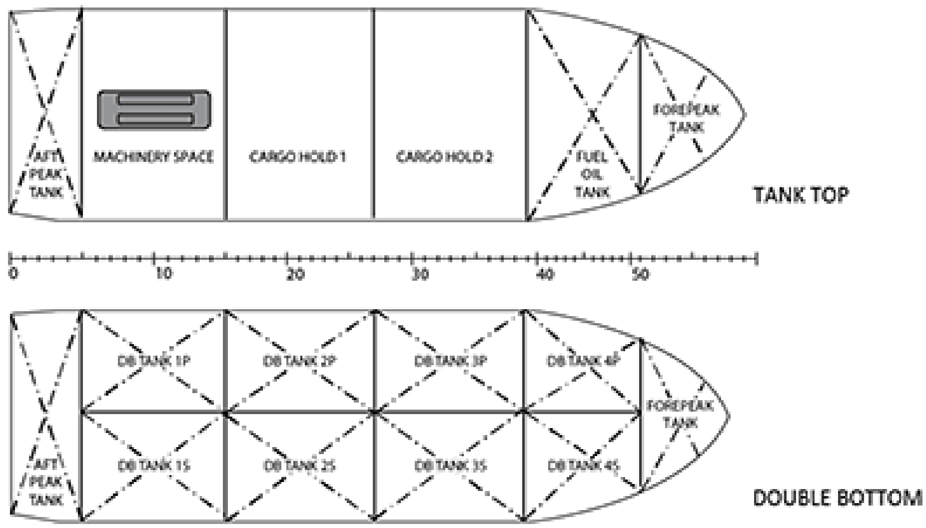
Appendix H – Ice chart



Source: Canadian Ice Service, with TSB annotations

Appendix I – Example of a damage control plan

MV "EXAMPLE"



PENETRATION						
FRAME NO.						
0	5	15	27	39	51	59
Aft peak tank	Machinery space Double bottom tank 1 port Double bottom tank 1 starboard	Cargo hold 1 Double bottom tank 2 port Double bottom tank 2 starboard	Cargo hold 2 Double bottom tank 3 port Double bottom tank 3 starboard	Fuel oil tank Double bottom tank 4 port Double bottom tank 4 starboard	Forepeak tank	
4	5	7	9	11	13	
14		17		20		
23			27			
		31				

In case of damage, all doors and hatches must be closed, as far as practically possible.

The colour code indicates the severity of the damage.

- Good stability margin
- Small stability margin
- The ship will capsize / sink

The figures in the table refer to page numbers in the damage control manual, which contains details about the damage, instructions about doors to be kept closed and countermeasures to be taken.

DAMAGE CONTROL PLAN

LIGHTSHIP CONDITION