MARINE INVESTIGATION REPORT

M00N0009

STRIKING OF ICE AND SUBSEQUENT SINKING

THE FISHING VESSEL "BCM ATLANTIC"

OFF THE COAST OF LABRADOR

18 MARCH 2000

The Transportation Safety Board of Canada (TSB) investigated this occurrence for the purpose of advancing transportation safety. It is not the function of the Board to assign fault or determine civil or criminal liability.

Marine Investigation Report

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Summary

While shooting a trawl at night, on shrimp fishing grounds off Labrador, the "BCM ATLANTIC" struck a piece of ice. The vessel was holed in the shell plating on the port side in the vicinity of a common bulkhead between the engine-room and the cargo hold. As a consequence, the vessel flooded and then sank some four hours later. All personnel on board donned immersion suits and abandoned ship into three liferafts. Some three hours later, a rescue aircraft and a nearby fishing vessel located the rafts and all 26 people were recovered. No serious injuries or pollution resulted from this occurrence.

Ce rapport est é galement disponible en franç ais.

Other Factual Information

	"BCM ATLANTIC" (ex "GADUS PETREL", ex "SEAFRIDGE PETREL")
Port of Registry	Halifax, Nova Scotia
Flag	Canada
Official Number	ON 359170
Type	Freezer trawler
Gross Tons[1]	877
Length	56.10 m
Draught (approx., at time of occurrence)	Forward: 3.70 m Aft: 5.70 m
Built	1973 - A.M. Liaaen AS - Aalesund, Norway.
Propulsion	1980 brake horsepower
Number of Crew	25
Passengers	1 Fisheries Officer
Registered Owner(s)	Mersey Seafoods Ltd., Box 1290, Liverpool, Nova Scotia

Description of the vessel

The "BCM ATLANTIC" was a single screw, conventional stern freezer trawler of all-steel, welded construction. The navigating bridge and crew accommodations were forward of midships. The vessel was subdivided into five compartments (below the main deck) by four transverse watertight bulkheads. The engine-room was located aft and shared a common bulkhead with the cargo hold.

The vessel was built to Det Norske Veritas (DNV) Ice Class A. It was imported and registered in Canada in 1980. Although the vessel was no longer classed with DNV, the scantlings to ice class were maintained and it was subject to inspection by Transport Canada (TC).

Fishery Resource Management Practices and Operating Environment

[1] Units of measurement in this report conform to International Maritime Organization standards or, where there is no such standard, are expressed in the International System of units.

The "BCM ATLANTIC" was one of 13 large fishing vessels that held licences, issued under the Northern Shrimp (Integrated) Management Plan of the Department of Fisheries and Oceans (DFO), to fish Northern (or Pink) shrimp. Annual total allowable catches (TAC) are established for six shrimp fishing areas (SFA)[2] for Canadian fishing vessels. These annual TAC are then divided into "Enterprise Allocations".[3] The current fleet of 13 freezer trawlers fishes for 17 offshore northern shrimp licences.[4] Most vessels involved are purpose-built for shrimp trawling and range in length from 42.6 m to 74.3 m, with hold capacities of from 400 m^3 to 1960 m^3. Fishing trips generally last until the hold is full, a period ranging from 25 to 75 days, depending on catch rates and hold capacity. These vessels make six to ten fishing trips per year, averaging a total of 200 to 320 days annually. The annual shrimp fishery opens at the start of the year and closes after the quota is taken (or runs through to December 31).

The Northern (or Pink) shrimp is one of the cold water species of shrimp found north of latitude 40° N in the Atlantic, Pacific, and Arctic oceans. The fishery takes place off the coast of eastern Canada, between Baffin Bay in the far north and 49°15' N, in seven SFAs numbered 0 through 6 from north to south. SFA 0 presents formidable ice and weather conditions and the Canadian fleet has not been active there in recent years. Offshore shrimp fishing activity usually begins in SFAs 5 and 6 in January, and then moves north throughout the year as the ice permits.

History of the Voyage

On 9 March 2000, the "BCM ATLANTIC" sailed from Liverpool, Nova Scotia, bound for shrimp fishing grounds off eastern Labrador. The vessel had on board a crew of 25 and one Canadian Fisheries (DFO) observer. The master and mate were responsible for navigational and fishing duties and the chief and second engineer for engineering duties; the remaining 21 crew members were dedicated to fishing and processing tasks. All officers and crew worked shifts of six-hours-on and six-hours-off.

En route to the fishing grounds, the "BCM ATLANTIC" made a stop in St. John's, Newfoundland, to repair the defective scanner motor of one of its two radars. It arrived at the fishing grounds on March 15 and immediately began fishing. The ice conditions in which the vessel was operating corresponded with the ice forecasts and were such that approximately four tenths of the sea surface was covered in floes of medium first year and grey white ice. (Environment Canada provided the vessels with Ice Analysis charts every 24 hours.[5]) Some accounts by the crew indicated that some growlers were present in the area. The observed weather conditions at the time of the occurrence were wind from the north at 20 knots, seas of approximately one metre, and an air temperature of -11°C. The visibility was poor, due to heavy snow squalls.

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[2] See Appendix B for a map of the SFAs; SFA 7 is managed by North Atlantic Fisheries Organization.

[3] Individual company quotas, i.e. a limitation on the catch. Also called a "quota licence".

[4] Vessels 45 feet or longer are required to fish offshore (outside 12 nautical miles from shore).

[5] Data from the Canadian Space Agency's radar satellite, the National Oceanic and Atmospheric Administration, and reconnaissance missions are integrated to produce the daily Ice Analysis charts.

At approximately 0330,[6] on March 18, while the vessel was in approximate position 53°09' N, 052°11' W, the master ordered the fishing crew to shoot the trawling gear while the vessel was swinging to starboard at a speed of six to seven knots. A manoeuvre at such a speed is required to effectively clear the trawl off the deck during the shoot. The chief engineer was on the bridge at the time and both radars, including the ice radar, were set at the 1.5-mile range. Some ice was observed on the screen at the time. Although a crew member was posted as a look-out for ice, he did not detect any unusual ice in the immediate vicinity. One of the crew, who was on deck, later reported seeing a large piece of ice in the area earlier but did not report to the bridge as it was not in the immediate vicinity of the vessel. Shortly after the trawl was shot, the chief engineer reported hearing a bump—the sound of an impact with ice. A crew member operating the trawl winch at the time also reported hearing the sound of an impact. Shortly thereafter, a deckhand in the factory area reported to the bridge, via intercom, that the vessel was taking on water.

Within a minute of hearing the impact, the chief engineer ran down to the engine-room and saw water flooding through a hole on the port side of the hull near a common bulkhead between the engine-room and the cargo hold. The visible portion of the hole was estimated to have been about one metre high, running up to the top of the port-side fresh water tank (see Appendix C). However, it was not possible to determine the width of the hole, or if the damage extended forward of the bulkhead into the cargo hold, as the area was partly covered by the machinery installations. A deckhand, who was working in the cargo hold at the time, later reported having heard water enter the fish hold from an undetermined position at or near the port side aft end of the fish hold bulkhead. Bilge alarms activated in the engine-room as well as on the deck. The chief engineer immediately started two bilge pumps, which had a combined capacity of 1.6 m^3 per minute. It was estimated that the engine-room was rapidly filling, at the rate of about one foot per minute.

Realizing that bilge pumps would not be sufficient to cope with the incoming water, the chief engineer informed the bridge that the ship was holed and was going down. He estimated that the lights would fail in about 20 minutes and advised the master to broadcast a Mayday message. Based on this information, the master made the decision to abandon ship before the lights were out. The chief engineer then shut down the engine and secured all access doors to and from the engine-room to prevent further flooding into the factory and other spaces.

At 0409 the master sent out a complete Mayday message advising that the crew would soon abandon the ship. The ship's position at the time was recorded as 53°09' N, 052°11' W (see Appendix A). The Canadian Coast Guard radio station in St. Anthony, Newfoundland, received the Mayday message and immediately informed the Marine Rescue Sub-Centre (MRSC) in St. John's, Newfoundland. The crew was asked by MRSC to take two portable 406 MHz Emergency Position Indicating Radio Beacons (EPIRB) with them on their liferafts.

Once the decision to abandon ship was made, the general alarm was sounded briefly and the master ordered the "BCM ATLANTIC" abandoned. The chief engineer went around the cabins and advised the crew to prepare for the abandonment. The crew members helped each other in donning and zipping up the immersion suits, as they had been trained to do in the Marine Emergency Duties (MED) course. Three crew members had some

[6] All times are coordinated universal time unless otherwise stated.

difficulty donning or zipping up their suits; the suits were of universal size, and one crew member could not zip up his suit because it was too small for him. One crew member reported having a tight suit zipper and had difficulty pulling it closed, even with a help of another crew member. The zipper on the suit of a third crew member was broken.

The crew assembled at their respective muster stations and launched all three inflatable liferafts (two 20-person and one 15-person) alongside the vessel. The crew then began to board the liferafts through the ship's side doors on the shelter deck. As expected, the lights failed about 20 minutes after the flooding was discovered by the chief engineer. The master and two other crew members remained on the bridge until the lights failed. By that time, the assigned port side liferaft had drifted off the boarding position at the side door. The master and remaining crew members had to jump into the water, from which they were hauled into the liferaft. Under the pressure of emergency activities, the master did not fully zip up his suit, and as a result he became wet and suffered from severe cold until he was rescued.

Within approximately 20 minutes of the Mayday message being sent out, all 26 persons on board successfully abandoned ship. Later, several crew members attributed this timely and organized abandonment to their recent boat drills, which they underwent immediately before leaving for this trip. (The crew had been required to undergo two boat drills, as they had been unable to perform the first drill to the satisfaction of the TC surveyor.)

Search and Rescue Operations

Concurrent with the abandonment of the ship, the Canadian Coast Guard radio station in Sydney, Nova Scotia, issued a Mayday relay. The MRSC then informed the Halifax Rescue Co-ordination Centre (RCC) of the occurrence and requested an aircraft. Fishing vessels in the area were advised of the situation by very high frequency (VHF) radiotelephone.

Several vessels responded to the call for assistance; these included four large Canadian fishing vessels engaged in shrimp trawling in the area: the "FAME", the "NEWFOUNDLAND OTTER", the "MERSEY VENTURE", and the "NORTHERN OSPREY". The "FAME", which was closest to the "BCM ATLANTIC", at approximately 30 nautical miles, was tasked at 0414 (five minutes after the original Mayday message was transmitted) to proceed to the distress location. The "FAME" estimated arrival at the distress location in about three to four hours, depending on the ice conditions.

At 0426 the Canadian Forces 103 Squadron Labrador helicopter R76 was tasked from Gander, Newfoundland, but, reportedly, a winter storm system passing through the area had created icing conditions that prevented the helicopter from taking off. At 0435 the primary Search and Rescue (SAR) aircraft, Hercules R310, was tasked from Greenwood, Nova Scotia.

At 0443 the Canadian Mission Control Centre (CMCC) at Trenton, Ontario, first detected the signals from the two EPIRBs carried by the crew in their liferafts. The signal data were analysed by CMCC. As the two EPIRBs were registered with the Canadian Beacon Registry (CBR) of the National Search and Rescue Secretariat, as

required,[7] the information about the ship and its owners was immediately retrieved from the Registry database by the CMCC. The owner was immediately contacted at the registered address.

At about 0600, approximately one and a half hours after being tasked, the Hercules aircraft departed Greenwood for the mission. Primary SAR aircraft, such as Hercules R310, maintain a one-half hour standby posture during the working period (0800–1600) and a two hours' posture during quiet hours (1600–0800) and weekends. The Hercules was airborne within the prescribed time.

At 0716 (about three hours after the Mayday was sent), the "FAME" first spotted the "BCM ATLANTIC" on its radar, at 3.8 nautical miles ahead, and later spotted flares from the liferafts. The crew of the "FAME" salvaged the two liferafts, and the two EPIRBs carried by the abandoning crew. The third liferaft later drifted away and was lost. At 0846 the "FAME" notified MRSC St. John's that all 26 crew members had been recovered and all were reported as fine, except for the master, who was suffering from mild hypothermia. The crew was then transported to St. John's aboard the "FAME".

At 0839 CMCC detected the signal of the third EPIRB from the "BCM ATLANTIC". This signal came from the EPIRB that had been fitted at the bridge and which had likely floated free when the vessel sank. The signal was immediately detected by the CMCC as an "unlocated" signal via the geostationary satellite systems and later identified as being sent from position 53°08' N, 052°11.4' W. Based on the time the signal was received from this EPIRB, the "BCM ATLANTIC" sank around 0800, about four and a half hours after being holed. The time of sinking is compatible with witness accounts.

Vessel Condition and Certification

During 1999 the "BCM ATLANTIC" made 10 fishing trips, spending approximately 300 days at sea. She completed her fishing activities for the season early in December 1999 and had been laid up since then. In early February 2000, during the annual inspection by TC, a crack was found in the plating of its bulbous bow requiring the vessel to be dry-docked for repair. Apparently, the crack had been caused by ice on a previous trip. During the dry-docking, further ice damage to the side plates was discovered. As a result, a total of six sections of side plating and some frames in the forward part of the hull had to be replaced.

The "BCM ATLANTIC" was last inspected and repaired to the satisfaction of TC Marine Safety on 09 March 2000, indicating that the vessel was deemed to be fit for the proposed voyage. The certificate (SIC 31) issued to the "BCM ATLANTIC" was due to expire on 08 March 2001.

All three liferafts of the vessel were last inspected in January and February 2000 by an accredited inspection depot. Emergency pack items were inspected, expiry dates were verified, and some items, such as rockets and flares, were replaced as required. Tests and Survey Report and Re-inspection Certificates were then issued on 19 January 2000, for the two 20-person liferafts, and on 07 February 2000, for the one 15-person liferaft.

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[7] *Ship Station Radio Regulations* require Canadian vessels longer than 20 m to carry an EPIRB, and the owners are required to register the beacons with the Canadian Beacon Registry.

Vessel Personnel

The master possessed a Canadian-issued Fishing Vessel Master's Certificate Class 1, Master Home Trade and Master Inland Waters certificates and had been in command of this vessel for approximately 18 years. He had considerable experience navigating on the east coast of Canada, including on the Grand Banks and within SFAs, and he was conversant with different ice conditions and with the interpretation of ice charts that the vessel received every 24 hours from the Canadian Ice Service of Environment Canada. Like most of the crew, he had spent about 300 days each year fishing in various ice conditions.

The chief engineer possessed a Canadian-issued Certificate of Competency as chief engineer for use on motor-driven fishing vessels and had been working with this company in the capacity of chief engineer on this and on other vessels for approximately 17 years.

All crew members of the "BCM ATLANTIC" had completed at least the basic MED training.

Neither fatigue nor work-related stress is considered to have been a factor in this occurrence.

Analysis

Risk of Operation in Ice

The safety of the ship is the responsibility of the master. This responsibility includes avoiding areas where there is ice that is beyond a vessel's capability to negotiate safely and operating at suitable speeds to avoid unsafe collisions with ice. The vessels engaged in the fishing of Northern shrimp operate year-round in the presence of varying ice conditions and are, therefore, prone to damage. Indeed, most of the 13 vessels in the fishery had suffered ice damage over the years. Since 1985, three other large fishing vessels have sunk, due to ice damage, in the same fishing areas.[8] The "BCM ATLANTIC" had experienced ice damage sufficient to require structural repairs in 1983, 1984, and 1985.

The "BCM ATLANTIC", like most other shrimp trawlers, was built to DNV's standards of ice strengthening but was no longer classed with the DNV. However, the scantlings to ice class were maintained to ice class and were subject to inspection by Transport Canada. Depending on the ice class, the requirement is for approximately 10% to 50% thicker plating and heavier frames in the main ice belt zones and in the forward and aft regions of the hull.

The force that results from a collision with ice depends on several factors, including the speed and size of the ship, the thickness and size of ice floes, the properties of the ice, and the shape and orientation of the ship's

[8] The "PANDALUS" in June 1985, the "NORTHERN OSPREY" in June 1990, and the "ICELANDIC HARVESTER" in September 1999.

hull. In this occurrence, the vessel speed of six to seven knots—required to shoot the trawl off the deck—was sufficient to fracture the shell plating in the area of strengthening in the ice belt zone.

Among the industry and research communities, knowledge of ice–structure interaction is still incomplete. There are no specific safety guidelines that correlate the properties of ice with the degree of ice strengthening appropriate to a particular SFA, time of year, and area of operation. Canadian research in this field continues. In the interim, there will always be an inherent risk of ice damage to vessels, such as those of the Canadian shrimp trawler fleet, that operate year-round in ice conditions. Under such operating conditions, ship personnel must not only be vigilant and exercise extra caution to reduce the probability of ice damage, they must also be well prepared for emergencies to minimize the consequences of such ice damage.

Emergency Preparedness

In an emergency, crew safety largely depends on the capability and reliability of survival equipment, as well as the crew's familiarity with—and skill in using—that equipment. The decision to abandon a vessel at sea is often made under intense pressure and executed in a very short time. Crew members who are familiar with their vessel's survival gear, and how to use it, are better able to respond to the emergency. The donning of immersion suits during emergency drills conducted several times a season can reduce the time required to find and don the equipment during a real emergency. Indeed, several crew members on the "BCM ATLANTIC" attributed the rapid and successful abandonment to the boat drill they were required to perform just before leaving for this trip.

Serviceability of Immersion Suits

One of the advantages of regular boat drills is that, during such exercises, defects in immersion suit zippers (and in any other life-saving equipment) can be identified and rectified before an actual emergency arises. Some crew members had difficulty in properly zipping up their immersion suits. This problem has been noted in previous TSB investigations involving fishing vessels. In the 1990 sinking of the fishing vessel "NADINE" in the Gulf of St. Lawrence, the investigation found that the crew of the "NADINE" had difficulty donning and zipping up their suits (TSB Report No. M90L3034). Some suits were found torn and the zippers on others were poorly maintained and difficult to close. These deficiencies were identified in Board Recommendation M94-07, issued 11 May 1994. In the April 1995 sinking of the fishing vessel "HILI-KUM" in British Columbia (TSB Report No. M95W0013), the Board attributed the hypothermia and subsequent drowning of two crew members to the poor state of repair and maintenance of their immersion suits. The corrosion found on the zippers of those two suits was consistent with exposure to salt water and lack of lubrication and maintenance.

As part of the current investigation, the TSB conducted a simple pull test of zippers on three immersion suits to determine the serviceability of their zippers. Two of the suits were selected at random from among those used during the abandonment of the "BCM ATLANTIC" and the third suit was new (off the shelf). The zippers were pulled closed using a pull gauge to measure the force required. The closing force on each zipper was recorded, before and after the application of a lubricant (beeswax) to the zipper. The test results indicated that a simple

application of beeswax for lubrication of the zippers could reduce the force required to pull closed the zippers by approximately 30% to 70% (see Appendix E for test results).

Registration of EPIRBs

The EPIRBs carried on the "BCM ATLANTIC" were registered as required and functioned as intended. However, many smaller vessels in Canada, including pleasure craft, that voluntarily carry EPIRBs not registered with the Canadian Beacon Registry. At present, the majority of EPIRB signals received at the CMCC are false, and the registered owner must be contacted to ensure that the signal is genuine before committing resources for a SAR operation. In the absence of accurate information, response action can be delayed, thus hampering effective SAR co-ordination efforts. In any distress situation, it is essential that shore-based facilities are able to respond without delay. Time lost in the initial stages of an occurrence can be crucial to its eventual outcome.

Fishery Resource Management

Unlike some seasonal competitive fisheries—such as salmon, herring, caplin, and lobster fisheries—the Northern Shrimp Management Plan is structured for year-round operation. Competitive fisheries practices force vessels and their crews to operate in adverse weather conditions during a limited open season. Fishing for such species takes place over long periods, inducing fatigue and resulting in performance degradation and compromised safety.

Under the Northern Shrimp Fishery Resource Management, the total annual allowable catch for each of the seven SFAs is divided into 17 equal individual company quotas (TACs). The fishery opens at the start of the year and closes after the quota is taken (or December 31). As such, under the Northern Shrimp Management Plan, the competition to harvest allocated resources is not as intense as it is in competitive fisheries, and there is less operational pressure on the crews and the owners to maximize their allowable catch quota.

Findings as to Causes and Contributing Factors

I. While swinging to starboard at six to seven knots, exposing the port side to ice contact, the vessel struck ice and was holed on the port side shell plating near the common bulkhead between the engine-room and the cargo hold.

II. The speed required to shoot the trawl off the deck was considered sufficient to fracture the shell plating at the point of contact with the type of ice encountered.

III. The impact with ice was noticed immediately and, within a minute, a hole in the engine-room was discovered.

IV. The hole likely extended forward of the engine-room and breached the watertight integrity of the cargo hold.

V. The total capacity of the engine-room bilge pumps was insufficient to cope with the water ingress.

VI. The vessel stayed afloat for approximately four and a half hours after being holed; the vessel most likely sank because two of the largest compartments were flooded with sea water.

Other Findings

1. The rapid and successful abandonment was attributed to the recent boat drill, conducted in the presence of a TC inspector.

2. Zippers on most of the immersion suits were not adequately maintained or lubricated for easy operation.

3. All three EPIRBs carried on the vessel were properly inspected and installed; the EPIRB that remained on board the sinking vessel apparently floated free, as intended, and transmitted a signal immediately.

4. Vessels less than 20 m long are not required to carry EPIRBs, and the owners of many such vessels do not register their EPIRBs with the Canadian Beacon Registry.

5. When EPIRBs are not registered, vital information is not readily available; this information is essential to key agencies to perform effective search and rescue co-ordination.

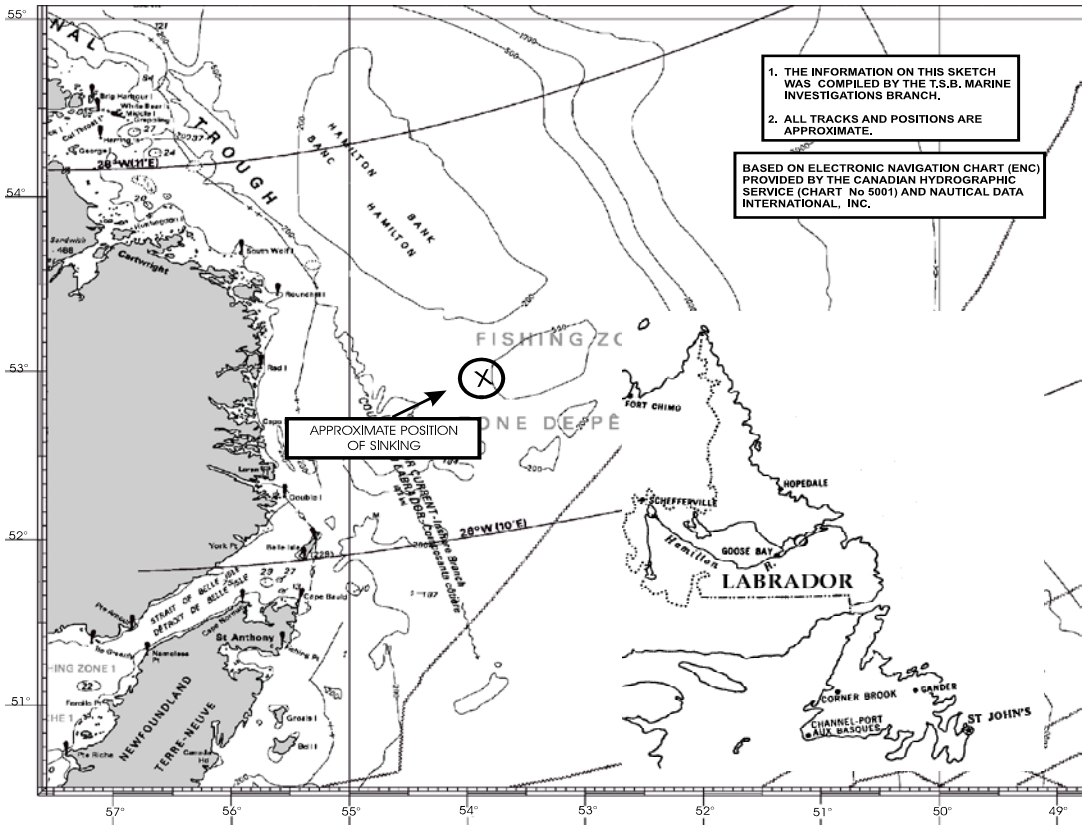
Safety Action Taken

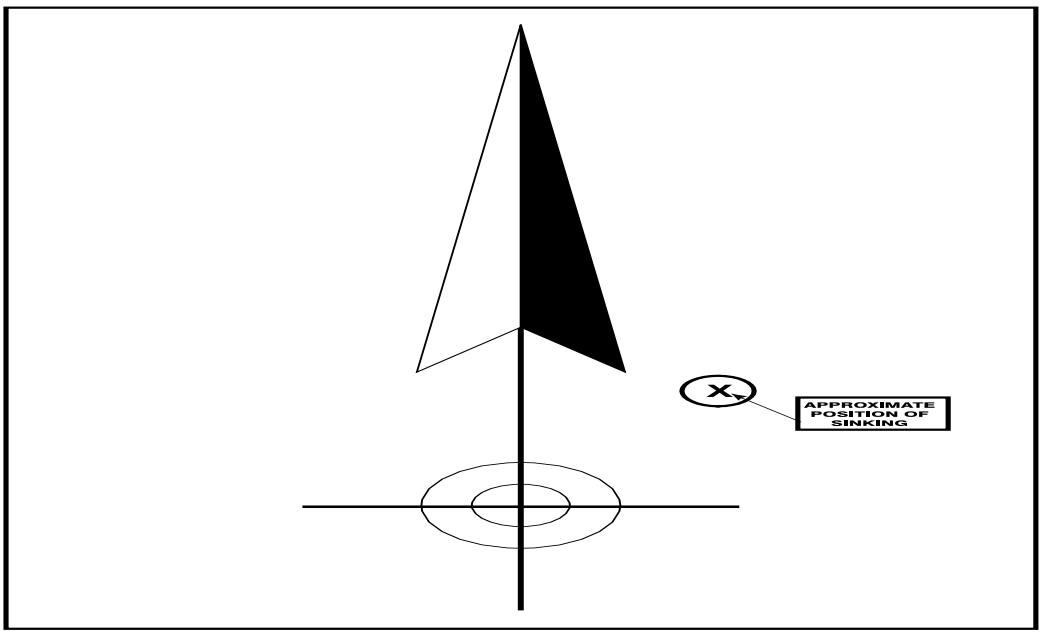
As a result of this occurrence, the TSB developed two Marine Safety Advisories (MSAs). One, MSA 06/00, was forwarded to the National Search and Rescue Secretariat, apprising it of the risks of vital information being unavailable to key search and rescue agencies, such as the Canadian Mission Control Centre, to expedite an effective search and rescue operation. In several past occurrences, rescue co-ordination efforts were hampered because information essential to effective SAR operations was not available to the CMCC. EPIRBs, particularly those carried on vessels less than 20 m long, were not properly registered. In such cases, the CMCC is unable to verify the authenticity of the distress signal, and this can result in a delayed SAR response. Subsequently, TC indicated that the new *Ship Station Radio Regulations* will require vessels over 8 metres in length and making Home Trade II voyages or greater, to carry 406 MHz EPIRBs effective 01 April 2002. TC Marine Safety Inspectors will ensure that these EPIRBs are properly fitted and installed as part of the regular inspection regime.

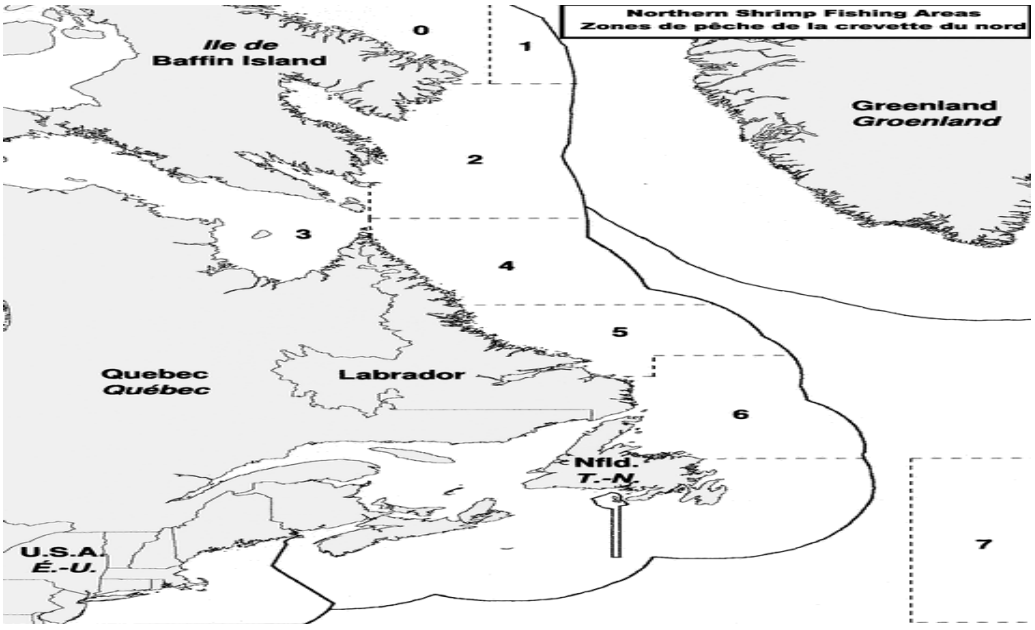
The other advisory, MSA 07/00, was forwarded to the Canadian Association of Prawn Producers, which represents 9 of the 13 shrimp fishing vessels, and to the individual owners of the other 4 vessels. MSA 07/00 apprised the owners of the importance of conducting boat drills at regular intervals to improve crew members' chances of survival in distress situations. MSA 07/00 also stressed the importance of proper maintenance of immersion suits, and contained the results of the simple test, conducted by the TSB, which showed how the operation of zippers could be improved with the simple application of a lubricant, such as beeswax. In response to MSA 07/00, TC indicated that it will issue a Ship Safety Bulletin, making recommendations respecting the maintenance of immersion suits and the donning of suits during boat drills.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board authorized the release of this report on 19 July 2000.

Appendix A - Sketch of the Occurrence Area



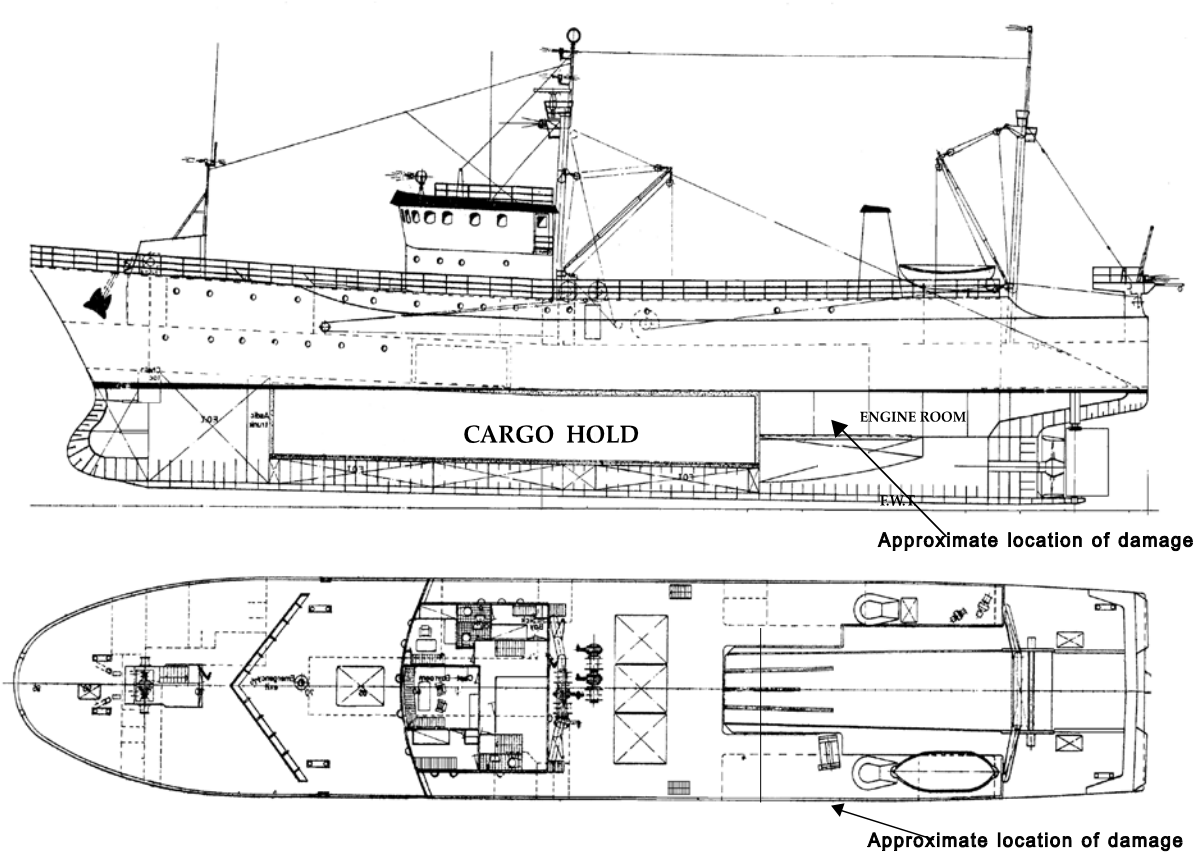




Appendix B - Shrimp Fishing Areas

Appendix C - Location of Ice Damage

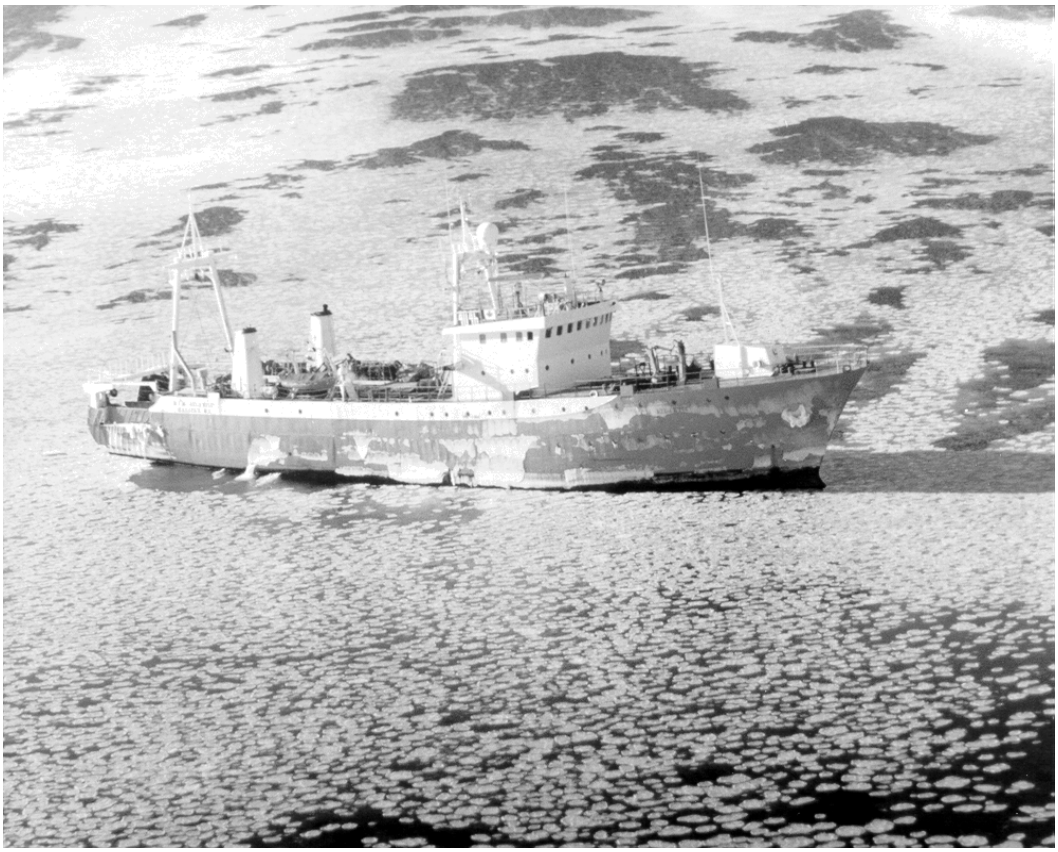
F/V "BCM ATLANTIC"



FORECASTLE AND BOAT DECK

Length Overall56.10 m
Breadth11.00 m
Depth 5.10 m
GRT 877
NRT 357

Appendix D - "BCM ATLANTIC"



F/V "BCM ATLANTIC"

Appendix E - Engineering Laboratory Report on Immersion Suit Zippers

PROJECT NUMBER AND TITLE - NUMÉRO DU PROJET ET TITRE			
LP 033/00 Examination of Zipper Fasteners on Immersion Suits			
OCCURRENCE NUMBER NUMÉRO DE DOSSIER DE L'ACCIDENT	VEHICLE IDENTIFICATION IDENTIFICATION DU VÉHICULE	OCCURRENCE DATE DATE DE L'ÉVÉNEMENT	DATE COMPLETED TERMINÉ LE
M00N0009	"BCM ATLANTIC"	36602	17 July 2000

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SUMMARY OF OCCURRENCE - RÉSUMÉ DES FAITS

As the crew donned their immersion suits in preparation to abandon the vessel, some of them found that excessive force was required to pull up the zipper on the front of their suit. Three suits were submitted to the Engineering Laboratory of the Transportation Safety Board so that the zipping force could be quantified.

FINDINGS - CONSTATATIONS

These suits had zippers that extended from the crotch to the neck. The zippers were pulled closed using a pull-gauge to measure the force required. The closing force on each zipper was recorded, first as received, and then following an application of beeswax to the zipper. The results were as follows:

Suit 1 - Bayley Model 7-01-00 Ser 2-65-84 Manuf 8-12-82. This suit was reported to have been used during the abandonment. As received, the lower two thirds of the zipper closed with a force of just over 26 pounds while the upper third of the zipper closed with a force of just over 55 pounds. Following an application of beeswax, the lower third of the zipper closed with a force of 16 to 18 pounds while the upper third required a force of just over 20 pounds.

Suit 2 - Mustang Model IS2 Ser 301200 Manuf 04/89. This suit was reported to have been used during the abandonment. As received, the lower two thirds of the zipper closed with a force of 21 to 25 pounds while the upper third of the zipper closed with a force of just over 38 pounds. Following an application of beeswax, the zipper closed with a force of 15 to 18 pounds, the upper third of the zipper being at the upper end of this range.

Suit 3 - Mustang Model OC4001 Ser 004298 Manuf Oct 99. This suit was reported to be new and previously unused. As received, the lower two thirds of the zipper closed with a force of 14 to 19 pounds while the upper third of the zipper closed with a force of just over 26 pounds. Following an application of beeswax, the zipper closed with a force of 7 to 8 pounds over its lower third, and 10 to 11 pounds over its upper third.