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**INCIDENTS AND ACCIDENTS IN WINTER NAVIGATION IN THE BALTIC SEA,
WINTER 2002 – 2003**

Sjöfartsverket
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ABSTRACT

Damage statistics of ships sailing in the Baltic Sea were gathered during the winter 2002-2003. The main purpose of the work is to collect hull damages, but also other ice related damages are included. The statistics gathered includes 98 incidents. Altogether 111 ships were involved to these incidents. The percentage of structural damages caused by ship-ice interaction was approximately 30 %. Other types of damages were propeller damages (35 %), ship collisions in ice (25 %), rudder damages and grounding events due to difficult ice conditions. The work was done by surveying the ships during dry-docking and by interviewing the technical personnel of the shipping companies. Other sources of information were authorities, a ship insurance company and media. This data can be used in development of ice class rules concerning ice strengthening of ships and in risk evaluation of winter navigation.

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LIST OF ABBREVIATIONS

BRT	brutto register tonnage
CP propeller	controllable pitch propeller
DWT	dead weight tonnage
FDD	freezing degree days
FIMR	Finnish Institute of Marine Research
FMA	Finnish Maritime Administration
FMI	Finnish Meteorological Institute
FSA	Federal Safety Assessment
HUT	Helsinki University of Technology
PB	port board (i.e. left side of the ship)
SB	starboard (i.e. right side of the ship)

1. INTRODUCTION

In this project ice damages on ships that are built according to Finnish-Swedish ice class rules (1985) are being gathered. Statistics of ice damages makes it possible to estimate design ice load level and proper extent for ice-strengthened areas. The main focus is on the hull damages i.e. damages on frames, stringers and plating. Hull damages can be divided in longitudinal direction to bow, mid and aft ship damages and in vertical direction side, bilge and bottom damages. Damages in different hull areas are caused in various operational conditions. Other damages, for example on rudder, propeller or engine malfunction are also documented. Ice related hull damages are divided to direct ice damages caused by ship-ice contact, to damages caused by ship-ship contact (for example collisions in ice channel) and to grounding events.

Incidents and accidents were gathered from several different sources. The main focus was to gain data direct from Finnish and Swedish ship owners. Technical personnel in 61 shipping companies were interviewed. Together 14 ships were visited during seasonal dry-dockings. Quite many incident reports were received from ship inspectors of the Finnish Maritime Administration. Some of the incidents are well documented (time/date, location, ice conditions, ship operations and detailed description of the damages), but most are not well known. The minimum information required for an ice-incident to be included in this study was the damage type and information of the damaged ship. According to the statistics gathered (altogether 98 incidents) the frequencies of different type of damages can be estimated and the reasons and consequences of the accidents in winter navigation can be studied. Also the influence of the parameters affecting to the damage probabilities and consequences can be evaluated. Thus this data can be of assistance in the risk analysis of winter navigation in the Baltic Sea (Jalonen, 2003). However, this work reports only the beginning of a long-term research project, where incidents and accidents are gathered spanning several winters. Based on long-term statistics of accidents and incidents in winter navigation, parameters like severity of the ice winter to the damage probability can be studied. In addition more data is needed before any general conclusions can be made.

Information of ice damage is needed to determine the design ice load levels. Proper design criteria will decrease ice damages and will increase safety at sea. The rule design ice load levels and the strength requirements (Finnish-Swedish ice class rules 1971 and 1985) are based on ice damage statistics (Johansson, 1967). This damage statistics includes information of 200 ships. For these ships ultimate strength capacities of different structural elements were calculated. This way design ice pressures for different ice classes were determined. Design ice pressures for ice class IA as a function of ship's capability to move in ice is presented in Figure 1. Here the capability is a measure of the displacement and engine power of the ship.

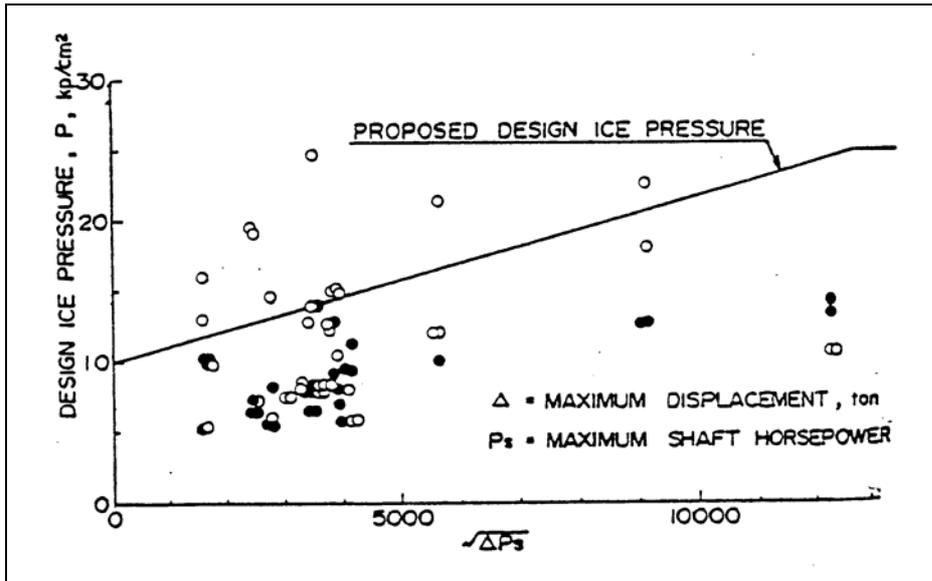


Figure 1. Design ice pressures of ice class IA (Johansson, 1967).

Recent ice damage statistics from the Baltic Sea were gathered between 1984 and 1987 (Kujala, 1991). In that work damages on different hull areas were statistically analyzed. Loads were evaluated based on damaged area and maximum deformations. Load intensity as a function of load length according to that study is shown in Figure 2. According to the analysis of the line-load required to cause the damages an exponential decrease of the load intensity as a function of load length was found.

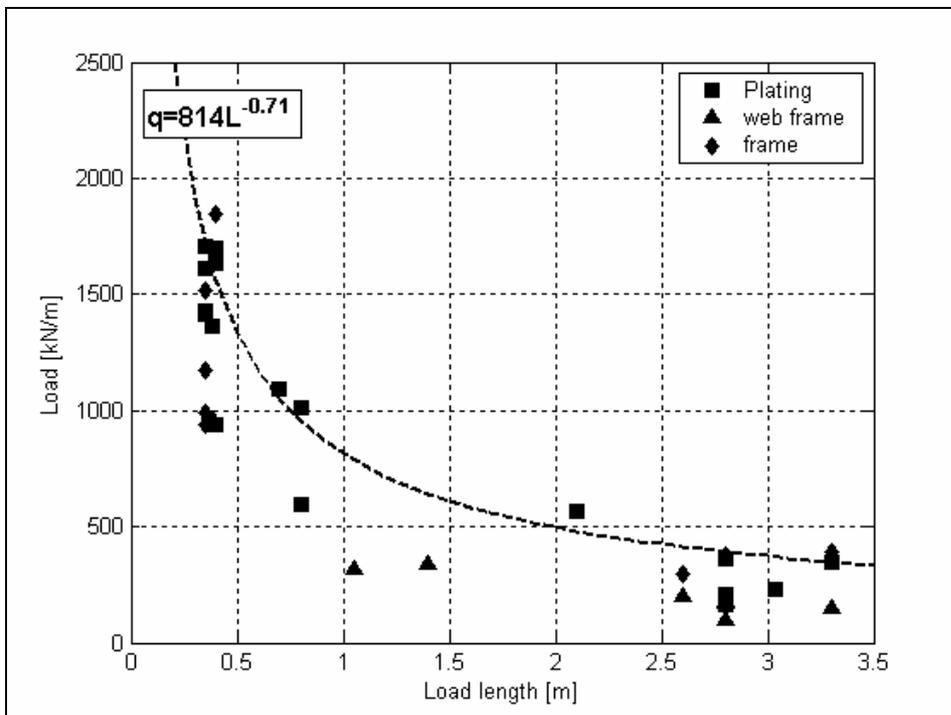


Figure 2. The line-load intensity [kN/m] as a function of the load length based on the analysis of ice damages (Kujala, 1991).

2. DESCRIPTION OF THE WINTER SEASON 2002-2003

In the early November 2002 ice cover started to develop in the Bothnian Bay and in the Gulf of Finland. Maximum ice cover extent was reached at early March (Figure 3). It was 232 000 km² at its maximum. Figure 3 also gives the maximum ice cover extent during the past 14 years. The maximum ice cover extent was only a bit larger than long-term average, but in many areas there were thick ridged and rafted ice fields. In winter 2003, compared to the recent 13 years, the maximum ice cover extent was about two times larger than average. The ice season lasted over one month longer than on the long-term average in the Gulf of Finland and about two weeks longer in the Bothnian Bay (FIMR, 2003). From that point of view the ice season 2002-2003 was difficult for winter navigation. Ice cover was disappeared by the end of May.

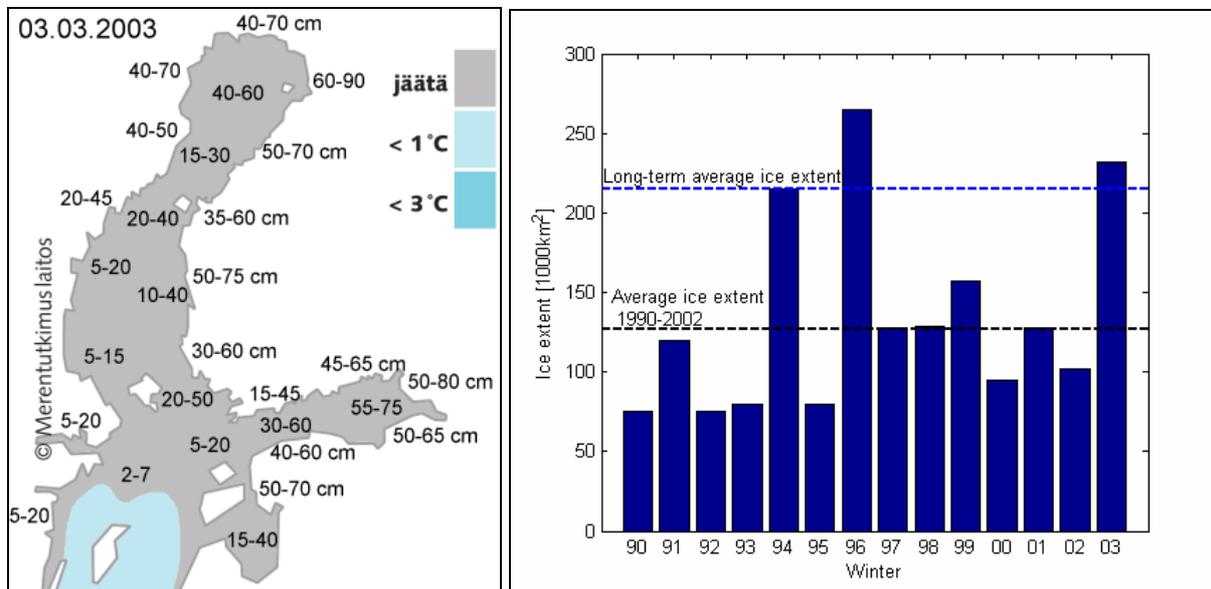


Figure 3. Maximum ice cover extent during winter 2003 and the maximum ice cover extents during the winters 1990-2003 (Finnish Institute of Marine Research).

Daily mean temperatures, cumulative freezing degree days and ice thickness data from three weather stations are presented in Figure 4. The northernmost station Hailuoto is located in the Bothnian Bay near to Oulu. Valassaaret is located in the Northern Quark and Rankki in the Gulf of Finland near Kotka. Maximum cumulative freezing degree days (FDD) were about twice as much in the Bothnian Bay than in the Northern Quark and in the Gulf of Finland. The ice season started about one month earlier in the Bothnian Bay than in the Northern Quark and in the Gulf of Finland.

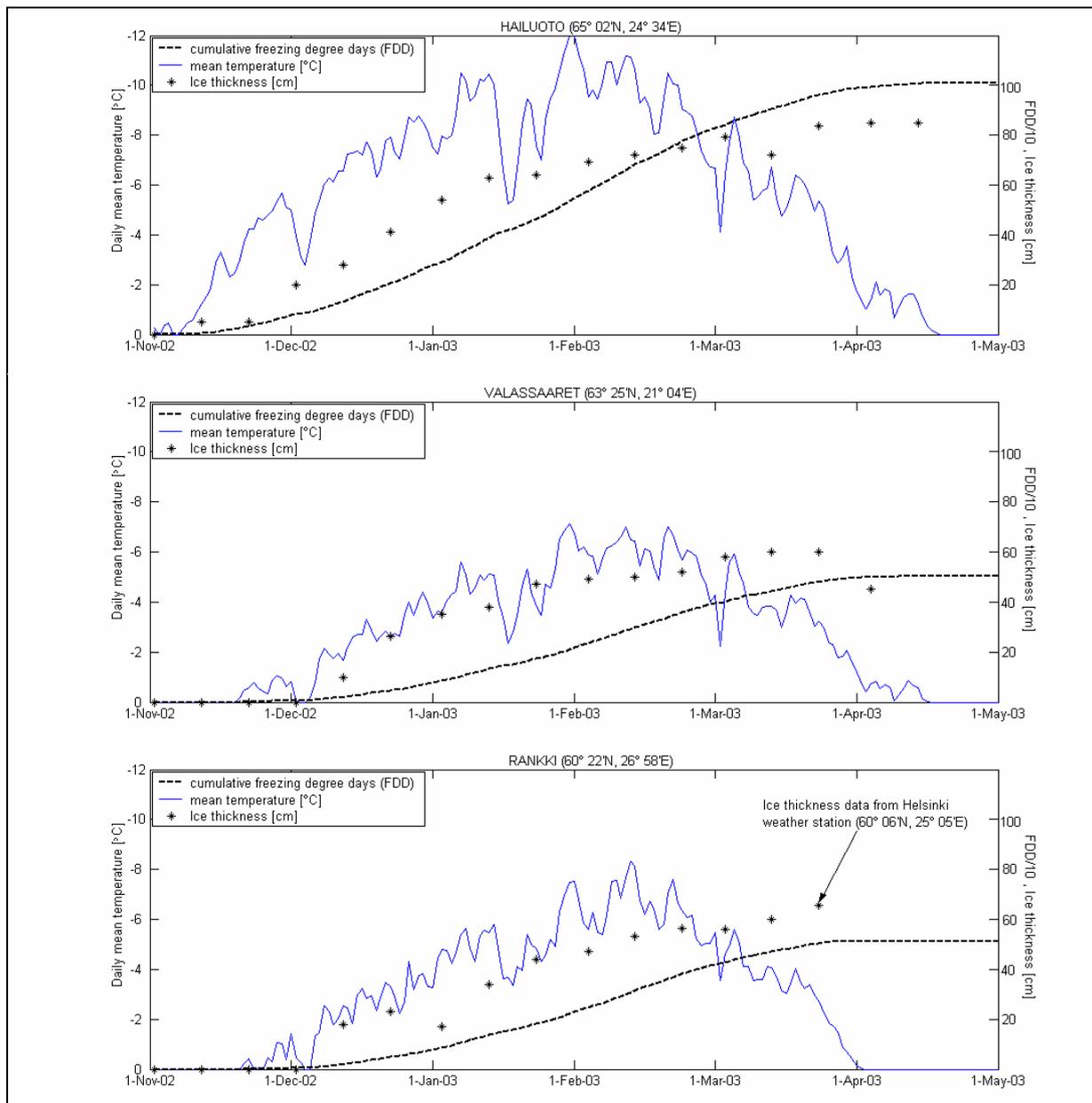


Figure 4. Daily mean temperatures, cumulative freezing degree days (FDD) and ice thickness data from three different weather stations located in the Bothnian Bay, Northern Quark and Gulf of Finland (FMI, 2003).

The statistics of ships which visited the Finnish ports between December 2002 and April 2003 in foreign traffic is presented in Figure 5 (FMA, 2003). The total number of ships was 863 of which 125 sail under the Finnish flag. The total number of ship visits during the winter season was 9013. The average deadweight of the ships is 8100 dwt. Most of the ships (86 %) were built according to the strength requirements of higher ice classes IA and IA Super. Over half of the port calls (59 %) were made by Ro-Ro ships and car-passenger ferries. The average age of the ships was 16 years. The most typical foreign flag states of the ships were Sweden, the Netherlands, Germany and Estonia. This data are to be compared with damage statistics in order to find out how many ships of the total traffic have damaged. Are ships of certain type, size, age or ice class more often damaged?

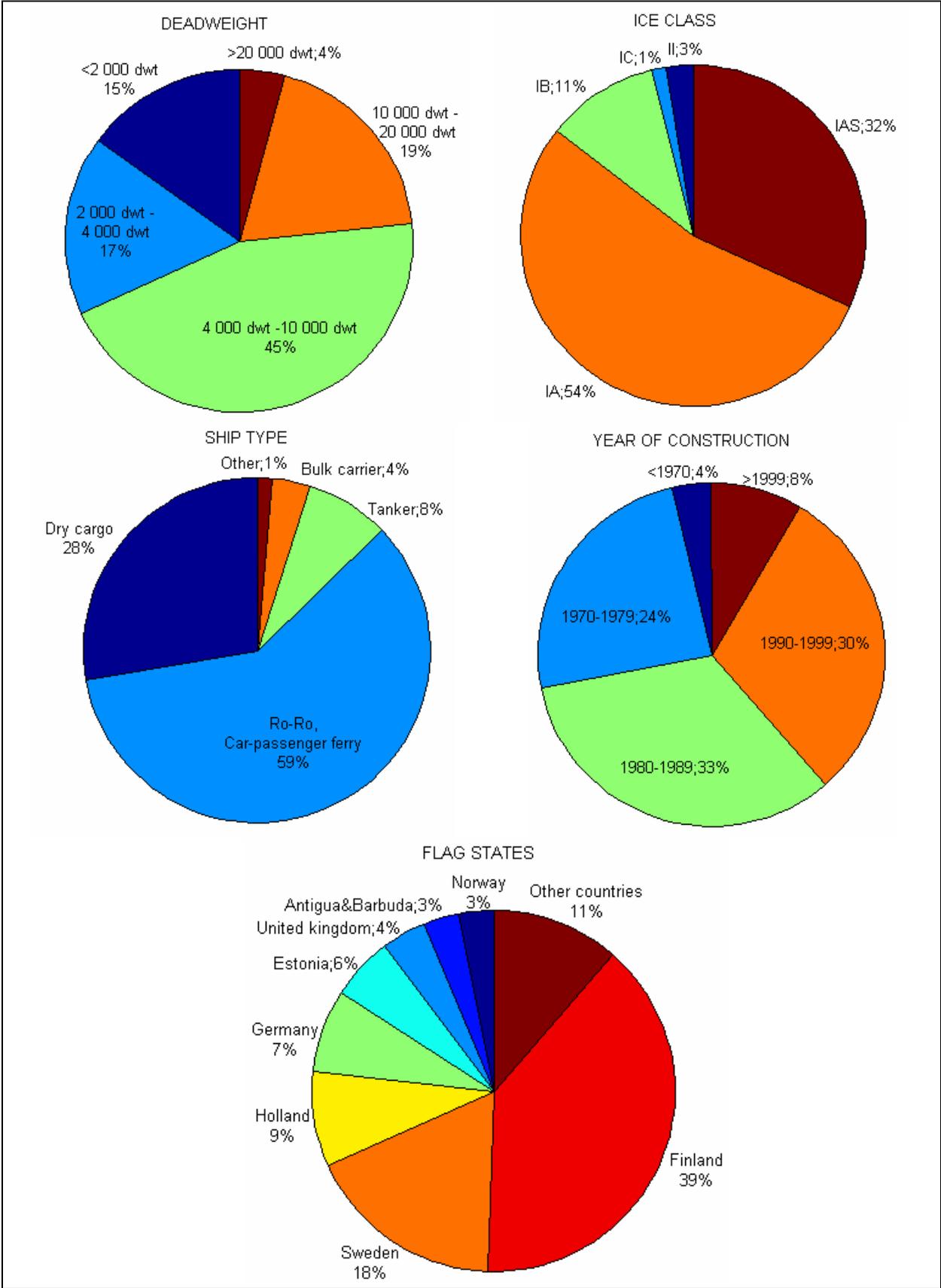


Figure 5. Information of the ships that visited the Finnish ports between December 2002 and April 2003.

3. RESEARCH METHODS

3.1 Methods used during the first year of the project

This project started at the end of year 2002 and continued through the year 2003. The first task was to make a list of the ship owners in Finland and Sweden. Then a letter was sent to over 70 shipping companies. In the letter the purpose of the project was described and information concerning the ships and possible ice accidents was inquired. After a while the shipping companies were approached by phone and email. During that phase of the work 61 shipping companies were interviewed. By interviewing technical personnel in shipping companies we got information of ice damages occurred during the recent years, list of the ships sailing in ice in the Baltic Sea, information on ships' operation areas and times in ice and information on pending dockings. We asked the technical personnel of shipping companies to report possible ice related accidents as soon as possible and at least before dockings. However, quite few responses were received from the shipping companies.

Authorities in Finnish Maritime Administration were interviewed, especially ship inspectors and icebreaker personnel. Large amount of the data came from FMA ship inspectors (see Table 1). Ships' crew and some inspectors of classification societies were interviewed during dry-dockings. Other sources of information were a ship insurance company, newspapers and ship repair docks.

Ships are usually dry-docked between late spring and early autumn. The essential part of the damage statistics was gathered by surveying the ships during dry-dockings. Graving docks visited were located in Finland (Helsinki and Turku) and in Estonia (Tallinn). During the surveys ice damages, i.e. size, shape and location, were identified. Altogether 14 ships were visited during the year 2003. Damages were observed visually estimating the location, size and shape of damaged area. Permanent deflections were measured with measuring tapes, if possible. If shell structures were damaged also inner structures i.e. frames and web frames may have been damaged. The damages of the inner structure may give more detailed information of the development of the damage. Also the inner structures were observed, if possible. All damages were photographed using digital camera.

Eventually the analysis of the results will include statistical analysis and evaluation of ice-induced loads that caused the damages. Loads can be calculated if damage location, extent and maximum permanent deflection are measured. However, the damage causing loads are not evaluated in this report. The damaged ships of different size, hull shape, operation profiles and ice class will be compared. Ice conditions when damages have occurred can be roughly estimated using routine ice charts and timetables of the ships. At least the sea area and the phase of the ice season can be compared to the damage statistics. The focus of this report is to describe the ice damages that occurred during the winter 2002-2003 and to do some basic statistical analysis of the damages.

3.2 Suggestions and improvements for data gathering methods

The data gathering methods should be improved in the future. Below is a short list of proposals of improvements of the data gathering methods:

- More shipping companies should be interviewed. Perhaps some large foreign companies that own several ice-strengthened ships. According to Figure 5 (chart below) 22 % of the ships that visited Finnish ports during the winter 2002-2003 sail under the flags of Germany, the Netherlands and Estonian flags.
- A simple enquiry form can be sent for example to Finnish and Swedish icebreakers and shipping companies. This ensures that data is gathered in a more uniform way.
- More contacts should be made with ship insurance companies. Insurance companies may have data enough for proper statistical analysis (Sjöstedt et al., 1973) and risk analysis.
- One possibility is to select two or more ports and analyse the traffic, ice conditions and accidents occurred on a route to these ports in a detailed way.

In the future special concern should be attached to the hull damages. The measurements of the damage extent and the damage severity can be improved and more sophisticated measuring methods than just visual observation should be used. According to this data the extreme ice load values will be estimated. Next two possible measuring methods are described:

Laser scanning. Laser technique is nowadays very common. Laser scanners are used for example in medical and food industry. If suitable equipment is found, it would be very useful and accurate when permanent deflections are measured in plating. The advantage of laser scanning is that the surface of deflected area can be easily transformed into digital format. Laser scanners can be rented from commercial companies.

Stereo photography. If larger damaged areas are found, it is time consuming and difficult to measure those with measuring tapes. Stereo photography, which can be done using one digital camera, gives shape of the shell structures of larger area. Kujala (1991) used stereo photography to identify ice damages. Institute of Photogrammetry and Remote Sensing (Helsinki University of Technology) has knowledge on stereo photography techniques.

4. DESCRIPTION OF THE GATHERED DATA

In this chapter different types of ice-related incidents and their consequences are listed. Then the incidents and accidents during the winter 2002-2003 are divided to different categories. The list of the incidents and the ships is also given. The names of the ships are not given due to confidential aspect. However, ship type, size, age, ice class etc. are given. Finally, some of the accidents and damages found are described in more detail.

4.1 General description of the ice damages

First the reasons that have caused or lead to an accident are listed and then the possible consequences are given. The identified hazards of winter navigation are based on earlier studies, see for example Juva (2002), Kujala (1991) and Sjöstedt et al. (1973). Also by interviewing the ship owners and the ships' crew the reasons and the consequences of the accidents could be outlined.

Damages can be caused by the following reasons:

- High speed in ice. This relates especially to ships of high propulsion power compared to their size. These ships may have open water speed over 20 knots. If the ship strikes an ice edge with full speed, damages may occur in the bow area. High speed in an ice channel may damage ship's side shell and plating above the water line on the bow area due to extended ice loading by the bow wave.
- Collision with other ship in an ice channel. When ships are moving in an ice channel successively with short lead, the first ship may get stuck in ice and the next one may collide with the first one. This situation may occur especially if the first ship is small and has low propulsion power and the other one is a much bigger ship.
- Damages during icebreaker assistance. A collision with an icebreaker may occur in short lead assistance, when the icebreaker gets stuck in ice. Damage may also occur in towing situation and in cutting situation, if the icebreaker cuts the ship too close and with high speed.
- Damages in an ice channel. Mid and aft ship hull areas may be in contact with the channel edges when the ship is turning. Bilge and bilge keels may be damaged especially in old channels with thick edges.
- Backing in ice. In heavy ice conditions ships get often stuck in ice. Then the ship has to back. Backing in ice may damage aft ship areas, especially the rudder and the propeller. Also aft areas of the ship hulls may be damaged when backing in ice.
- Compressive ice. The ice channel may get closed due to the moving ice field. In this situation the ship gets stuck in ice and damages occur often in the mid ship area on the flat side region.
- Ice ridges. Ice ridges may extend 3 m above and 20 m below the water level. Ice pieces of ice ridges may damage side, bilge and bottom areas, especially when a ship

is towed through an ice ridge. Seawater wells in the bottom of the ship may get stuck due to small ice pieces from the ice ridge.

- Manoeuvring in port. Ice rubble in port may become several meters thick. In addition, among the ice rubble there may be objects like rocks and wood. Manoeuvring in this ice rubble may damage several parts of the ship hull and the propulsion machinery.
- Darkness and snowfall. During wintertime it is dark almost round the clock. This fact combined with snowing, wind and freezing temperature naturally makes ice navigation more difficult than that during the open water season.
- Ships in bad repair or ships with insufficient ice strengthening. Ice damages on the ship hull are often cumulative, i.e. dents develop during the winters. This means that ships may have relatively large deformations on the plating and on the frames. Due to corrosion and abrasion the thickness of the plating may have worn several millimeters. Ships without proper ice strengthening or ships in bad repair are likely to suffer more serious damage than other ships.
- Inexperienced crew in ice navigation. During the last fifteen years ice conditions in the Baltic Sea have been quite easy for ice navigation. The average maximum ice extent during these years has been only half of the long-term average maximum value (Fig. 3). Experience of winter navigation may have been forgotten or may have not developed.
- Icing effect. Ship's superstructure icing is caused by the lifting of spray into the relative wind by the ship bow. The spray is then super-cooled and carried over the ship superstructure to freeze on bulkheads, decks, and rigging. This concerns especially small ships, like fishing vessels and tugs.
- Grounding events. A Grounding event may occur due drifting of the ship with a moving ice field. The other possibility is that the ship seeks for an easier route in difficult ice conditions and then accidentally grounds.
- Vibration of the structures due to ice loading.

And the damages found are:

- Dents on the plating, frames, stringers and web frames. These are often cumulative. Dents are repaired during seasonal dry-dockings. In Baltic Sea dents caused by ship-ice contact are normally between 10 mm to 100 mm deep.
- Fractures. Cracks and ruptures occur most often on the plating. These can be found from ships, which are in bad repair. The reason of ruptures is often that plating has worn out. Cracks are usually observed in a junction of plate and frame below water line level.
- Wear in painting. Ice pieces wear ship's painting due to abrasion. This can be clearly seen at the water line level, but also in the bilge and the bottom areas.
- Bilge keel damages. Bilge keel damages and ruptures have been surveyed on four passenger vessels during winter 2003. These are related to manoeuvring in harbour or in an ice channel.

- Dents and holes above waterline. The reason for holes above waterline is a collision with icebreaker or collision with some other ship in an ice channel.
- Propeller, rudder and thrusters damages. The most common reason is backing in ice or manoeuvring in port. Propeller damage is either blade damage or damage in the control system of CP propellers.
- Main engine malfunction due to heavy ice conditions.

4.2 Summary of the ice damages during the winter 2002-2003

In this section the ice related incidents and damages are listed. The damages are of different types. The consequences are in some cases minor (these may not have been noticed until seasonal dry-docking, no need to repair) and in some cases serious (evacuation of the ship crew, ship towed to the nearest port and instant repair or docking was needed). The data is gathered from several sources. Altogether 14 ships were surveyed during dry-dockings or right after the incident. The rest of the data comes from authorities, ship owners and newspapers. The total number of the incidents is 98. The number of ships involved in these incidents is 111. This is more than the number of incidents, because in case of collision there are at least two ships. Operators of the ships are Finnish, Swedish, Estonian and Russian shipping companies. The damages found can be roughly divided into eight categories:

1. Dents or ruptures due ship-ice contact (30 instances).
2. Ship collisions due to heavy ice (23 instances).
3. Grounding events due to heavy ice (3 instances).
4. Ships in bad condition or inadequate ice class (ruptures 5 instances).
5. Propeller damages (36 instances).
6. Rudder damages (7 instances).
7. Surface damages (painting) (3 instances).
8. Main engine or other machinery malfunction (3 instances).

The same ship may have had damages of different categories. In Table 1 a short description of the incidents is given. Explanations of the abbreviations are given in Table 2. All ice classes are transferred to Finnish-Swedish ice classes using equivalency tables (FMA, Bulletin no. 16/27.11.2002).

Table 1. List of ice related incidents in the Baltic Sea during winter 2002-2003

Ship Number	Date	Ship type	L [m]	B [m]	T [m]	DWT	P [kW]	Ice class	Year build	Damage type	Sea Area	Ice conditions	Source
1	30-Apr-03	Ferry	292.5	38.8	7.8	7500	35200	II	2003	PR	GOF	Ice channel	FMA
2	22-Apr-03	Dry cargo	120	15.2	7	7795	3840	IA	2002	PR	BBO	In ice	FMA
3	17-Apr-03	Dry cargo	88.8	12.8	6.7	2620	1180	IB	1976	PR	GOF	In ice	Other
4	11-Apr-03	Icebreaker	83.5	19.4	6.75	5209	10200	-	1979	GR	GOF	In ice	Other
5	10-Apr-03	Cargo ferry	162.6	20.6	6.7	8708	12600	IAS	2001	RU	BBO	In ice	FMA
6	5-Apr-03	Dry cargo	78.7	12.3	5.1	2590	1100	II	1974	GR	BPR	In ice	Other
7	02-Apr-03	Dry cargo	100	15.9	4.9	3725	3280	IA	2001	RU	GOF	In ice	FMA
8	01-Apr-03	Cargo ferry	188.9	23.7	5.9	6300	13200	IB	1986	PR, HB	BPR	Ice channel	FMA
9	01-Apr-03	Tug	40.4	9.8	4.3	175	2700	IA	1965	PR,HB	GOR	In ice	Other
10	01-Apr-03	Cargo ferry	153.4	28.2	5.82	2880	15300	IA	1981	PR	GOF	In ice	Other
11	28-Mar-03	Dry cargo	108.4	15	5	3070	1030	II	1978	CL	GOF	IB assist.	Other
12	25-Mar-03	Bulk carrier	199.6	29	11.7	44363	9630	II	1982	HD	GOF	IB assist.	Other
13	25-Mar-03	Dry cargo	108.5	15.9	5.8	5257	2880	IA	1999	PR	BBO	In ice	FMA
14	24-Mar-03	Icebreaker	67.7	18.3	6.1	2700	3970	-	1971	PR	GOF	In ice	Other
15	20-Mar-03	Dry cargo	108.5	15.9	5.8	5257	2880	IA	2000	PR	BBO	In ice	FMA
16	20-Mar-03	Cargo ferry	86.3	16.8	4.2	990	4030	IA	1971	PR	GOR	Ice channel	FMA
17	14-Mar-03	Tanker	124.8	17.2	7.1	8000	4100	IA	1993	CL	GOF	In ice	Other
18		Tanker	134.7	19.6	8.3	10620	4000	IA	1986				
19	13-Mar-03	Mine carrier	76.9	11.6	3	1300	5200	-	1992	RU, HD	GOF	In ice	Other
20	12-Mar-03	Dry cargo	134.5	16.5	7.1	8950	5280	IA	2000	CL	GOF	Ice channel	FMA
21		Tanker	140.7	21.2	7.3	11500	6000	IA	1982				
22	11-Mar-03	Dry cargo	102.2	15.2	5.1	4140	2440	IA	1986	CL	GOF	Ice channel	FMA
23		Bulk carrier	130.3	17.3	6.9	6000	4500	IAS	1977				
24	10-Mar-03	Dry cargo	77.3	12.8	5.5	2400	1210	IA	1970	CL	GOR	Ice channel	FMA
25	06-Mar-03	Cargo ferry	71	16.3	4.2	880	2820	IA	1971	PR	GOF	IB assist.	FMA
26	05-Mar-03	Tug	26.4	8	3.6	245	550	IA	1966	PR	GOF	In ice	Other
27	05-Mar-03	Dry cargo	130.2	15.9	7.5	9070	3960	IA	1998	CL	GOR	In ice	FMA
28	04-Mar-03	Trawler	-	-	-	-	-	-	-	HD	BPR	In ice	Other
29	02-Mar-03	Cargo ferry	71	16.3	4.2	880	2820	IA	1971	PR	GOR	In ice	FMA

Table 1. List of ice related incidents in the Baltic Sea during winter 2002-2003

Ship Number	Date	Ship type	L [m]	B [m]	T [m]	DWT	P [kW]	Ice class	Year build	Damage type	Sea Area	Ice conditions	Source
30	02-Mar-03	Ferry	128.9	19.7	5	1500	8825	IA	1966	HR, HB, HD	BBO	In ice	HUT
31	28-Feb-03	Reefer	140	16.6	4	4500	1940	IC	1996	RU	GOF	In ice	Other
32	27-Feb-03	Bulk carrier	143.4	18.6	7.5	10935	4413	IA	1985	HD	GOF	In ice	FMA
33	27-Feb-03	Dry cargo	108.5	15.9	5.8	5257	2880	IA	1999	PR	BBO	In ice	FMA
34	27-Feb-03	Bulk carrier	89.7	13.6	5.7	4025	2010	IA	1994	CL	GOF	Ice channel	Other
35		Tanker	178.8	25.3	11	28640	-	IC	1986				
36	27-Feb-03	Ferry	23.3	6.8	3.6	300	750	-	1992	PR	GOF	In ice	Other
37	26-Feb-03	Cargo ferry	162.6	20.6	6.7	8708	12600	IAS	2001	RU	BBO	In ice	FMA
38	24-Feb-03	Bulk carrier	89.7	13.6	5.7	4025	2010	IA	1994	CL	GOF	Ice channel	Other
39		Tanker	178.8	25.3	11	28640	-	IC	1986				
40	22-Feb-03	Dry cargo	81.6	13.4	5	2500	1950	II	1975	PR	GOR	In ice	FMA
41	20-Feb-03	Dry cargo	86.5	13	5.6	2600	1470	IC	1977	PR	GOF	In ice	FMA
42	18-Feb-03	Dry cargo	104.9	16	6.3	4150	2940	IA	1989	CL	GOF	Ice channel	FMA
43	18-Feb-03	Cargo ferry	122.3	19.8	6.2	5760	7500	IA	1998	PR	GOR	In ice	Other
44	15-Feb-03	Tanker	160.9	23.1	10.1	22700	7930	IA	1984	HD	GOF	In ice	HUT
45	14-Feb-03	Dry cargo	77.3	12.8	5.5	2400	1210	IA	1970	CL	GOR	IB assist.	FMA
46	14-Feb-03	Dry cargo	132.2	15.9	7.1	8300	3960	IA	2000	EN	BBO	In ice	FMA
47	14-Feb-03	Bulk carrier	90.4	13.6	5.7	4200	2400	IA	1999	RU	BBO	In ice	FMA
48	10-Feb-03	Dry cargo	100	14.6	6.4	5500	2600	IA	1997	CL	BBO	IB assist.	FMA
49		Icebreaker	104.7	23.85	8.3	9660	16200	-	1975				
50	06-Feb-03	Dry cargo	103.5	16.2	6.1	4450	2990	IA	1991	CL	GOF	Ice channel	FMA
51		Cargo ferry	122.3	19.8	6.2	5760	7500	IA	1998				
52	05-Feb-03	Trawler	33.5	7.5	3.5	350	750	IC	1968	HD	BSE	In ice	FMA
53	04-Feb-03	Bulk carrier	98.9	13.8	5.75	4550	2880	IA	1999	CL	BBO	Ib assist.	FMA
54		Icebreaker	99	24.2	8	9130	21850	-	1986				
55	02-Feb-03	Bulk carrier	95.8	16.5	5.4	3925	2800	IAS	1986	PR, HD	BBO	In ice	HUT
56	01-Feb-03	Bulk carrier	179.4	25.7	11.1	31850	9450	IA	1980	CL	GOF	Ice channel	FMA
57		Dry cargo	109.7	17.8	7.2	6920	3360	IA	1996				
58	30-Jan-03	Reefer	75.4	13.2	5.1	2225	1370	IB	1980	PR	GOF	In ice	Other

Table 1. List of ice related incidents in the Baltic Sea during winter 2002-2003

Ship Number	Date	Ship type	L [m]	B [m]	T [m]	DWT	P [kW]	Ice class	Year build	Damage type	Sea Area	Ice conditions	Source
59	30-Jan-03	Tanker	100.8	12.5	6.5	4300	3180	IA	1998	CL	BBO	IB assist.	FMA
60		Icebreaker	99	24.2	8	9130	21850	-	1986				
61	28-Jan-03	Dry cargo	81	11.8	4.4	1855	1280	IC	1978	PR	GOF	In ice	Other
62	26-Jan-03	Cargo ferry	145.6	23.3	8.8	13100	10550	IA	1996	PR	GOF	In ice	FMA
63	26-Jan-03	Reefer	149	21.5	7	8900	5880	IB	1984	HD	GOF	IB assist.	Other
64	25-Jan-03	Cargo ferry	74.2	16.6	3.8	726	2650	IA	1972	PR	GOR	In ice	FMA
65	23-Jan-03	Tug	29.1	9	3.6	300	2650	IA	1989	PR	GOF	In ice	FMA
66	21-Jan-03	Tug	28.8	8.3	3.8	240	1240	IA	1968	HD	GOF	Compress.	HUT
67	18-Jan-03	Dry cargo	140	16.8	6.7	5845	1430	IC	1987	HD	GOF	IB assist.	Other
68	18-Jan-03	Dry cargo	114	13.2	5.5	2480	-	II	1969	HR	GOF	Compress.	FMA
69	18-Jan-03	Dry cargo	108.4	15	5	2500	1030	II	1986	RU	GOF	In ice	FMA
70	18-Jan-03	Dry cargo	100	16.5	5.3	4700	2800	IA	2001	CL	GOF	Ice channel	FMA
71	17-Jan-03	Dry cargo	89.6	13.2	5.7	2800	1200	IB	1989	HR	GOF	In ice	Other
72	15-Jan-03	Dry cargo	119	13.4	3.8	3000	1280	IC	1989	PR	GOF	In ice	Other
73	15-Jan-03	Bulk carrier	95.8	16.5	5.4	3925	2800	IAS	1986	HD	GOF	In ice	FMA
74	15-Jan-03	Tug	28.5	8.1	4.6	150	1000	IA	1964	PR	GOF	In ice	Other
75	13-Jan-03	Dry cargo	81	11.8	4.4	1855	1280	IC	1978	HR	GOF	In ice	FMA
76	11-Jan-03	Tanker	242.4	40	14	51160	11000	IC	1993	HD	GOF	Compress.	Other
77	11-Jan-03	Dry cargo	99.8	14.7	7	4200	-	IA	1984	PR	GOF	In ice	Other
78	08-Jan-03	Tanker	99.6	17.1	6.5	6200	3230	IA	1989	HD, GR	GOF	Compress.	Other
79	05-Jan-03	Dry cargo	71.4	11.3	3.9	1840	590	II	1984	CQ	GOR	In ice	FMA
80	03-Jan-03	Ferry	23.2	5.4	1.9	-	310	-	1909	EN	BPR	In ice	FMA
81	02-Jan-03	Trawler	-	-	-	-	-	-	-	HD	GOF	In ice	Other
82	15-Dec-02	Cargo ferry	107.5	17	6.1	4450	2960	IA	1989	RU	BSE	In ice	Other
83	12-Dec-02	Dry cargo	81	12	4.4	1855	1280	II	1982	HR	SAI	In ice	FMA
84	03-Dec-02	Dry cargo	134.6	21.5	7	9450	7200	II	2003	PR	BBO	In ice	FMA
85	-	Dry cargo	82.5	12.5	5.3	3000	2040	IA	2000	PR	-	In ice	Other
86	-	Cargo ferry	175	28.7	7.4	11600	23000	IAS	1994	PR	-	In ice	Other

Table 1. List of ice related incidents in the Baltic Sea during winter 2002-2003

Ship Number	Date	Ship type	L [m]	B [m]	T [m]	DWT	P [kW]	Ice class	Year build	Damage type	Sea Area	Ice conditions	Source
87	-	Bulk carrier	137.2	21.6	8.2	13370	6250	IAS	1995	HU, HB	GOF	In ice	Other
88	-	Dry cargo	80	13.8	5.4	2900	1460	IB	1972	PR	GOF	In ice	Other
89	-	Tanker	164.5	22.2	9.5	16420	11000	IAS	1976	HC	ART	In ice	HUT
90	-	Tanker	164.5	22.2	9.5	16420	11000	IAS	1976	HC	ART	In ice	HUT
91	-	Tanker	161	23	8.6	17080	6600	IA	1994	RU	-	In ice	FMA
92	-	Dry cargo	117.3	18.2	7.1	6870	5760	IA	1998	PR	-	In ice	FMA
93	-	Tanker	232	42	20.3	96350	-	IA	1994	HD	-	In ice	FMA
94	-	Tanker	182.6	27.3	11.2	37000	9460	IB	2001	PR	-	In ice	FMA
95	-	Dry cargo	118.3	18	7.4	7210	3680	IA	1972	HD	GOF	In ice	FMA
96	-	Dry cargo	135.1	20.7	8.7	10500	4840	IA	1984	EN	-	In ice	FMA
97	-	Dry cargo	93.1	-	-	5340	3825	II	1993	PR	-	In ice	FMA
98	-	Bulk carrier	143.3	18.5	7.6	10890	4410	IA	1976	HC	BBO	In ice	HUT
99	-	Ferry	201.8	32.6	6.8	4650	31800	IAS	1993	HD, HB	ARP	In ice	HUT
100	-	Ferry	158.9	25.2	5.6	1700	19100	IA	1992	PR, HB	GOF	In ice	HUT
101	-	Bulk carrier	159.1	27.2	6.7	14000	-	IAS	1986	CL	BBO	IB assist.	HUT
102	-	Icebreaker	99	24.2	8	9130	21850	-	1986				
103	-	Dry cargo	82.3	12.6	4.9	2600	1200	IB	1987	CL	-	Ice channel	FMA
104	-	Tanker	101.4	15.9	6.25	4650	2940	IA	1980				
105	-	Cargo ferry	169.4	27.6	6.3	34390	15760	IAS	1989	CL	GOF	In ice	FMA
106	-	Dry cargo	82.3	12.6	4.9	2600	1200	IB	1987	CL	GOF	IB assist.	FMA
107	-	Icebreaker	83.5	19.4	6.75	5209	10200	-	1979				
108	-	Tug	30.5	9	4.6	300	1470	IAS	1968	PR	ARP	In ice	Other
109	-	Icebreaker	-	-	-	-	-	-	-	CL	BBO	IB assist.	SMA
110	-	Icebreaker	-	-	-	-	-	-	-	CL	BBO	IB assist.	SMA
111	-	Icebreaker	-	-	-	-	-	-	-	CL	BBO	IB assist.	SMA

Table 2. The explanations for abbreviations in Table 1.

Damage Type	Sea area	Source
PR=Propeller damage	GOF = Gulf of Finland	FMA= Finnish Maritime Administration
RU=Rudder damage	BBO = Bay of Bothnia	
GR=Grounding event	BSE = Bothnian Sea	HUT= Helsinki University of Technology
CL=Collision	GOR = Gulf of Riga	
EN=Engine damage	ARP = Archipelago	SMA = Swedish Maritime Administration
HD=Hull damage	BPR = Baltic Proper	
HC=Hull cumulative	SAI = Saimaa	Other=ship owners/ship insurance/news etc.
HB=Bilge damage	ART = Arctic waters	
HR=Hull rupture		

4.3. Detail description of some of the damages found

4.3.1 Ship number 98 (10900 DWT Bulk carrier, ice class IA)

The ship was docked on Tallin's shiprepair yard on June 2003 for one week. The main reason for docking was replacement of the damaged side plates (Fig. 6). All the dents were cumulated during 22 years of ships operation. Replacement of plates was now made for the first time. Most of the dents were in the midship area on the sides, between frames 60 to 100. Dents were smaller towards the bow. The most damaged plates had already been removed, but the dents on the rest of the plates were about 50 mm deep. According to the ships master, the damages had occurred when turning in ice, and most of the damages had already happened during the first four years of operation. The dents evolved only slightly during the following years. Because of the turbulent flow behind the dents, some of the plates had eroded to thickness of only 5 mm (originally 13-15 mm). Together 19 tonnes of new 14,5 mm thick steelplate was replaced on the ship sides. In addition, there was a dent on ship bow, which had happened when the towing fork of an icebreaker collided into it. There were also few small dents on the bottom of the ship, most of them 30-50 mm deep. The bolt covers on propeller had fallen away every winter and they were not replaced for five years. There was no damage on the bolts and the propeller. There were no damages in the rudder, because the ship does not reverse in ice.

The ship had been operating the whole winter 2003 between the ports of Luleå and Raahe. Operation was mainly in ice channel, except one three week period when there was a lead in the ice field and the operation could be done in open water. Last winter was no exception compared to other winters in their operation area. There was one hard compressive ice situation, when the crew started to prepare to abandon the ship, but the compression eased off before the icebreaker came to help. There was no damage to the ship because of this incident. The ship has an ice class IA and it has transverse framing. The ship is docked every second year.



Figure 6. Renewed plating in the mid ship area of a bulk carrier.

4.3.2 Ship number 66 (Tugboat, ice class IA)

This ship was damaged in the Gulf of Finland 21st of January 2003 due to moving and compressive ice field (Fig. 7). The tug was traveling in an ice lead near Kaunissaari. The ship got stuck and started to drift sideways along the ice masses with speed of 2-3 knots. Ice pieces piled up against ship's side shell. Pile-up and drifting lasted about 20 minutes and after that ice pieces started slide below the ship bottom. When the compression eased off the ship drove to the fast ice field and waited for icebreaker assistance. Icebreaker towed the ship to the nearest harbour. The whole episode lasted about two hours until the icebreaker came.



Figure 7. Ice chart of 20th of January 2003 and the position of the incident.

The consequence was that 8 frames in SB side (frames #15-19 and #21-24) and 4 frames in PB side had a permanent deflection of 10-30 mm 20 cm below the water line depth. In

addition the frame supporting brackets buckled and some pipelines were broken. Plating between the frames had only minor permanent deformation (about 10 mm). The ship has transverse framing system. The frame spacing in the ice belt is 270 mm and the frame span is 2.4 m. The frame dimensions are L-100x65x10. In Figure 8 three damaged frames are shown. Later the same winter the ship had a propeller damage, damages for shell plating in the bow thruster tunnel, slightly indented shell side plates (SB) between frames # 13-25 and bilge keels damage (replaced about 40 m). These damages were observed on 18th of March 2003.

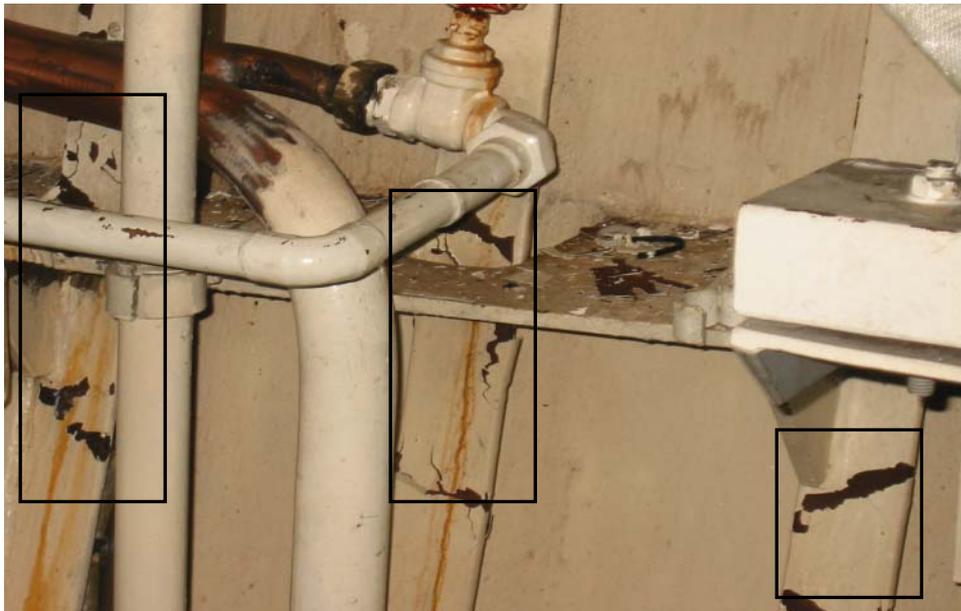


Figure 8. Damaged frames in the mid ship area of ship number 66.

4.3.3 Ship number 76 (95 000 DWT Oil tanker, ice class IC)

The ship was on her way from St. Petersburg (Russia) to Fredericia (Denmark) when she got stuck in compressive ice near Suursaari (27°30'E, 60°00'N) on 11th of January 2003. The ship was carrying cargo. During the compression the ice blocks piled up against SB side of the ship. The plating in the mid ship area (SB, flat side) got permanent deflection in the area of two frame spacing for a length of about 100 m (frames #65-125 and #135-195). The maximum indents were about 30 mm. In Figure 9 part of the damaged area of the tanker is presented. The draught was 14 m and the damaged area was about 1.5 m below waterline. According to the ship's master the vertical extension of the ice belt is too narrow. The ship had an ice damage (dents) below the ice belt during winter 1994. The reason was contact with the edge of an ice channel in ballast condition.

The ship is built according to the Finnish-Swedish ice class IC. It has longitudinal framing system in the mid ship. The frame spacing in the ice belt is 800 mm, the thickness of the plating is 18 mm, the frame type is P-280x11 and the frame span is 3.2 m. The difference of the ship and the icebreaker beam is over 10 m. This means that the ship has to break ice during icebreaker assistance.



Figure 9. The permanent deflection of the side plating of the 95000 DWT tanker. The picture is taken from ship side in the mid ship area. The vertical extent of damage was two frame spacing (1.6 m) and the maximum indent shown in the picture was about 30 mm deep.

4.3.4 Ship number 55 (3900 DWT Bulk carrier, ice class IA Super)

This bulk carrier operates between ports in the Bothnian Bay (Oulu, Pietarsaari, Vaasa and Kantvik) and Archipelago all year round. The ship had a propeller damage due to heavy ice in the Quark on 2nd of February 2003. The control system of the CP-propeller was broken and the ship was towed to the Turku Repair Yard.

During the docking several damages were found and the repair took for one month. The shape of the thruster tunnel in the bow was renewed. During the past years ice blocks had caused several small cracks in the entrance of the tunnel. In the bow area below the ice belt the plating had several dents on both sides. The maximum deflection of the plating between frames was about 50 mm. This plating was replaced and new frames were added between old ones so that the frame spacing in that area decreased from 1.3 m to 0.65 m. During the docking 7 new frames were added to the both sides. In the aft area plating was replaced on an area of about 4x4 m². There were several dents in the mid ship area below the ice strengthened region and in the bilge areas (Fig. 10). The maximum indents in the mid ship were 30 mm. The ship has a mixture of transverse and longitudinal framing system. In the bow area the plate thickness is 18 mm in the ice belt and 9.5 mm below the ice belt. The damaged areas were below the ice-strengthened region.



Figure 10. The permanent deflection on the plating below the ice strengthened region of ship number 55.

4.3.5 Ship number 30 (10 500 BRT Passenger-car ferry, ice class IA)

This ship was ice damaged on 2nd of March 2003 on a voyage between Vaasa and Umeå. Ice conditions in the Quark were difficult due to southern winds. The ship operated one third of the voyage in the ice channel and the rest of the voyage in ridged and rafted ice field. Icebreaker assistance was essential during that time. The voyage between Vaasa and Umeå takes normally 6 hours but in heavy ice it takes twice that time. The plating of the ship was ruptured in ice and the ship was docked in the Turku Repair Yard.

One crack was located in the mid ship (beside frame #88, SB side) below the ice belt in a ballast tank. The crack was in the junction between a frame and plating and it was 25 cm long in vertical direction. The plate deflection was 30-50 mm around the crack. Due to corrosion the thickness of the plating was decreased from 12 mm to 6 mm. Frames #83-94 were type L-150x90x10, the frame spacing was 750 mm (in ice belt 375 mm) and the frame span in the damaged location was 1150 mm.

Bilge keel was damaged on the PB-side and it was replaced for a length of 7 m. There were permanent deformations of the bow plating above the ice belt (Fig. 11). Those are caused by navigation with high speed in an ice channel. Smaller dents of the plating were observed on several locations on the ice belt and below the ice belt. The painting was worn off due to ice abrasion.

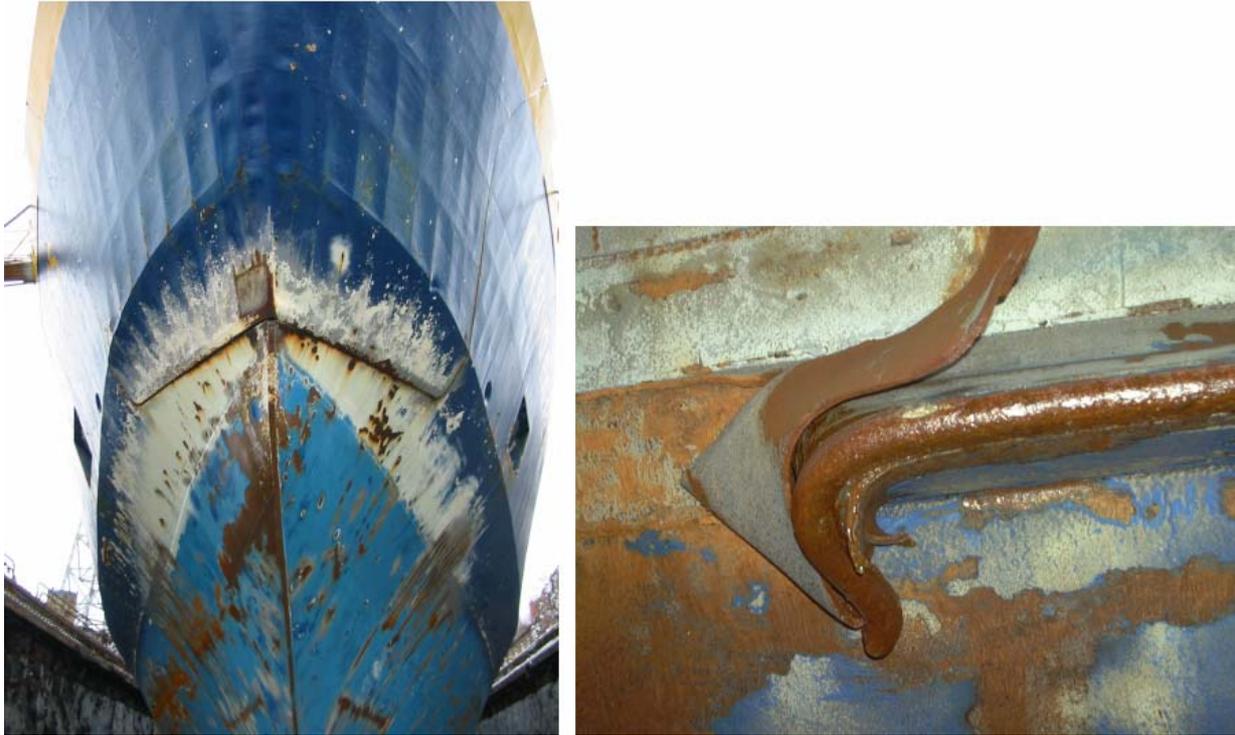


Figure 11. Permanent deflections above the ice belt (left picture) and damaged bilge keel (right picture) of the passenger ferry. Bilge keel was peeled off the shell plating for a length of 7 m.

4.3.6 Ship number 44 (22700 DWT Chemical tanker, ice class IA)

This ship operated in the Gulf of Finland between the ports of St. Petersburg, Porvoo and Hanko during January and February 2003. The ship encountered ice for 40-60 days during winter 2003. The ship was docked in the Turku Repair Yard in June 2003. Previous dry-docking was done during summer 2000.

In the forepeak at the water line level a couple of frames and brackets were buckled. In the bow area there were cracks and buckling in the junction between frames and stringers. These damages were just above and below the ice belt (Fig. 12). Below the ice belt and on the bilge there were 20-30 mm deep dents. The dents were located between frames #130-176 i.e. length of 40 m. Below the waterline 60 % of the painting was worn off. This is partly due to ice abrasion.

The thickness of the plating in the ice belt is 27 mm in the bow and 17.5 mm in the mid ship. Below the ice belt the plate thickness decreases to 14 mm. In the bow area the ship has transverse framing (frames #167-180) but otherwise longitudinal framing. The frame spacing in the bow area is 600 mm (300 mm in the ice belt) and otherwise 800 mm (400 mm in the ice belt). The frames in the bow area are of type P-280x11.



Figure 12. The damages below the ice belt and damages of inner structures of the ship number 44.

4.3.7 Ship number 100 (25 600 BRT Cruise ship, ice class IA)

The ship was docked in May 2003 due to propeller damage. The ship operated during winter 2003 regularly between ports in Helsinki and Tallinn. The blades of both propellers were damaged in ice in the port of Tallinn. The reason is not known. The painting was worn off on many locations and the bilge keels were damaged on both sides (Fig. 13). The bilge keel on SB-side was ruptured for the length of 7 m and on PB-side for the length of 4.5 m. The probable reason was collision with the edge of an ice channel. There were permanent deflections of the plating in the bow area. The dents were located on the ice belt and on the bilges. The dents were 40 mm deep at maximum. The ship has transverse framing and the frame spacing is 800 mm (in the ice belt 400 mm).



Figure 13. A bilge keel rupture and a propeller damage of ship number 100.

4.3.8 Ship numbers 89&90 (16420 DWT Product tankers, ice class IA Super)

These ships are sister ships and the damages found were quite identical. Both ships have stronger hull than what Baltic ice class IA Super demands. Ships operated during winter 2003 between the Gulf of Finland and the Bothnian Bay. During the past years they had also operated in the arctic waters. Ships had indents on several locations (Fig. 14), but those are probably due to operating in multi-year ice in arctic waters. They had up to 50 mm deep dents in the forepeak. Smaller dents were found in the bow and in the mid ship in the ice belt. Below the ice belt there were up to 30 mm deep dents in the bow, mid and aft areas. The damaged areas were of a length four frames spacing and height of three stringers spacing at maximum. The ships have transverse framing in bow and aft areas. The frame spacing on the bow ice belt is 350 mm, the frame span is 2500 mm and the frame type is HP320x13. The thickness of the plating is 24 mm.



Figure 14. Dents in the bow area of a chemical tanker due to collision with multi-year ice.

4.2.9 Ship number 99 (59 900 BRT Passenger-car ferry, ice class IA Super)

The ship had seasonal docking in May 2003. The ship operated regularly between ports in Turku and Stockholm during winter 2003. On the ship's route there was ice present between the end of December 2002 and early of March 2003. Ice conditions were mainly level ice, floe ice and brash ice in channels. There were no ice ridges on this route. According to the ship's master the winter 2003 was more severe than usually and this is best demonstrated by an increased fuel consumption.

Five types of minor ice related damages were found. The bilge keels were ruptured from both sides for a length of 4 m (Fig. 15). The bilge keels were welded to flat bars and the flat bars

were welded to the ship side shell. Also these flat bars peeled off the ship hull. These damages occurred possibly in the ice channel near the port of Turku. Two seawater well gratings in the bottom of the ship fall off due to ice pieces. The gratings were bolted on with 8 bolts. The aft thruster was broken due to ice pieces in the port of Turku or in the port of Mariehamn. The painting was worn off from the bottom of the ship. On the bow area there were 10-20 mm deep dents on the plating. The dents were located in the ice-strengthened region and below the ice belt. This ship has transverse framing.

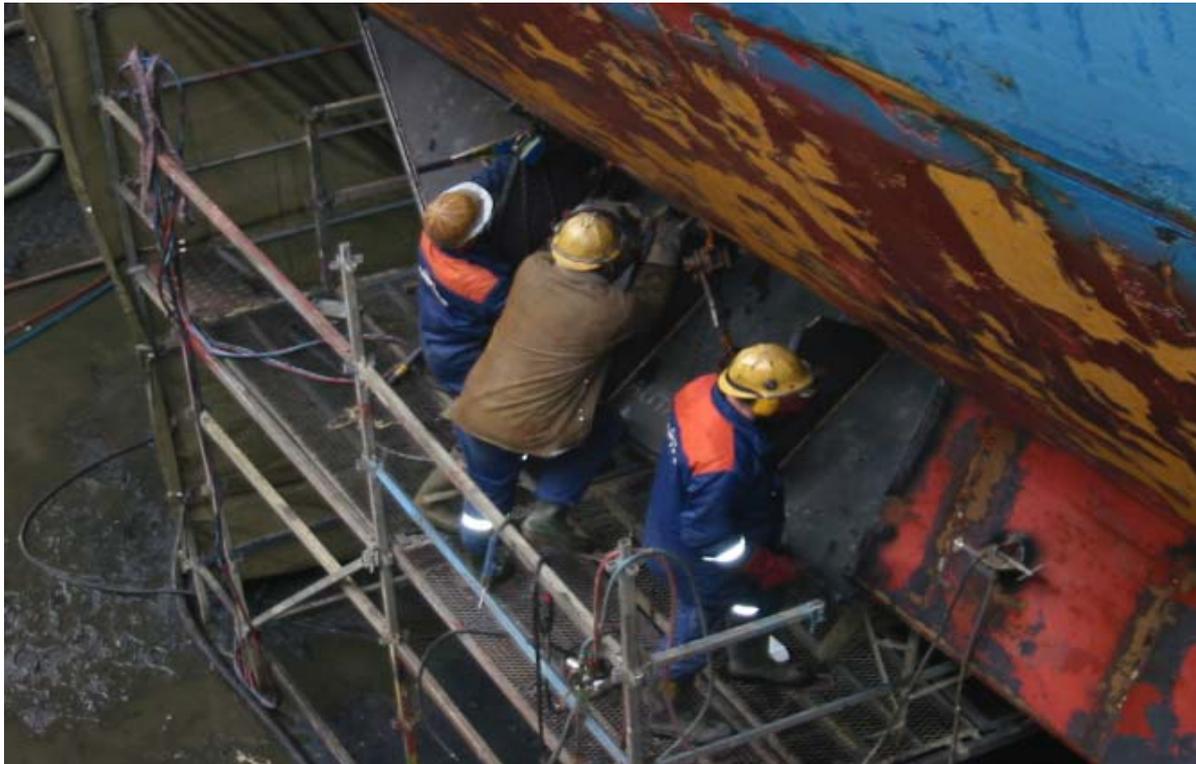


Figure 15. Replacement of the damaged bilge keels for ship number 99.

4.3.10 Ship number 101 (Push barge, 14 000 DWT, ice class IA Super)

This ship was dry-docked in May 2003. With a powerful pusher the pusher-barge combination has an ice class IA Super. The ship operates between the Bothnian Bay (Raahe) and the southern ports in the Baltic Sea. The ship has transverse framing in the bow and longitudinal framing in the mid ship area.

The ship had three types of ice related damages. The bow was damaged during icebreaker assistance near Raahe. The ship and icebreaker collided during assistance. The damaged area was above the water line. The frames and the plating were replaced for an area of 5 m². The permanent indents were 200 mm deep, but no cracks were observed. The bow thruster was damaged in the port of Raahe due to ice rubble. Two thruster blades were damaged and they were replaced. In the aft shoulder area (SB-side) on the water line the plating had permanent

deflections of 30 mm deep (Fig. 16). The damaged area was within 3 frames and 3 stringer spacings.



Figure 16. Permanent deflections of ship number 101.

4.3.11 Other types of ice related damages

Other types of ice related damages are collisions between merchant vessels, damages during icebreaker assistance, groundings due to heavy ice, engine damages and ice damages due to improper ice strengthening.

Bow damages of a ship after collision with icebreaker towing fork in the Bothnian Bay is shown in Figure 17. Icebreaker got stuck in heavy ice and the assisted ship could not avoid collision. The damaged area was located on the forepeak 2 m above the water line. The hole was 2 m wide and 5 m deep. Also icebreaker's towing fork was damaged.

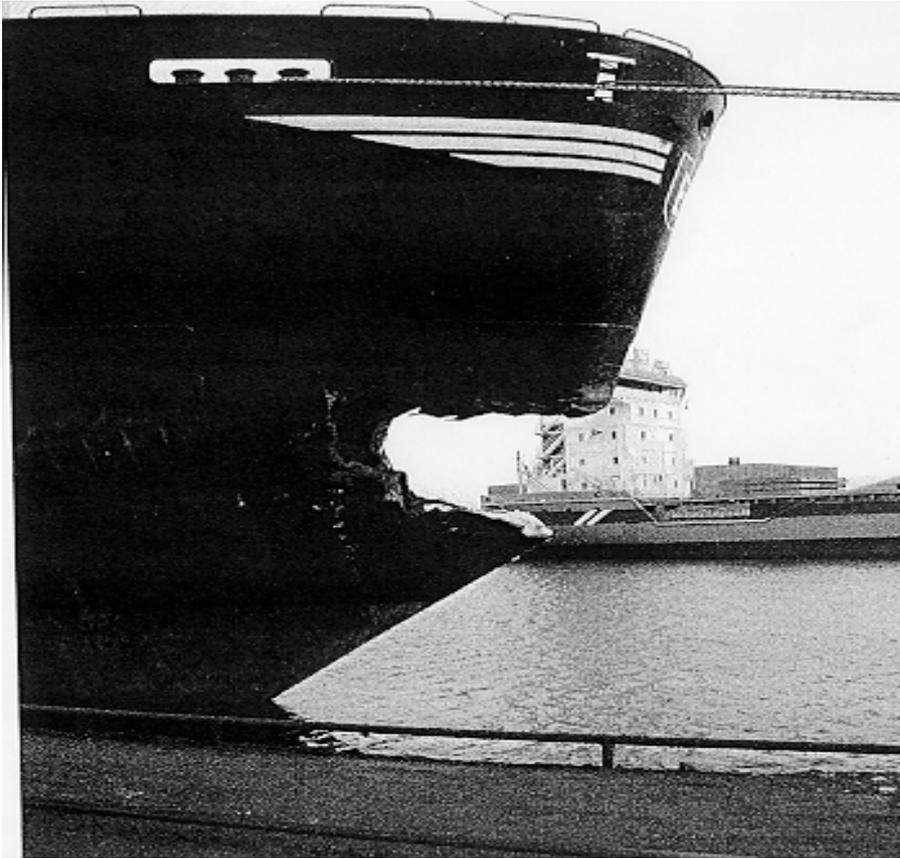


Figure 17. Damaged bow due to collision with an icebreaker.

The bulk carrier (ship number 12) in Figure 18 belongs to ice class II. The ship was damaged during icebreaker assistance between 19th and 25th of March 2003. The ship followed an icebreaker with full propulsion power in ridged and rafted ice in the Gulf of Finland. The ship crew was evacuated due to water leakage into the ship hold and after that the ship was docked for repair. Frames # 247-181 on both sides were buckled (from fore peak to bow shoulder). The plating on the PB-side had two fractures and several dents of max depth 150 mm at the water line depth. The plating on the SB-side had several deep dents but no fractures. Around the fractures the permanent deformation of the plating was about 200 mm deep. The fractures were of length of 2 m in horizontal direction. Two frames were broken off due to fractures. The frames, the plating and the stringers on the damaged area were renewed. The ship has transverse framing system. The thickness of the plating in damaged area was between 13 mm and 15 mm. The frame spacing is 850 mm.



Figure 18. Damaged areas of a bulk carrier (ship number 12).

An example of a damaged rudder machinery is shown in Figure 19. As can be seen the joint rod has buckled. The damage occurred in early March 2003. The ship had to back in ice and the rudder was overloaded due to ice. On the rudders there were minor dents due to ice loading.



Figure 19. Damaged rudder machinery.

The passenger-car ferry (37 700 BRT) in Figure 20 operated between Helsinki and Tallinn during winter 2003. The ship has ice class IA Super. The painting eroded off due to ice abrasion on the bow ship (water line height) and from the mid ship towards bow in the bilge and the bottom areas (PB side) for a length of 40 m. Abrasion and corrosion from inside or outside of the ship side shell may decrease the plate thickness for several millimeters. So it can reduce the strength of the structure substantially. In the bow ice belt there were minor dents (about 10 mm deep) on the plating. Overall this ship was in good condition.



Figure 20. Wear of the painting due to ice abrasion of a passenger-car ferry. The surface damage was located in the bilge and bottom areas of the ship hull.

5. ANALYSIS OF THE ICE RELATED DAMAGES

5.1 General statistics

A summary of the ship types, ice classes, deadweight tonnages and year of construction of the damaged ships is presented in Figure 21. Most of the damaged ships were dry cargo carriers and cargo or passenger ferries. Most of the ships were relatively small (on the average 8 400 dwt) and most of the ships belong to the ice class IA. The number of smaller and lower ice class ships is small due to winter navigation restrictions. However, one third of the damaged ships belong to ice classes II, IC and IB. The same figure for all the ships that visited Finnish ports during the winter season is 15 % (Fig. 5). These damages may have occurred before the navigation restrictions were given, the ships may have had exceptional permit or the ship was on her way to some other port than a Finnish port. The first navigation restriction was given in November 2002 to the northern ports and by mid-February 2003 the restrictions were at strictest. Examples of traffic restrictions to four Finnish ports during winter 2002-2003 are shown in Figure 22. The number of small vessels, deadweight tonnage below 2 000 dwt, is 20 %. Most of these small ships are tugs and fishing vessels. The number of bulk carriers is emphasised in the ice-incident statistics. About 12 % of the incidents occurred for bulk carriers, but the number of these ships of the total traffic was only 4 %. The average age of a damaged ship is 18 years. The percentage of ships less than 3 years old is 12 %. This data can be compared to Figure 5 in which all the ships that visited the Finnish ports during the winter 2003 are presented.

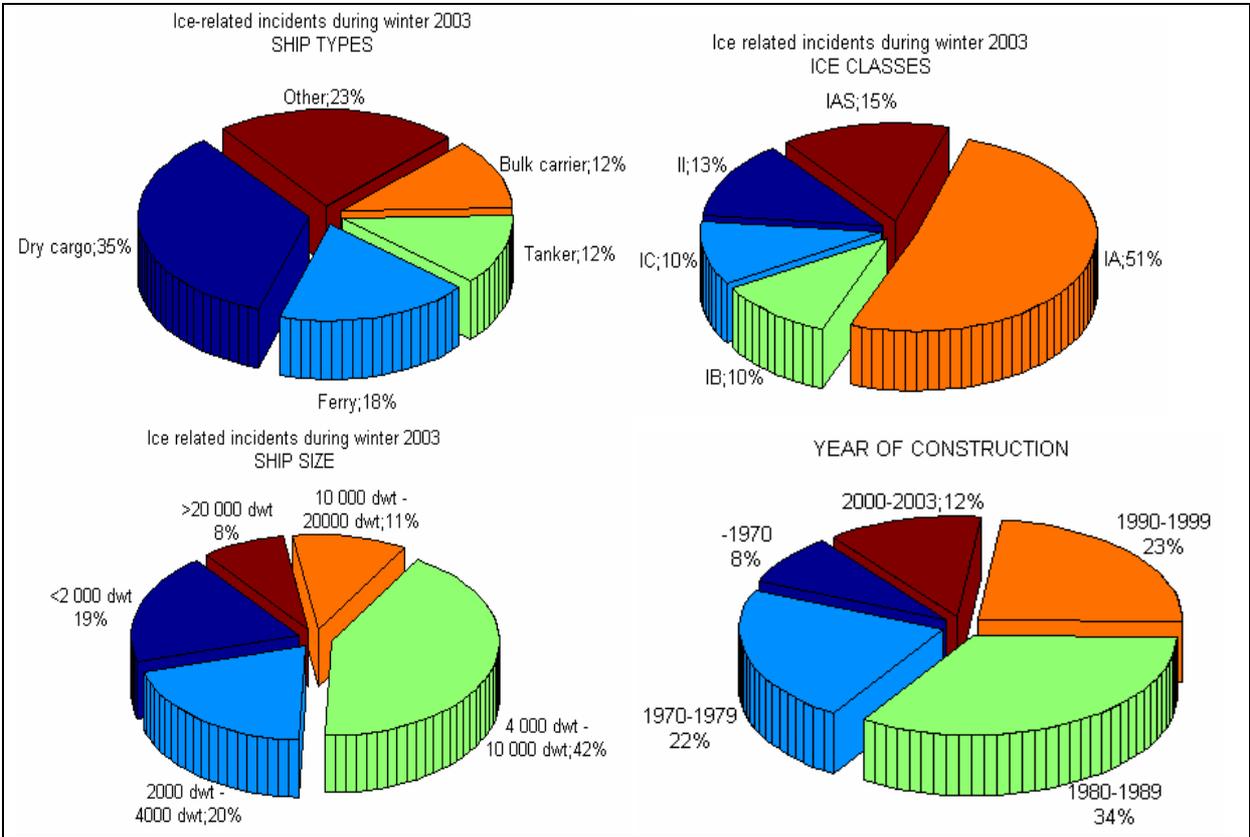


Figure 21. A summary of the ships included in the study.

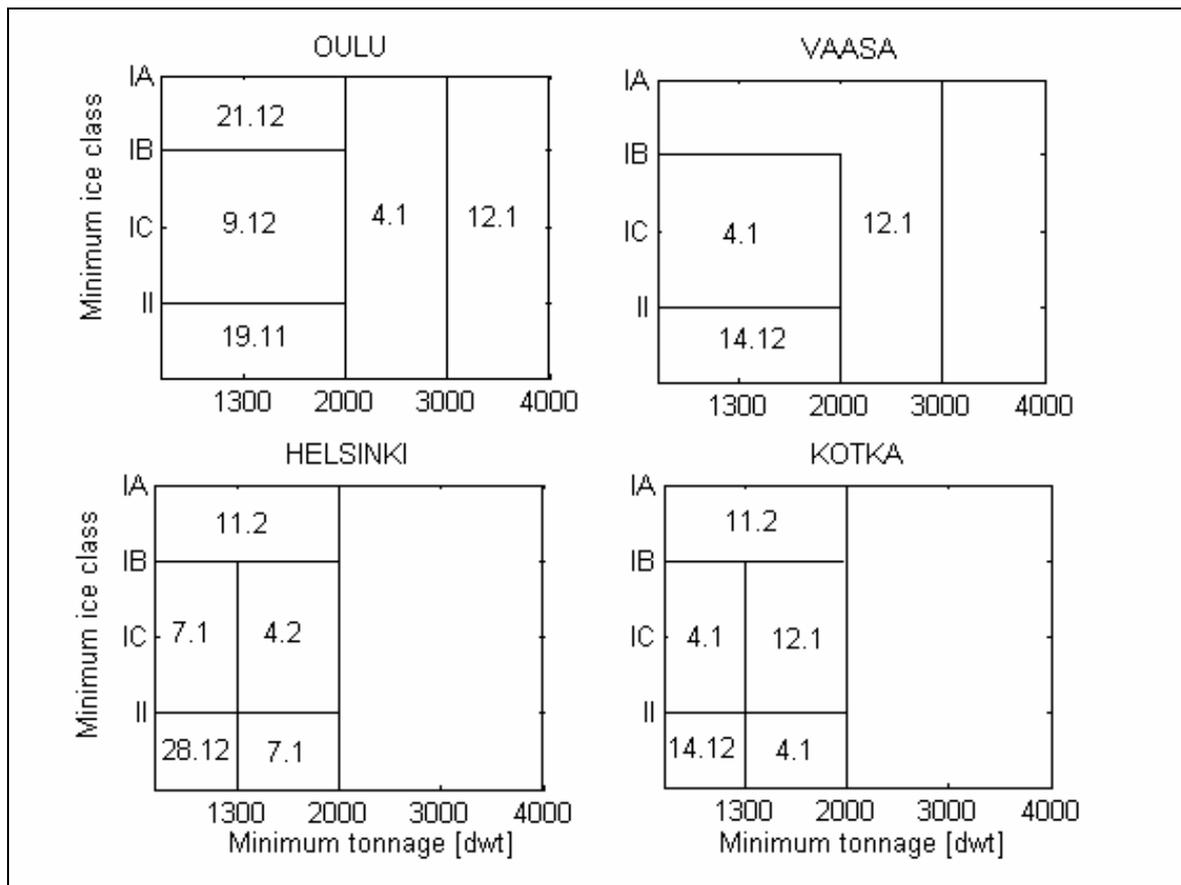


Figure 22. Traffic restrictions to the Finnish ports in winter 2002-2003.

A summary of the damages that occurred during winter 2003 is presented in Figure 23. The main part of the damages occurred in the Gulf of Finland, which is the most operated sea area. Three main types of damages are propeller damages, hull damages and damages due to collision with other ships (merchant vessel or icebreaker) in heavy ice. The conditions during the incident are arranged in four groups. “In ice” means that damage occurred generally in ice. In that case the conditions are not well known. “In ice channel” means that ship was moving independently in an ice channel or in an ice lead. Ships may have damaged also during icebreaker assistance. Compressive ice may have caused direct hull ice damage or the ship may have drifted to ground with the moving ice field. Most of the damages occurred between mid January and end of March 2003. During that period the ice conditions were the most severe.

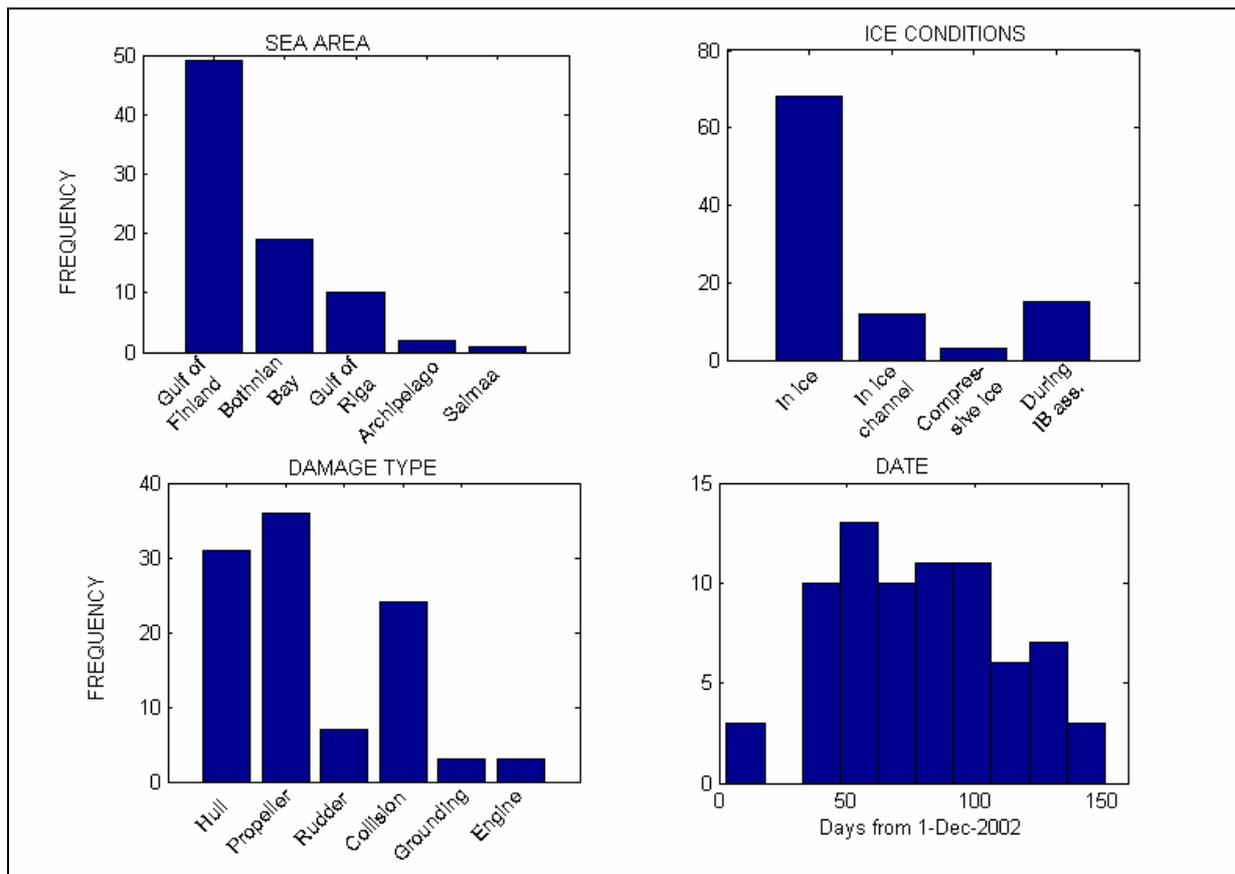


Figure 23. A summary of the ice damages included in the study.

The ice classes of damaged ships and the damages are arranged for different sea areas in Figure 24. Most of the damages occurred in the Gulf of Finland. In the Gulf of Finland all ice classes were well represented. Two most typical ice damages in the Gulf of Finland were damages to steering devices and hull damages. In the Bothnian Bay there was only one incident concerning a ship that has the ice class II. This propeller damage occurred during early winter before the navigation restrictions. Otherwise the damaged ships in the Bothnian Bay had ice class IA or IA Super. In the Bothnian Bay the two most typical damages were rudder/propeller damages and ship collisions in an ice channel due to heavy ice conditions.

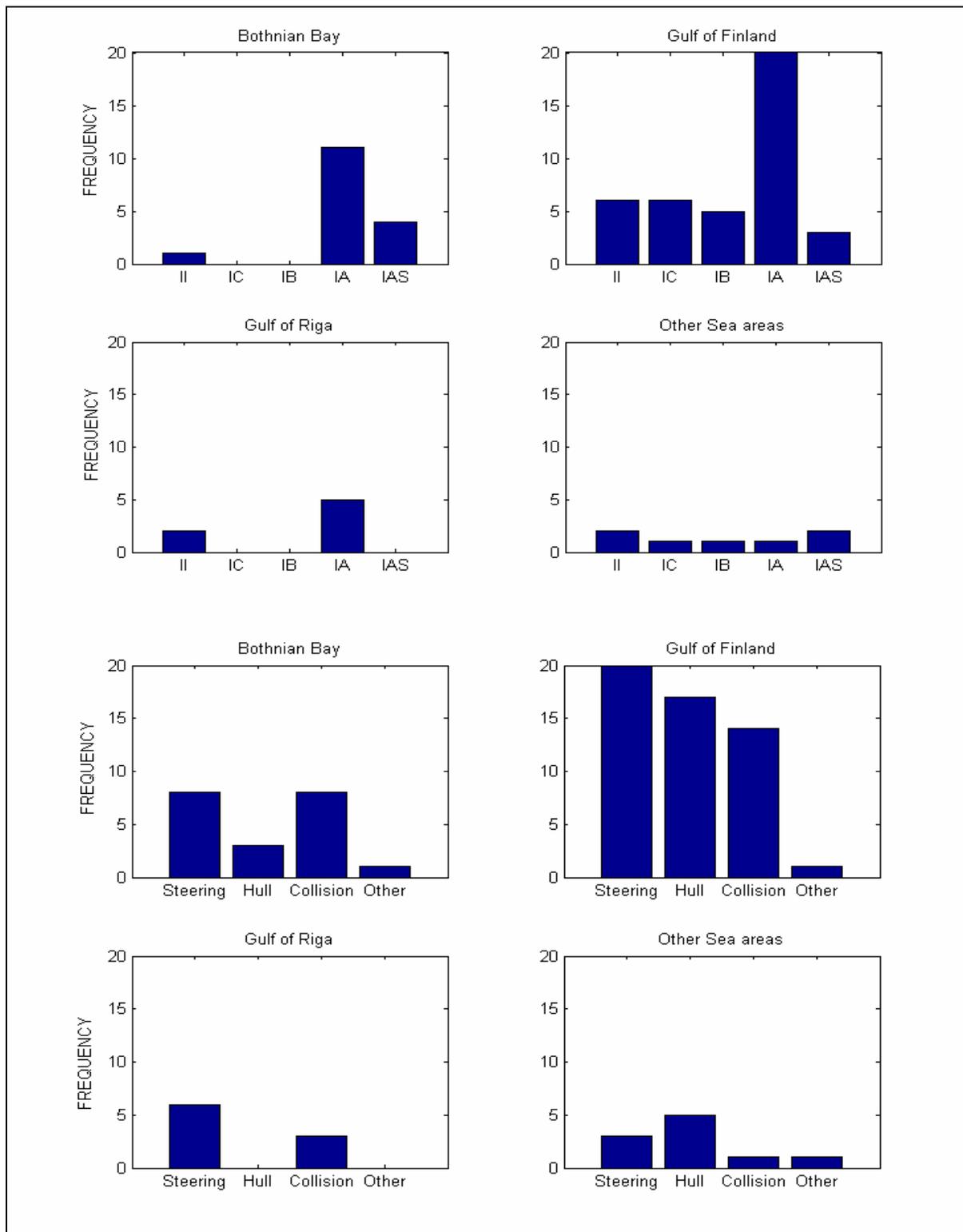


Figure 24. Ice classes of the damaged ships and damages that occurred in different sea areas.

5.2 The hull ice damages

The phrase hull ice damage is used in this report for all damages caused by ship-ice contact. The damages are permanent deflections on the hull structures. These damages can be small indents of the shell plating between frames, or in the worse cases, deformation of large areas

with collapse of frames and fractures of the shell plating. The total number of different types of hull damages included in this study is 27. Only damages that occurred in the Baltic Sea are included. A summary of these damages is presented in Table 3.

Table 3. A summary of the hull damages. TRA means transverse framing system and LON means longitudinal framing system.

Ship n:o	Framing	Horizontal location of the damage	Vertical location of the damage	Damage	Number of damaged frames /spacings	max. Dents [mm]	Horizontal extent [m]	Vertical extent [m]	Fractures	Fracture length [m]	Nearest harbour or ship's route
1	TRA	MID	below	bilge	-	-	-	-	-	-	Turku-Stockholm
9	TRA	MID	below	bilge	-	-	-	-	-	-	Turku
12	TRA	BOW	in ice belt	plating/frame	134	200	50	10	Yes	2	St. Petersburg
19	TRA	AFT	below	plating	-	-	-	-	-	-	-
28	-	-	-	ship sides	-	-	-	-	-	-	58'21'5N, 021'26'E
30	TRA	BOW,MID	all areas	plating, bilge	-	30	-	-	Yes	0.25	Vaasa-Umeå
32	-	-	-	plating	-	-	-	-	-	-	-
44	TRA/LON	BOW	on and below	plating/frame	-	30	-	-	-	-	St.Petersburg, Hanko
52	-	BOW	on ice belt	plating/frame	-	100	-	-	-	-	Pori
55	TRA/LON	BOW,MID	below	plating	-	50	-	-	-	-	-
63	-	BOW	on ice belt	ship sides	-	-	-	-	-	-	St. Petersburg
66	TRA	MID	on and below	plating/frame, bilge	12	20	2.4	1	-	-	Helsinki-Porvoo
67	-	BOW	on ice belt	ship sides	-	-	-	-	-	-	St. Petersburg
68	-	MID	on ice belt	plating	2	-	-	-	Yes	-	Loviisa
71	-	AFT	below	plating	1	-	-	-	Yes	0.15	Loviisa
75	TRA	BOW	below	plating	2	-	-	-	Yes	0.3	Loviisa
76	LON	MID	on ice belt	plating/frame	120	30	100	1.6	-	-	Suursaari
78	-	-	-	ship sides	-	-	-	-	-	-	Tallinn
81	-	-	-	ship sides	-	-	-	-	-	-	59'29'2N, 024'10'2E
83	TRA	BOW	below	plating	1	-	-	-	Yes	0.3	Saimaa
87	-	-	-	bilge	-	-	-	-	-	-	-
93	-	-	-	ship sides	-	-	-	-	-	-	-
95	-	-	-	ship sides	-	-	-	-	-	-	-
98	TRA	MID	on and below	plating	40	50	-	-	-	-	Luleå-Raahe
99	TRA	BOW	on and below	plating, bilge	-	20	-	-	-	-	Turku-Stockholm
100	TRA	BOW	on and below	plating, bilge	-	40	-	-	-	-	Helsinki-Tallinn
101	TRA/LON	MID	on ice belt	plating	3	30	4	1.4	-	-	Raahe

The most typical hull ice damage is that where the ship plating has a permanent deformation (Fig. 25). If frames were deflected, then plating was also damaged. The dents on the plating were normally between 10 mm and 50 mm deep (i.e. 1-3 times the plate thickness). If fractures also occurred, the dents were between 50 mm and 200 mm around the fracture. The bilge keels were damaged on ships having relatively high speed in ice and a small draught. Most of the damages occurred on the bow and on the mid ship regions (Fig. 26). In the

vertical direction, the damages were located on and below the ice-strengthened region. According to the ice class rules, the vertical extension of the ice belt below the ballast waterline shall be between 0.5 m and 0.75 m, depending on the ship's ice class. In some cases, indents due to ice loading were found on the bilges and the ship bottom, several meters below the ballast waterline. Aft ship damages were due to backing in ice, and damages above the ice belt were caused by the bow wave associated with high speed in ice. Most of the fractures were located on the bow area. These ships were already initially in bad condition (a lot of corrosion, abrasion and denting) or there was inadequate ice strengthening. In one case, the fracture was located on the bottom of the aft ship region.

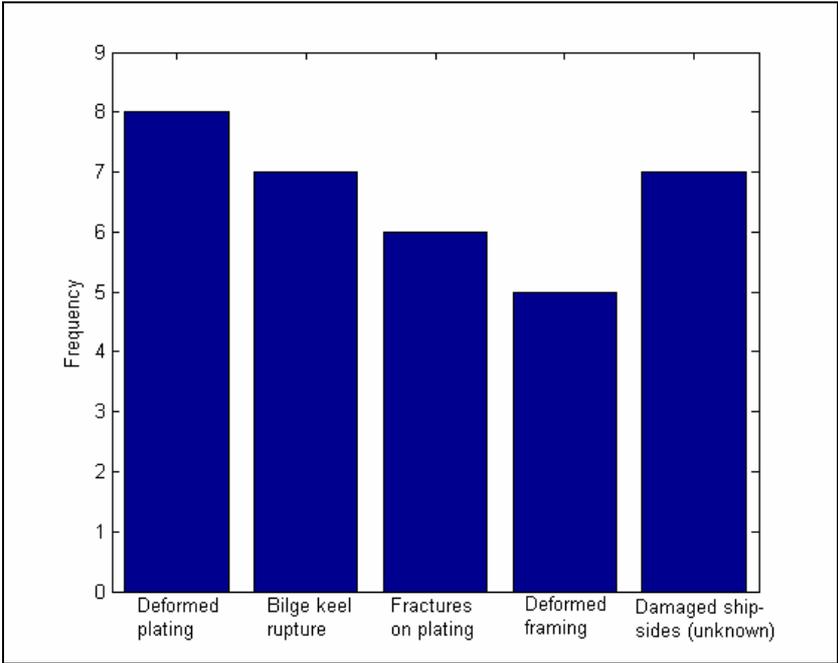


Figure 25. Summary of the damages found on different ships.

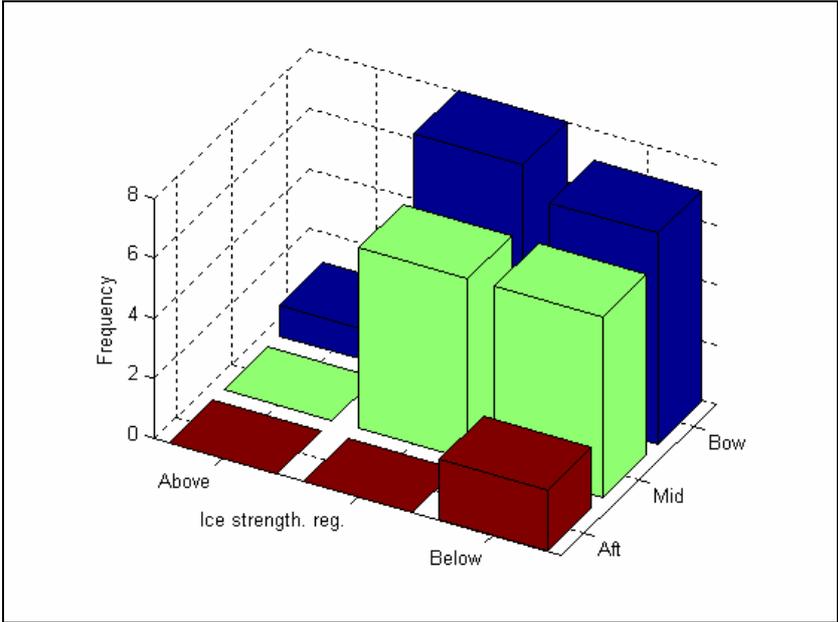


Figure 26. Locations of damaged areas of different ships.

A summary of ships and ice conditions during the incidents is presented in Figure 27. Approximately 43 % of the damaged ships belong to ice classes II, IC and IB. The average age of the ships is 21 years and the average deadweight is 12 800 dwt. The same figures for all ships that visited Finnish ports during the winter season are 15 %, 16 years and 8 100 dwt. The amount of bulk carriers is 23 %. The same figure among all ships that visited Finnish ports is 4 %. Hull ice damages in ice channel are a bit more rare compared to all damage statistics. About 15 % of hull damages occurred in compressive ice field.

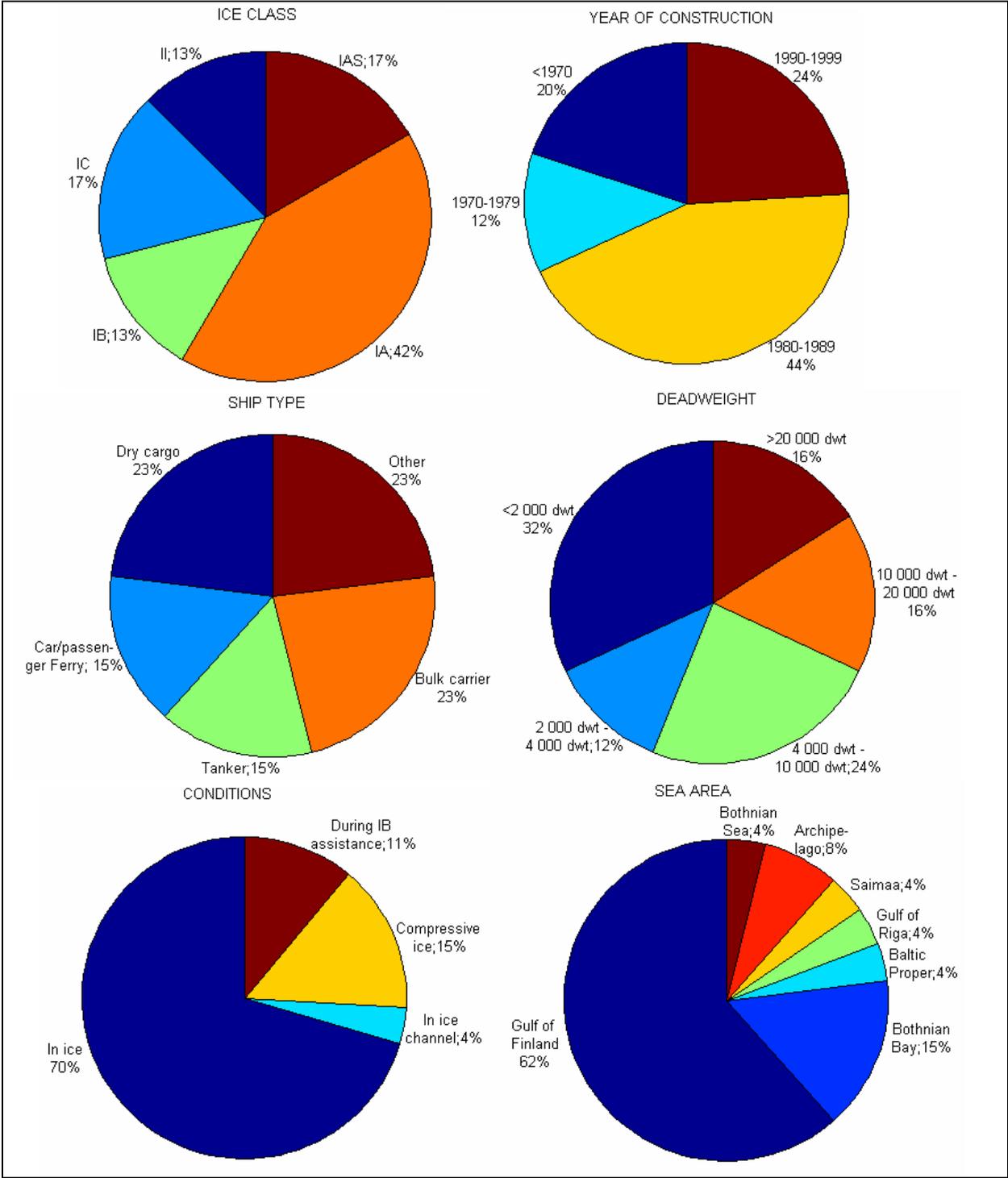


Figure 27. Information of ships having hull ice damages.

Cumulative frequencies of ice related damages as a function of time are presented in Figure 28. Most of the hull damages have occurred in the early winter. Approximately 65 % of the hull damages occurred between December 2002 and February 15th 2003. The probable reason for hull damages during early winter is that operational restrictions for ships belonging to lower ice classes were not yet placed. The other possible reason is that the ice extent and ice concentration are much lower during early winter. This means that ice moves more freely due to winds and currents. Local ice conditions can change more quickly and there is a higher risk for ships subjected to a compressive ice field. Most of the collisions, groundings, propeller and rudder damages occurred in heavy ice conditions between February and March.

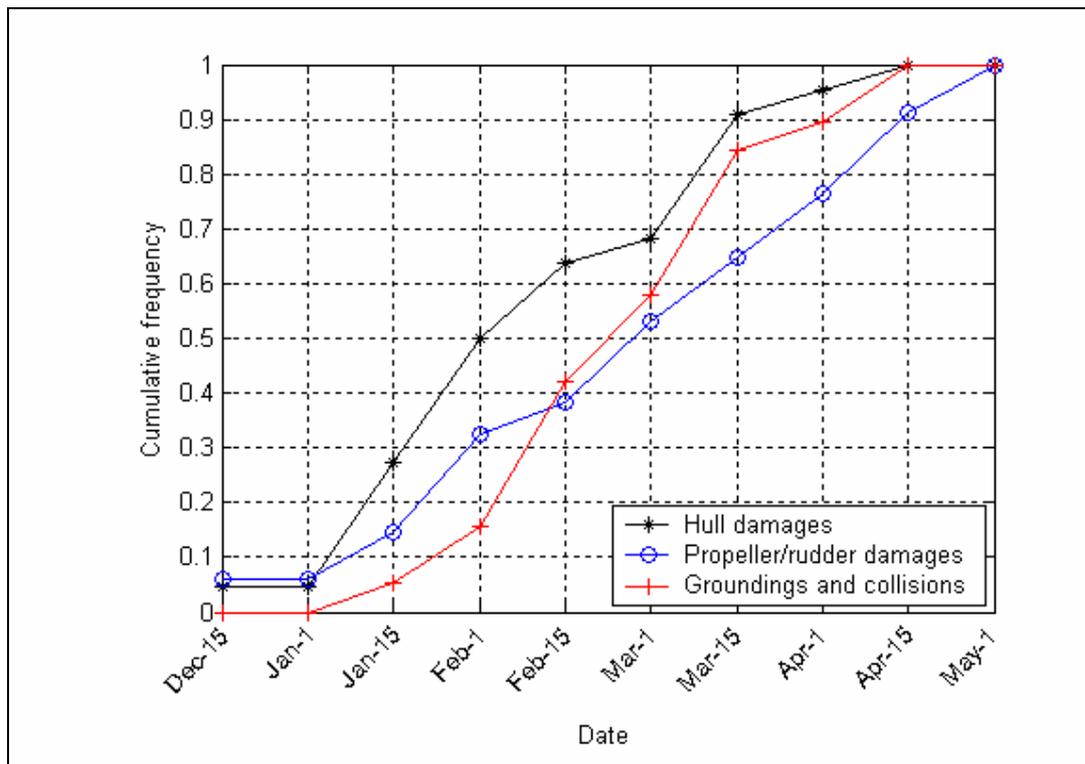


Figure 28. Cumulative frequencies of the hull and the other damages as a function of time.

Estimation of the probability for ice damage

A comparison between ice classes and ship types of damaged and undamaged ships are presented in Figure 29. The damaged ships have suffered a structural damage due to ship-ice contact. Because only Finnish and Swedish shipping companies were interviewed, most of the damaged ships are from Finnish traffic. However, a few of the damaged ships are from Russian and Estonian traffic. Some of these ships were towed to the Finnish ports after the incident and, in some cases, exact information about the ships' destination port was missing. Thus, all the information of the incidents gathered from different sources is included in the study. The statistics of damaged ships are compared with that of all foreign traffic ships that visited Finnish ports between December 2002 and April 2003. The reason why the

comparison is made only with the Finnish traffic is that most of the damaged ships are from Finnish traffic and that detailed information about the ships and their port calls was available only for Finnish traffic. The information about the damages and ship traffic from the other countries was very scarce and limited. The total number of ship visits to Finnish, Estonian and Russian ports was approximately 16 000 (Jalonen, 2004) during the winter months. The share of the traffic to Finnish ports was 63 % of this total traffic. Thus, it can be assumed that the ships that visited Finnish ports represent the ice-strengthened fleet in the Baltic winter navigation system quite well.

The total number of different types of incidents included in the statistics of ice damages was about 100, and the total number of ships that visited Finnish ports was about 1000. This means that approximately 10 % of the ships had some sort of ice-related damage or incident during the winter of 2003. The total number of ship visits in Finnish ports was about 10 000. This means that during 1 % of the voyages some kind of ice damage occurred. Keeping this in mind, the following kind of rough comparison can be made.

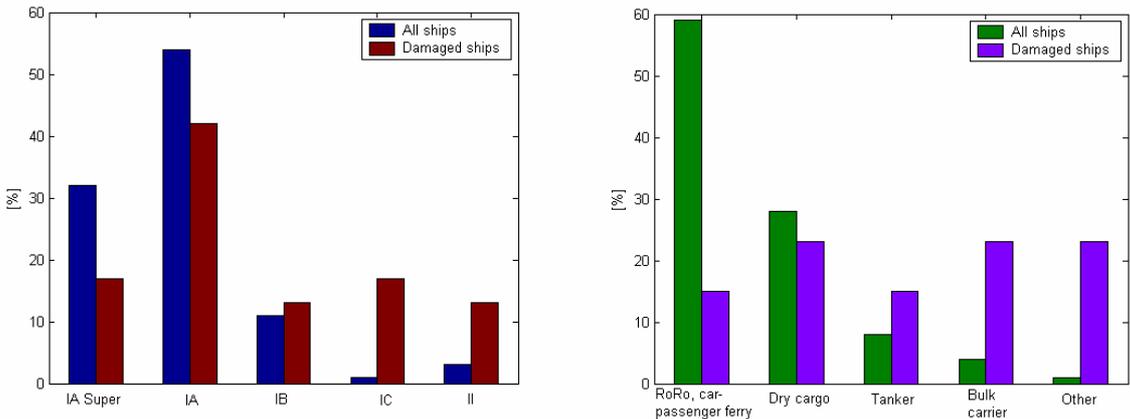


Figure 29. Comparison of ice classes and ship types of damaged and undamaged ships.

According to Figure 29, 85 % of the ships that visited Finnish ports were ice class IA or IA Super and 15 % were ice class II, IC or IB. Of the damaged ships, 58 % were ice class IA or IA Super and 42 % were ice class II, IC or IB. If we assume that during 1 % of the voyages an ice damage occurs, we get a damage probability (damages/voyage x 100 %) $58/85 \times 1 \% = 0.68 \%$ for ice classes IA and IA Super and $42/15 \times 1 \% = 2.8 \%$ for ice classes II, IC and IB. This means that ships belonging to lower ice classes suffer structural ice damage approximately four times more likely than ships having ice classes IA and IA Super ($2.8 \% / 0.68 \% = 4.1$).

Next, the same comparison is made between the two highest (IA and IA Super) and the two lowest (II and IC) ice classes. About 5 % of the ships that visited Finnish ports belong to ice classes II and IC and 30 % of the structural damages have occurred in these ships. So, the damage probability is 6 %. Compared to the damage probability of the two highest ice classes

(0.68 %), the result is that ships belonging to ice classes II and IC suffer ice damage about nine times more likely than ships belonging to ice classes IA and IA Super ($6\% / 0.68\% = 8.8$). The estimation of the influence of the ice class on the damage probability presented above is very rough and it has several deficiencies. A detailed comparison should take account the distance traveled in ice, sea area, port visited, ice conditions and phase of the winter season. Also, the influence of the winter navigation restrictions and icebreaker assistance should be considered. These deviate a lot depending on the ship type and ice class. In addition, damages should be classified as serious and minor damages. The location of the damaged area should also be considered, i.e. if it is inside or outside the ice-strengthened region. This gathered statistics of ice damages is quite narrow, covering only one winter. The damage statistics include also ships which did not visit Finnish ports, and statistics of ships that visited Finnish ports include only ships in foreign traffic. However, the presented comparison gives a rough estimate of the ice damage probability for ships of different ice classes.

6. SUMMARY AND CONCLUSIONS

The concept of ice damage includes many types of incidents, not only direct hull damages. Many rudders and propellers were damaged during the winter 2002-2003. Also, a collision with another ship in an ice channel is a quite common accident. Serious hull ice damages are rare and those kinds of damages did not occur during winter 2002-2003. The statistics gathered includes 98 incidents. Altogether 14 ships were visited during seasonal dry-docking or right after the incident.

Structural hull damages caused by ship-ice contact in the Baltic Sea were reported in 27 incidents. Most of them were relatively small indents on the plating (up to 50 mm deep). Most of the dents were observed in the bow and the mid ship hull areas. Larger damages in the mid ship area were caused by compressive ice. In some cases frames were also damaged. Some of these structural damages may have developed over several years. Altogether six fractures of the ship side-shell plating were reported. The common factor was that these ships were in bad condition (large initial deformations of the plating and corrosion) or they had inappropriate strengthening for winter navigation.

The damage statistics were compared with all the foreign traffic ships that visited Finnish ports between December 2002 and May 2003. A rough comparison revealed that approximately 10 % of the ships had some sort of ice-related damage, and that during 1 % of the voyages, some kind of ice damage occurred. An estimation of the influence of ice class on the risk of ice damage was made. The conclusion was that ships belonging to the lower ice classes, II and IC, are about nine times more likely to suffer hull damage than ships belonging to the highest ice classes, IA and IA Super.

On the basis of damage statistics from only one winter it is hard to make any general conclusions. This work should continue to cover more than one winter.

7. ACKNOWLEDGEMENTS

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