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*Proceedings 17th International Conference on Port and Ocean Engineering under
Arctic Conditions, POAC'03, 1, pp. 203-212, 2003-06-16*

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Proceedings of the 17th International Conference on
Port and Ocean Engineering under Arctic Conditions
POAC'03
Vol. 1, pp 203-212
Trondheim, Norway, June 16-19, 2003

VESSEL DAMAGE IN THE CANADIAN ARCTIC

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ABSTRACT

A large number of vessels operating in ice-covered waters have been damaged by ice. The extent of damage ranges from slight deformation of the hull to large fracture or puncture. It is important to understand and classify the type and extent of damage to minimize future damage. Detailed information on ship damage in the Canadian Arctic since 1978 has been collected along with the ice conditions that caused the damage. This paper provides information on the type of damage and the ice conditions that caused damage for different Vessel Classes. An analysis is made based on the presence or absence of multi-year ice. The data and analysis show that in 73% of the damage events, there was multi-year ice present in the ice regime. Further, the data show that more severe damage events occur with multi-year ice in the ice regime. Overall, the analysis clearly illustrates that the major factor causing vessel damage is contact with multi-year ice.

INTRODUCTION

Navigation in Canadian waters north of 60°N latitude is regulated by the Arctic Shipping Pollution Prevention Regulations (ASPPR, 1989). Transport Canada, in consultation with stakeholders, has made extensive revisions to these Regulations by introducing the Arctic Ice Regime Shipping System (AIRSS, 1996). These revisions focus on reducing the risk of structural damage to ships which could lead to the release of pollution into the environment, yet providing the necessary flexibility to ship owners by making use of actual ice conditions. Transport Canada approached the Canadian Hydraulics Centre (CHC) of the National Research Council of Canada in Ottawa to assist them in developing a methodology for establishing a scientific basis for AIRSS. In developing the methodology, the CHC used an approach that is based on seven Tasks (Timco et al., 1997). As part of these Tasks, a very comprehensive Ice Regime System (IRS) database was developed (Timco and Morin, 1998; Timco and Kubat, 2002). This database contains information related to occurrences of both

damage and non-damage events, where each event is characterized by 79 fields that relate to vessel characteristics, route, climate, ice conditions, and damage.

Damage in the CHC/IRS database was categorized according to its type and severity as described in Table 1. These categories were described in the database by a Damage Severity (DS) number as shown in the Table. A Damage Severity number greater than three was used to indicate that the damage had the potential for causing pollution.

The vessels were subdivided according to the Vessel Classes in ASPPR (1989) as shown in Table 2. The Canadian Arctic Class (CAC) vessels are designed to operate in severe ice conditions whereas the Type class vessels are designed to operate in more moderate first-year ice conditions.

Table 1: Definition of Damage Severity number.

Damage Severity Number	Description
0	No damage
1	High measured stress
2	slight deformation of hull, denting, propeller
3	small puncture or fracture, extensive denting
4	large hole
5	vessel sank

Table 2: “Limiting” Ice Type versus Ship Category.

Ship Category	Limiting Ice Type
CAC1	None
CAC2	Multi-year Ice
CAC3	Second-year Ice
CAC4	Thick First-year Ice
Type A	Medium First-year ice
Type B	Thin First-year ice - 2nd stage
Type C	Thin First-year ice - 1st stage
Type D	Grey-White Ice
Type E	Grey Ice

Damage information was obtained from several sources including the Transportation Safety Board, the Norland/AKAC damage database (Norland & AKAC, 1993), B. Wright of Wright & Associates, as well as numerous individual reports of vessel damage. Bob Gorman of Enfotec and Capt. Peter Dunderdale of Nobel Denton independently reviewed the events. The IRS database contains information on 211 different damage events in the Arctic. In some cases, there is incomplete information about the Vessel Class, ice concentration, or the severity of the damage. Eliminating the events with incomplete information, and also events with DS equal one, which represents only high measured stress, there are 125 events with a Damage Severity ranging from 2 to 5. These events are used in the present analysis.

Figures 1 and 2 show the breakdown of these 125 events according to Vessel Class and Damage Severity, respectively. Figure 2 also includes information for each Damage Severity number for those ice regimes in which there is only first-year (FY) sea ice, and those in which there is also multi-year (MY) ice present. Note that in the later case, there can be a mix of first-year ice and multi-year ice, or only multi-year ice. The data show that there was multi-year ice present in 91 damage events and only first-year ice in 34 damage events.

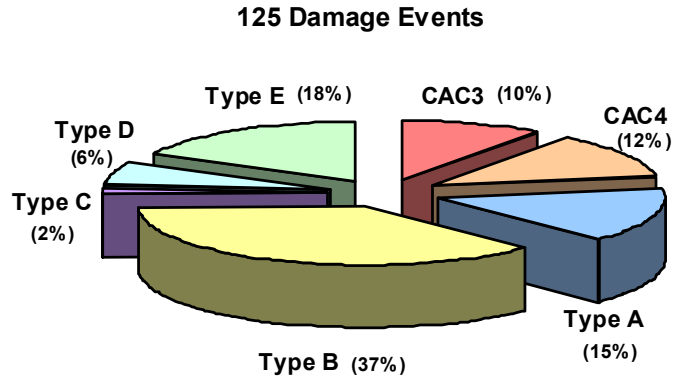


Figure 1: Breakdown of the damage events in the CHC/IRS database according to Vessel Class.

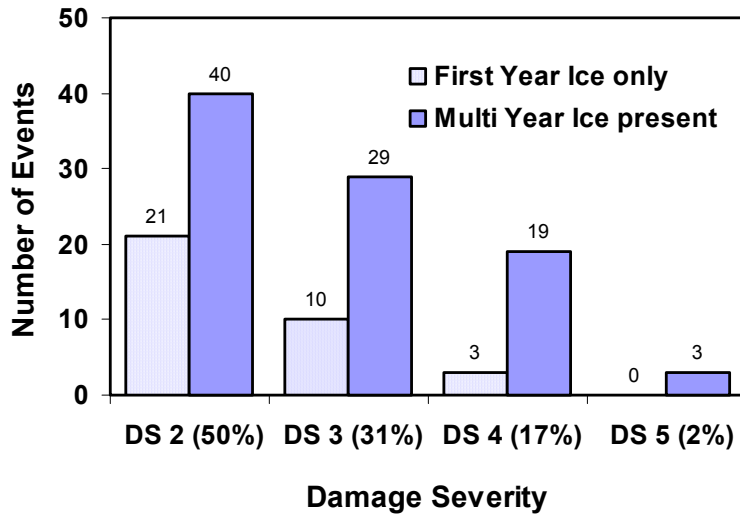


Figure 2: Breakdown of the damage events in the CHC/IRC database according to Damage Severity and ice conditions.

Figure 3 shows the breakdown of the damage for each Vessel Class. For CAC vessels, the vast majority of the damage events had multi-year ice in the ice regime. For Type vessels, there are a number of damage events in which there was only first-year ice in the ice regime. However the majority of damage events for Type vessels, 66%, had multi-year ice in the ice regime. Figure 3 also shows the trend that higher Damage Severity was associated with ice regimes that contained multi-year ice.

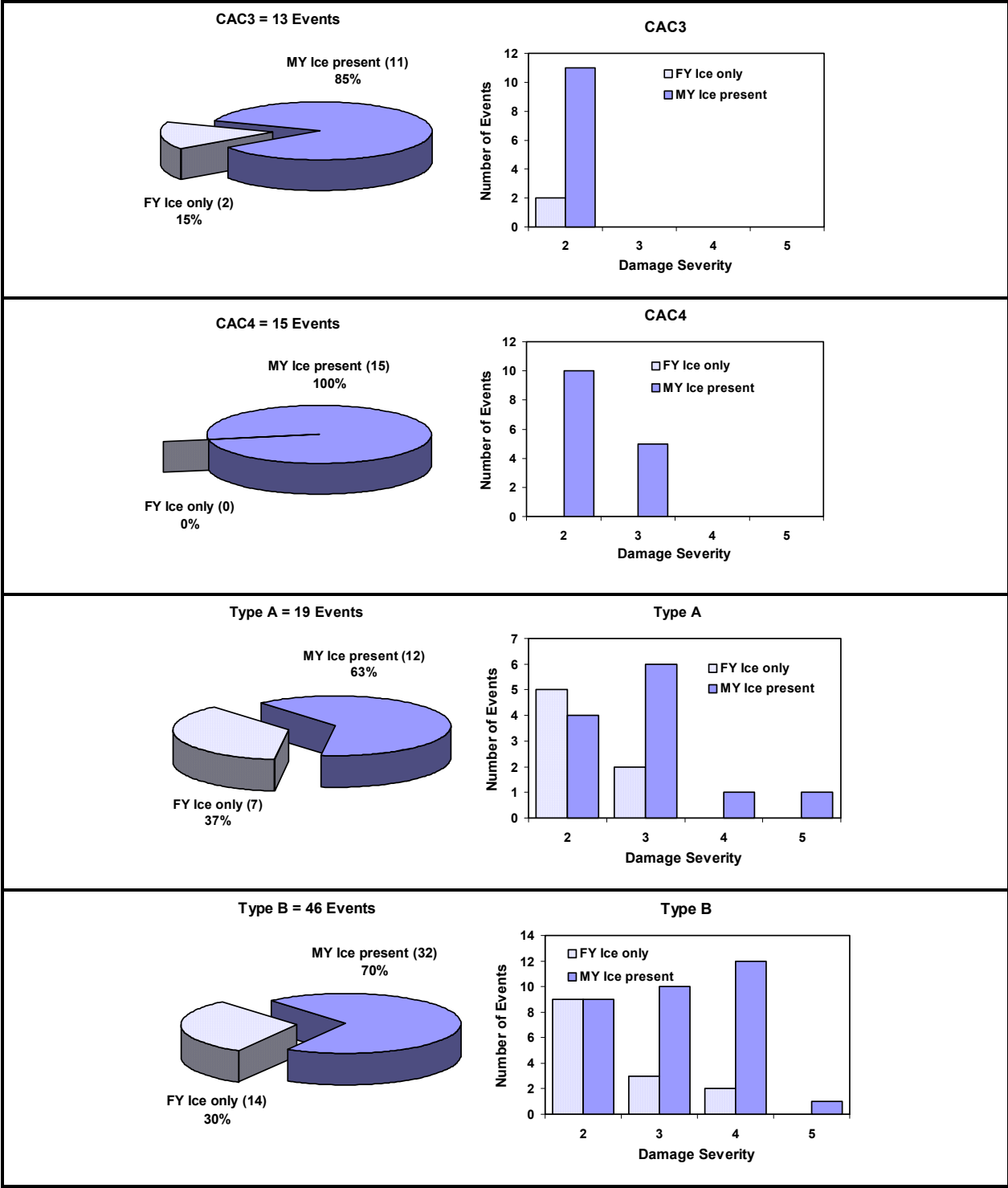


Figure 3: Pie Charts and Column Charts showing the number of damage events for each Vessel Class according to ice regime and Damage Severity.

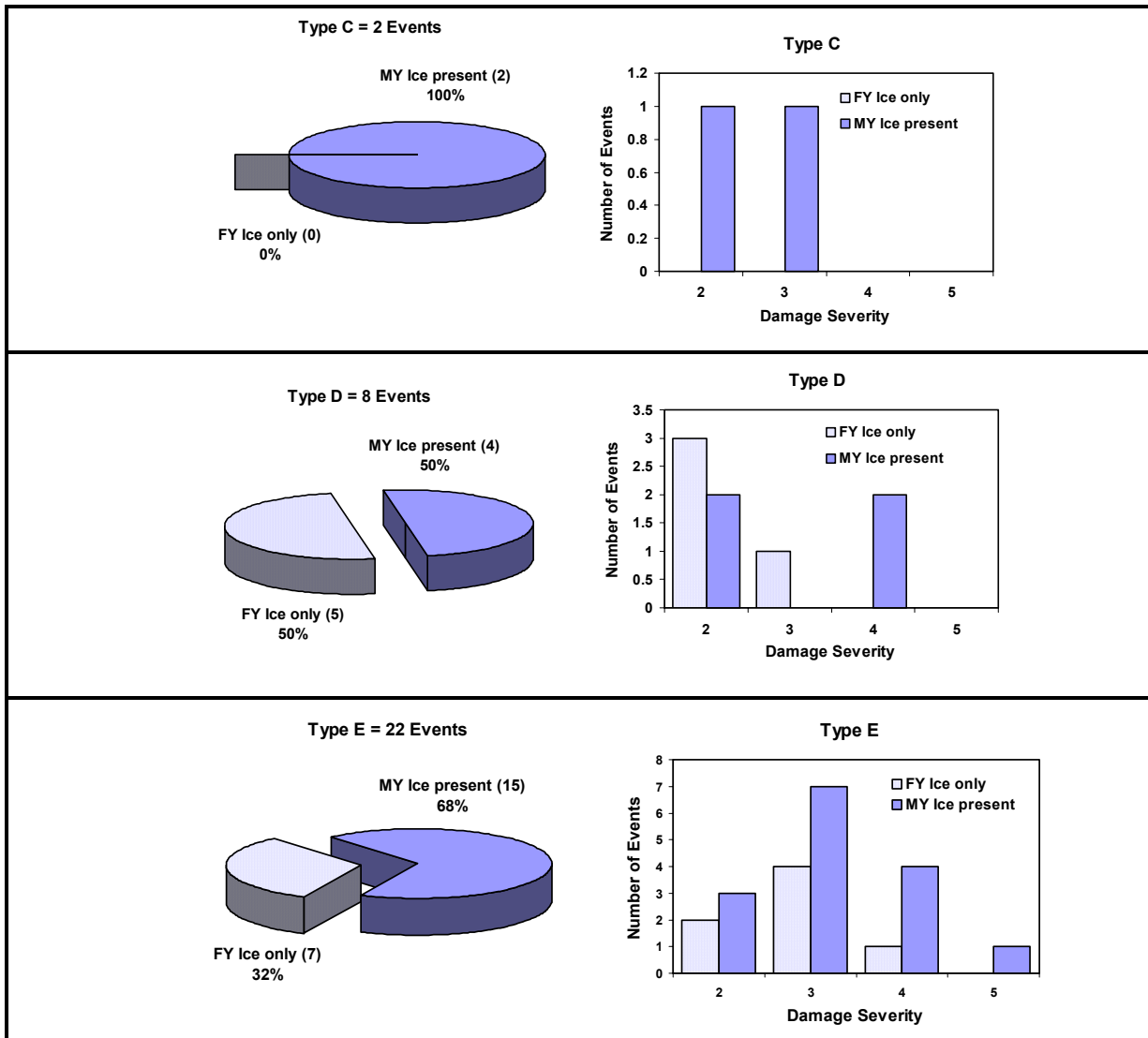


Figure 3 – Continued: Pie Charts and Column Charts showing the number of damage events for each Vessel Class according to ice regime and Damage Severity.

It is interesting to examine the cause of damage listed for the damage events in the Arctic. Tables 3 to 9 provide this information for CAC3 to Type E vessels, respectively. The tables also provide information on the Damage Severity, the presence of multi-year ice in the ice regime, and the damage description for each event. The events are further characterized to indicate if the damage occurred while the vessel was being “escorted” by an icebreaker. Note that the wording used for the damage description and the cause of damage is taken from the original source. The tables show:

CAC3 vessels – There are 13 damage events for CAC3 vessels. Damage to CAC3 vessels was minor, (i.e. damage to propeller or denting) and was mainly caused by hitting MY ice or MY floes. In two cases, damage occurred while the CAC3 vessel was escorting another vessel. In one case, damage was due to high speed ramming.

CAC4 vessels - There are 15 damage events for CAC4 vessels. All CAC4 vessel damage events occurred in waters which contained MY ice. In two cases, damage occurred while the CAC4 vessel was escorting another vessel, and in two other cases, while the vessel itself was under escort, i.e. damaged by ice in the track behind the icebreaker. In another case, the vessel came into contact with an iceberg. CAC4 vessel contact with the ice resulted in cracks, buckling, or propeller damage.

Type A vessels - There are 19 damage events for Type A vessels. Damage to Type A vessels was mainly caused by contact with the MY ice or heavy FY ice. In six cases, the vessels were damaged while following an icebreaker. In 50% of the events, the vessels were holed or punctured; in few events, the vessels hull was buckled.

Type B vessels - There are 46 damage events for Type B vessels. The most damage events in the IRS database were recorded for Type B vessels. These were mainly caused by the impact with MY ice or heavy FY ice. Twenty-six percent of the events happened while the vessel was under escort. In one case, a vessel hit a hidden piece of MY piece or a growler. One damage event was due to high speed in reduced visibility.

Type C vessels - The database contains only two damage events for Type C vessels, both caused by the contact with MY ice.

Type D vessels - There are 8 damage events for Type D vessels. Damage to Type D vessels was caused in ice regimes with both first-year ice only and ice regimes with multi-year ice present. Two damage events happened when the vessel was following the icebreaker.

Type E vessels - There are 22 damage events for Type E vessels. These vessels were mainly damaged in ice regimes with multi-year ice present. However in thirty-two percent of the damage events, there was only first-year ice present. Eleven damage events happened while the vessel was under escort.

Tables 3 to 9 show that in twenty-six percent of damage to all vessels, the vessels were under escort. Damage in this case was often attributed to heavy ice conditions in the track of the icebreaker.

Table 3: Damage events for CAC3 vessels.

DS	MY	Escort	DAMAGE DESCRIPTION	CAUSE OF DAMAGE
2	yes		Denting	cause unknown (8/10 MY and 1/10 FY)
2	yes		Denting	cause unknown (9/10 MY and 1/10 FY)
2	yes		Minor damage to propeller	vessel struck MY ice while freeing the other vessel
2	yes		Denting	cause unknown (9/10 MY)
2	yes		Denting	cause unknown (8/10 MY)
2	yes		Denting of hull bottom	transiting shallow water, grounding on ice pieces
2	yes		Minor	damage to the propeller while proceeding through ice
2	yes		Some (medium)	transiting through heavy MY ice
2			Minor	hitting FY ice
2	yes		Minor denting at lower bow	ice management, high speed ramming
2			Problems with the vessel's impressed current systems	cause unknown (9+/10 FY)
2	yes		Damage to the port and starboard propellers	icebreaking operation in severe ice conditions
2	yes		Propeller damage	jammed ice in the propellers (10/10 SY)

Table 4: Damage events for CAC4 vessels.

DS	MY	Escort	DAMAGE DESCRIPTION	CAUSE OF DAMAGE
3	yes		Cracks and frame deformation including buckling	transiting through area of MY ice
3	yes	yes	Port side damage	struck MY ice when attempting to follow turn made by escort
3	yes		Cracks and plate dishing/denting	vessel beset in MY ice
3	yes		Cracks - location unknown	vessel rocking in MY while beset
3	yes		1 m crack Port side bow shell plating	vessel engaged in trials - ramming MY ice floe
2	yes		Ice damage Minor	port shield plate damaged in ice
2	yes		Minor	vessel struck 7/10 MY ice
2	yes		Propeller damage	damage due to ice (10/10 SY)
2	yes		Shell plating, buckled frames	while transiting Baffin Bay (1/10 MY and 9/10 FY)
2	yes		Minor	deflecting an iceberg
2	yes		Minor	ice damage while escorting other vessel in old ice
2	yes		4 damaged propeller blades	unknown (4/10 SY and 6/10 FY)
2	yes	yes	Propeller damage	unknown (5/10 SY)
2	yes		Propeller damage	unknown (5/10 SY)
2	yes		2 bent blades, 1 blade scored, 1 blade with upper third part broken	while freeing a vessel in pressured ice

Table 5: Damage events for Type A vessels.

DS	MY	Escort	DAMAGE DESCRIPTION	CAUSE OF DAMAGE
5	yes		Vessel holed and sank	vessel rolled sideways into an old ice floe
4	yes		Holed in port side, engine room flooded	struck MY floe
3	yes		Port side shell plating indented and cracked 8 ft. below waterline	cause unknown (3/10 MY and 7/10 FY)
3	yes	yes	All three rudder stocks twisted and bent	cause unknown (3/10 MY and 7/10 FY)
3			Small leak near stern post / Holed	presumed to be due to ice (10/10 FY)
3		yes	Vessel damaged on starboard bow, apparently holed	following too close to escort in pressure conditions
3	yes	yes	Hull plating ruptured and supporting frames collapsed	cause unknown (4/10 MY and 2/10 FY)
3	yes		Holed - leakage in one small ballast tank	proceeding through MY floe
3	yes	yes	Small puncture in bow - frame deformation including buckling	cause unknown (9+/10 total: 7/10 MY and 2/10 FY)
3	yes		Small puncture in bow - frame deformation including buckling	cause unknown (9+/10 total: 2/10 MY and 7/10 FY)
2	yes		Minor plating and frame damage, Propeller cones damaged	backing and ramming in multi-year ice
2	yes		Dent in hull on port side near deck level	unknown (1/10 MY and 7/10 FY)
2	yes	yes	Indentation of shell plating	following track of icebreaker
2			Hull damaged	impact with heavy ice pieces (FY)
2	yes		Minor	severe ice conditions (1/10 MY and 4/10 FY)
2	yes	yes	Denting - stern; frame deformation	vessel beset in pressured ice (8/10 MY and 2/10 FY)
2			Some damage to plating, deflections of transverse frames	vessel under heavy compression of ice (9/10 FY)
2			Buckling of frames	vessel in compressive ice (9/10 FY)
2			Frames buckling	vessel in compressive ice (9/10 FY)

Table 6: Damage events for Type B vessels

DS	MY	Escort	DAMAGE DESCRIPTION	CAUSE OF DAMAGE
5	yes		Sunk	holing of outer hull
4	yes		Bow thruster compartment holed	old ice piece broke off from submerged floe and rose up forcefully
4		yes	15 m hole, considerable damage to plating and frames	while beset in ice, the ice rafted, nipped and crushed vessel port quarter.
4	yes		Bulbous bow holed on port side, forepeak tank open to sea	vessel was stricken in 8/10 ice (4/10 old ice, 4/10 FY)
4	yes		Holed in both bows, forepeak tank open to sea	heavy impact with MY ice (9/10)
4	yes	yes	Holed in starboard bow	sheered into heavy ice while manoeuvring in icebreaker track (10/10 MY)
4	yes	yes	holed in port bow	sheered into heavy ice while manoeuvring in escort track (5/10 MY and 3 FY)
4	yes		Forepeak port side holed, No.1 cargo hold open to sea	excessive speed; ship master attributes cause to darkness & bad weather
4	yes	yes	Hole in #1 Bower hold -Starboard site	hitting MY ice while being escorted
4			Forepeak tank holed	impact with hidden multi-year piece or growler
4	yes		Vessel damaged hull on port side	impacted ice (1/10 MY, 9/10 FY)
4	yes		Damaged area 6 sq.m., holed and flooded No.1 ballast tank	vessel pushing ahead into multi-year ice
4	yes	yes	Port side bow fractured, 2 sq.m., forepeak and cofferdam flooded	track filled with heavy pieces of ice (5/10 MY and 3/10 FY)
4	yes		Ice damage at stern, port side, forepeak holed	unknown (2/10 MY and 8/10 FY)
4	yes		Large hole, underway moving ahead, forepeak	unknown (2/10 MY and 2/10 FY)
3	yes		Vessel holes near stern	unknown (1/10 MY and 5/10 FY)
3			Bow plating holed below waterline / Minor	unknown (9/10 FY)
3			Holed	proceeding through heavy (9-10/10) FY ice
3		yes	Holed	proceeding through very close pack ice (10/10 FY)
3	yes	yes	Port side cracked near stern in way of forepeak ballast tank	struck several ice floes during escort
3	yes	yes	Holed	impacted ice piece going through a strip
3	yes		Vessel holed forward	contact with ice (3/10 MY and 7/10 FY)
3	yes		Holed, minor pollution	impact with MY ice
3	yes		Bow plating holed 2 m below waterline	unknown (6/10 MY)
3	yes		4-5 frames buckled in forepeak area, small weld cracks	entered fog bank at 4 knts, 2 medium MY floes left no room to manoeuvre
3	yes		Holed	proceeding through very close pack ice (MY) and striking MY floe
3	yes		Damage to port side shell plating and internal structure	contact with floe of MY ice
3	yes		18" - 24" gash, frames badly buckled	hit piece of SY ice
2	yes		Minor	while transiting through 2/10 MY and 1/10 FY
2			Bow and side plating damage	struck a heavy floe (FY)
2		yes	Damage to propellers; stbd. nozzle, rudder stock and skeg	transiting through a track being tightly packed with ice (10/10 FY)
2	yes		Small indent in bow	unknown (5/10 MY and 4/10 FY)
2	yes	yes	Minor	ice damage during escort
2	yes		Denting - bow	fforward transit in ice
2			Dent	sustained damage while navigating in ice
2	yes		Minor	transiting through 6/10 MY and 3/10 FY
2	yes		Minor	ice damage (1/10 MY and 2/10 FY)
2			Minor	minor ice damage found in drydock inspection (9/10 FY)
2			hull dented	shell damage discovered on dry docking (10/10 FY)
2	yes		Shell plating and internals, bow thruster compartment & cargo tanks	vessel beset in ice (9/10 FY)
2	yes		Starboard shell plating and in way of the bow thruster compartment	unknown (7/10 FY)
2		yes	Outboard half of starboard kort nozzle and rudder damaged	ice thrust back by escort
2	yes		Port prop damaged in heavy ice	propellor damaged in heavy old ice (5/10 SY)

Table 7: Damage events for Type C vessels.

DS	MY	Escort	DAMAGE DESCRIPTION	CAUSE OF DAMAGE
3	yes		Small puncture in outer hull	ice (1/10 MY and 9/10 FY)
2	yes		Hull plating and frames damaged; no pollution	unknown (9/10 MY)

Table 8: Damage events for Type D vessels.

DS	MY	Escort	DAMAGE DESCRIPTION	CAUSE OF DAMAGE
4	yes		Large hole in bow	unknown (5/10 MY and 4/10 FY)
4	yes		Very severe damage along starboard extending along #1 and #2 holds	vessel further north than normal route (2/10 MY and 3/10 FY)
3			Indentations on bulbous bow; dents and fracture on port side	unknown (5/10 FY)
2		yes	Damage to plating on bow - pushed-in plating on stern port side	encountered heavy floes of drift ice (7/10 FY)
2			External damage to starboard propeller and shaft	propeller impacted ice
2	yes	yes	Hull damaged at various places (bow, forepeak, engine room)	unknown (1/10 MY and 8/10 FY)
2	yes		Propeller lost - Minor	lost starboard propeller contacting 1/10 MY+ 3/10 FY); bergy waters
2			Areas of shell plating heavily set in; frame buckled and distorted	vessel beset in ice under heavy pressure (9+/10 FY)

Table 9: Damage events for Type E vessels.

DS	MY	Escort	DAMAGE DESCRIPTION	CAUSE OF DAMAGE
5	yes		Holed in starboard bow; vessel sank when watertight compartment was inadvertently open to the sea	presumed impact with ice (7/10 MY)
4	yes		Severe damage to hull bottom of bulbous bow	unknown (1/10 MY and 4/10 FY)
4	yes		Extensive damage to forefoot of bulbous bow; forepeak tank holed	unknown, CCGS reports strips and patches of 9/10 in area
4	yes		Holed bulbous bow at waterline	direct impact with ice (2/10 MY)
4			Bulbous bow and starboard hull holed	passing through patches of heavy ice at very slow speed
4	yes		Holed shell and buckled frames	forward transit in heavy pack
3	yes	yes	Bow plating damaged at waterline, 1sq.m. area, craking at forepeak	attributed to difficult movement behind icebreaker
3	yes		Crack in plating at starboard bow 3 m back from stern; propeller blade bent at tip	unknown (1/10 MY and 7/10 FY)
3	yes	yes	Damaged both sides of forepeak	following in icebreaker track which was closing quickly
3	yes	yes	3 rudders sheared off, 1 bent and jammed; frames damaged both sides; plating dented.	heavy ice conditions behind icebreaker
3		yes	Cracked hull and damaged frames	while under escort
3			Port gearbox damaged; both port and starboard propellers leaking oil	propeller and gearbox damage contacting ice (7/10 FY)
3	yes	yes	Damage to forepeak compartment	track was filled with thick FY ice pieces (1/10 MY and 9/10 FY)
3	yes		Sides of vessel. Also propeller and rudder. Shell dented, buckled frames	vessel beset in pressure, sides squeezed in extreme pressure
3		yes	3rd plate below sheer set in and distorted over lower 1 m full length.	unknown (9/10 FY)
3	yes	yes	Extensive damage sustained in way of the bow, shell plating and propellers.	violent contact with ice (9/10 MY)
3		yes	Bow plates damaged at water level with some plates cracked in forepeak	vessel transmitting through heavy ice (9+/10 FY)
2	yes		Minor indents at breast hook area	unknown (1/10 MY and 3/10 FY)
2	yes		Damage to the propeller and rudder	unknown (5/10 MY and 4/10 FY)
2		yes	Vessel reports light damage to 5 frames at forepeak	unknown (9/10 FY)
2		yes	Minor damage below the buoyancy line.	ice damage occurred following discharge of cargo
2	yes	yes	Indentation 0.15 m for a length of 10 frames. No leakage or cracks	violent contact with ice while following icebreaker

SUMMARY

This paper has presented a summary and analysis of 125 events that caused damage to vessels in Arctic waters. The analysis showed that there was multi-year ice present in the ice regime in 73% of the damage events. For CAC vessels, there are few damage events, but virtually all those that did occur had ice regimes with multi-year ice present. For Type vessels, 66% of the damage events occurred in ice regimes which contained multi-year ice. The remaining 34% occurred with only first-year ice in the ice regime. Approximately one quarter of the damage events occurred when the vessel was in escort. The data also show that damage is more severe in ice regimes that contain multi-year ice. Overall, the data and analysis illustrate the damage potential and hazards presented by multi-year ice.

ACKNOWLEDGEMENTS

The authors would like to acknowledge Transport Canada the financial support of this work, and to thank Victor Santos-Pedro for his interest and support of this research.

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