DATA COLLECTION PROGRAM ON ICE REGIMES

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ABSTRACT

A field program was designed and carried out on board six Canadian Coast Guard icebreakers during the summer of 2002. Information was collected on the ice conditions (ice regimes) and the stage of melting (decay) of the ice. In total, 195 ice regimes were documented and photographed. Based on this information, the severity of the ice regimes was evaluated in terms of the Canadian Ice Regime Shipping System. This paper provides a description of the data collection program and an overview of the results. The program was highly successful in all aspects.

INTRODUCTION

The Arctic Shipping Pollution Prevention Regulation regulates navigation in Canadian waters north of 60°N latitude. These regulations include the date Table in Schedule VIII and the Shipping Safety Control Zones Order, made under the Arctic Waters Pollution Prevention Act. Both of these are combined to form the “Zone/Date System” matrix that gives entry and exit dates for various ship types and classes. It is a rigid system with little room for exceptions. It is based on the premise that nature consistently follows a regular pattern year after year.

Transport Canada, in consultation with stakeholders, has made extensive revisions to the Arctic Shipping Pollution Prevention Regulations (ASPPR 1989; AIRSS 1996). The changes are designed to reduce the risk of structural damage in ships which could lead to the release of pollution into the environment, yet provide the necessary flexibility to ship owners by making use of actual ice conditions, as seen by the Master. In this system, an "Ice Regime", which is a region of generally consistent ice conditions, is defined at the time the vessel enters that specific geographic region, or it is defined in advance for planning and design purposes. The Arctic Ice Regime Shipping System (AIRSS) is based on a simple arithmetic calculation that produces an "Ice Numeral" that combines the ice regime and the vessel's ability to navigate safely in that region. The Ice Numeral (IN) is based on the quantity of hazardous ice with respect to the ASPPR classification of the vessel (see Table 1). The Ice Numeral is calculated from

$$IN = [C_a \ x \ IM_a] \ + \ [C_b \ x \ IM_b] \ + ... \qquad \textbf{(1)}$$

where IN is the Ice Numeral, C_a is the Concentration in tenths of ice type "a", and IM_a is the Ice Multiplier for ice type "a" (from Table 1). The term on the right hand side of the equation (a, b, c, etc.) is repeated for as many ice types as may be present, including Open Water. The values of the Ice Multipliers are adjusted to take into account the decay or ridging of the ice by adding or subtracting a correction of 1 to the multiplier, respectively (see Table 1). The Ice Numeral is therefore unique to the particular ice regime and ship operating within its boundaries. At present, there is only partial application of the Ice Regime System, exclusively outside of the Zone/Date System.

Table 1: Table of Ice Multipliers in the AIRSS

Ice Types	Vessel Class						
	Type					CAC	
	E	D	C	B	A	4	3
Old / Multi-Year Ice	-4	-4	-4	-4	-4	-3	-1
Second-Year Ice	-4	-4	-4	-4	-3	-2	1
Thick First-Year Ice	-3	-3	-3	-2	-1	1	2
Medium First-Year Ice	-2	-2	-2	-1	1	2	2
Thin First-Year Ice - 2nd Stage	-1	-1	-1	1	2	2	2
Thin First-Year Ice - 1st Stage	-1	-1	1	1	2	2	2
Grey-White Ice	-1	1	1	1	2	2	2
Grey Ice	1	2	2	2	2	2	2
Nilas, Ice Rind	2	2	2	2	2	2	2
New Ice	2	2	2	2	2	2	2
Brash	2	2	2	2	2	2	2
Open Water	2	2	2	2	2	2	2

Ice Decay: If MY, SY, TFY or MFY ice has Thaw Holes or is Rotten, add 1 to the IM for that ice type
Ice Roughness: If the total ice concentration is 6/10s or greater and more than one-third of an ice type is deformed, subtract 1 from the IM for the deformed ice type.

The ASPPR deals with vessels that are designed to operate in severe ice conditions for both transit and icebreaking (CAC class) as well as vessels designed to operate in more moderate first-year ice conditions (Type vessels). The Ice Regime System determines whether a given vessel should proceed through that particular ice regime. If the Ice Numeral is negative, the ship is not allowed to proceed. However, if the Ice Numeral is zero or positive, the ship is allowed to proceed into the ice regime. Responsibility to plan the route, identify the ice, and carry out this numeric calculation rests with the Ice Navigator who could be the Master or Officer of the Watch. Due care and attention of the mariner, including avoidance of hazards, is vital to the successful application of the Ice Regime System. Authority by the Regulator (Pollution Prevention Officer) to direct ships in danger, or during an emergency, remains unchanged.

Credibility of the new system has wide implications, not only for ship safety and pollution prevention, but also in lowering ship insurance rates and predicting ship performance. Therefore, the Canadian Hydraulics Centre of the National Research Council of Canada in Ottawa has worked with Transport Canada to assist them in developing a methodology for establishing a scientific basis for AIRSS (see e.g. Timco and Kubat, 2002).

As part of this work, the CHC, in collaboration with the Canadian Ice Service (CIS), developed a data collection program onboard the Canadian Coast Guard icebreakers that was carried out in 2002. The program was designed to collect information on the ice regimes over a wide area of the Arctic. To do this, Field Books were developed and given to the Ice Service Specialists (ISS) of the CIS. The ISS personnel were onboard six Canadian Coast Guard Icebreakers throughout the summer navigation season in the Canadian Arctic. They used these Field Books and digital cameras to collect information on the ice regimes and the stage of ice decay. Information on the ice regimes was used in conjunction with input from the Commanding Officers of the icebreakers to assess the likelihood of damage to the vessel in different ice conditions. In addition, the results from this program were used to validate a new prototype product developed by the CIS to provide information on the strength of first-year level ice in the Arctic (Gauthier et al., 2002; Langlois et al, 2003). This paper discusses the procedure and results of this data collection program.

FIELD BOOKS

Field books were developed to allow the collection of key information in a systematic format. Figure 1 shows a page from the Field Book for the CCGS TERRY FOX. The books were subdivided as follows:

General Information – This section collected general information on the observation including: Observation Number, Date, Time, Latitude, Longitude, Geographic Location, Vessel Speed, Visibility, Ice Roughness, Floe Size.
Digital Photographs – The ISS were supplied with digital cameras and asked to photograph the observed ice regimes.
Stage of Melt – The surface conditions were noted according to the following format: No Snow Melt, Snow Melt, Ponding, Drainage, or Rotten/Decayed.
Ice Regime – Information on the ice regime was collected by noting the concentration of each Ice Type based on the World Meteorological Organization (WMO) definitions. The ISS was asked to define the ice regime as “the ice that the vessel will likely encounter”.
Ice Numeral – The Ice Numeral was calculated based upon the observed ice conditions and the Ice Multipliers that were supplied for each vessel in the Field Books.

Comments from the Officer of the Watch – A number of questions were asked to the Officer of the Watch to correlate the ice conditions to their assessment of the potential for damage by the ice to the ship. The questions are as follows:

1. How would you rank the severity (damage potential) of this ice regime?
   - high potential of damage　　　- potential for damage
   - not likely to damage vessel　　- highly unlikely to damage vessel
2. Do you think that the Ice Numeral reflects the degree of severity of the ice conditions?
   Yes　No　If no, why not?
3. Did you alter your mode of operation with this ice regime?
   Yes　No　If so, how?

General Comments – Space was left for any comments from either the ISS personnel or Officer of the Watch.

General Information	
Observation #	Location:
Date:	Vessel Speed (knots):
Time:	Visibility (n.mi):
Latitude:	Ice Roughness (please circle): Low Medium High
Longitude:	Floe Size (m):
Digital Photo File Name:	

Stage of Melt
(please circle)

No melt	Snow melt	Ponding	Drainage	Rotten/ decayed

CIS Ice Strength Index

Ice Regime

☐ Daily Ice Analysis Chart (date)　☐ Visual

Ice Type	Ice Conc.		Ice Multiplier (IM) (please circle)				Ice Type Contribution
	C		Normal	Decay*	Ridged**		C X IM
MY		x	-1	-1	-2	=	
SY		x	1	1	0	=	
TFY		x	2	3	1	=	
MFY		x	2	3	1	=	
FY		x	2	3	1	=	
GW		x	2	3	1	=	
G		x	2	3	1	=	
N		x	2	3	1	=	
OW		x	2	2	2	=	
Sum =	10		Ice Numeral =				

*use Decay Ice Multiplier if the Stage of Melt is Drainage or Rotten/Decayed
**use Ridged Ice Multiplier if Ice Type is more than 30% ridged

CO　　OOW　　ISS

Comments from the Officer of the Watch

How would you rank the severity (damage potential) of this ice regime?
☐ high potential of damage　☐ potential for damage
☐ not likely to damage vessel　☐ highly unlikely to damage vessel

Do you think that the Ice Numeral reflects the degree of severity of the ice conditions? ☐Yes ☐No　If no, why not?

Did you alter your mode of operation with this ice regime?
☐Yes ☐No - if so, how?

General Comments and Work Area

Observation # ________

Figure 1: Page from the Field Book for the CCGS TERRY FOX.

These Field Books were used on six Canadian Coast Guard icebreakers. General information pertaining to the vessels for this study is given in Table 2. It should be noted that the icebreakers were assigned a Vessel Class in order to calculate the Ice Numeral. These Vessel Classes were suggested by Andrew Kendrick of Fleet Technology Ltd. based upon preliminary analysis of the vessels. It is important to understand that the Vessel Class used here is not necessarily the Vessel Class that would be assigned by Transport Canada for these vessels. This assignment would require a more thorough analysis.

Table 2: Information on the CCG Vessels

Vessel Name	Data Collection		Commanding Officers	Ice Service Specialists	Number of Observations	Number of Photographs	Assigned Vessel Class
	Start	End					
LOUIS S. ST-LAURENT	9-Aug-02	25-Oct-02	S. Klebert M. Marsden	R. Provost J.Y. Rancourt D. Crosbie	54	31	CAC3
TERRY FOX	6-Jul-02		M. Champagne G. Barry L. Meisner	G. Campbell	21	41	CAC3
HENRY LARSEN	14-Jul-02	9-Sep-02	J. Vanthiel J. Broderick	S. Payment	7	7	CAC3
PIERRE RADISSON	29-Jun-02		M. Bourdeau S. Brûlé	R. Boisvert F. Guay	43	55	CAC4
DES GROSEILLIERS	12-Jul-02	19-Sep-02	G. Tremblay R. Dubois	B. Simard S. Leger	57	40	CAC4
SIR WILFRID LAURIER	19-Jul-02	25-Aug-02	M. Taylor N. Thomas	S. Thomas C. Stock	13	26	Type A

The vessels sailed in different parts of the Canadian Arctic. Figure 2 shows the details about where the observations were made along the routes of the six vessels during the data collection program.

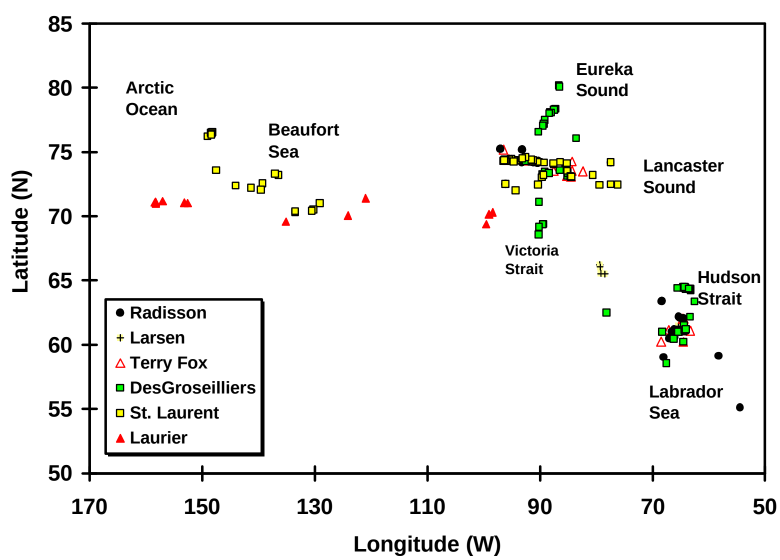

Figure 2: Location of data collection for the six Coast Guard icebreakers.

ISSUES

A number of issues had to be resolved to ensure a successful program. These are briefly discussed below:

1. There were four government departments (Transport Canada, National Research Council, Environment Canada, Fisheries and Oceans) working on this program and it was important that all departments were committed to this work and understood the importance. Further, it was important to ensure that all departments and individuals were kept informed of the status of the work. This was done in a step-wise approach in the development of the program. Discussions were held with the individual

departments to explain the program and to seek their acceptance and participation in the program. Once all departments agreed to participate, co-ordination and communication was done primarily by e-mail.

2. The Canadian Coast Guard and the CIS Ice Service Specialists were not completely familiar with the details of the Ice Regime System. This was addressed by having the authors meet with these groups at their pre-Arctic meetings and discuss the program and the Ice Regime System.
3. The Field Books were developed to ensure that information required by both the CHC and the CIS would be collected in a form that was as simple as possible to use.
4. Since the icebreakers had three different vessel classes, the Ice Multipliers were not the same for all of the icebreakers. Therefore, the books were customized for each icebreaker. Further, since the working language on two of the icebreakers is French, these Field Books were translated and produced in the French language.
5. Digital cameras were purchased along with a system for downloading photographs onto the ISS computers. These were packaged together with the manuals and given to the ISS. The quality of the photos taken was excellent by all of the ISS and there were no problems in the use of the cameras. However, a few of the ISS personnel has problems downloading the images to their laptop computer since it did not have the necessary USB port required by the video card reader. In those cases, the ISS downloaded the images onto one of the computers on the icebreaker and subsequently retrieved them.

ANALYSIS

Calculating the Ice Numeral

Overall, the data collection project showed that defining ice regimes and calculating the Ice Numeral was not a problem. Figure 3 shows the overall breakdown of the calculated Ice Numeral for the 195 events. In the majority of cases (84%), the Ice Numeral was calculated correctly based upon the observed ice regime. However, three different types of mistakes were made in some cases:

- In 9% of the cases, the Open Water was not included in the ice regime. Since the Open Water Ice Multiplier is +2 for all vessels, this led to an overly negative Ice Numeral for those ice regimes.
- In 4% of the cases, the wrong Ice Multiplier was used. For example, the ice regime was identified as having decayed ice, but the decay bonus of +1 was not applied to the Ice Multiplier.
- In 3% of the cases, a mistake was made in summing the contributions from each ice type when determining the Ice Numeral.

Despite the 16% errors in determining the Ice Numeral, these results are encouraging. The program shows that determining the Ice Numeral is relatively straightforward once the ice regime has been defined. The mistakes of neglecting the Open Water and incorrect summing can be corrected by simply taking more care. The mistake of choosing the incorrect Ice Multiplier would be remedied with more experience with the Ice Regime System.

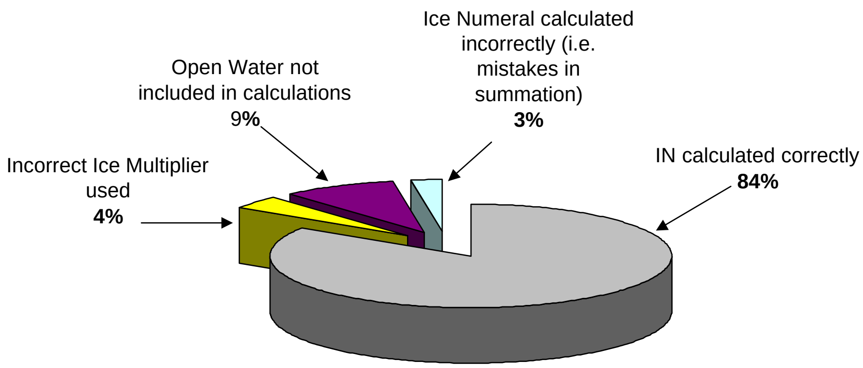

Figure 3: Pie Chart showing the breakdown of the calculated Ice Numeral

Surface Properties and Ice Decay

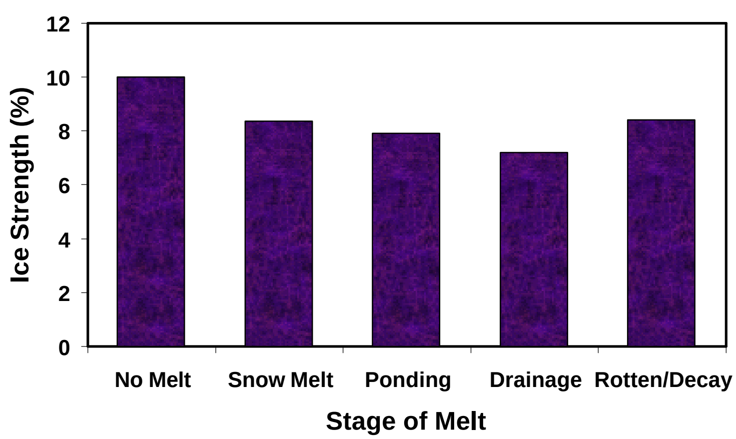

Figure 4: Histogram of the average ice strength versus the Stage of Melt of the surface ice.

Information was also collected to try to relate the surface conditions of the ice (i.e. the Stage of Melt) to the strength of the bulk ice sheet. If a correlation could be found, the Stage of Melt could be used to infer the strength of the bulk ice sheet. To collect information on this, the ISS were asked to characterize the surface properties as: No Snow Melt (i.e. a snow cover), Snow Melt, Ponding, Drainage, or Rotten/Decayed. These surface properties were correlated to the ice strength that was obtained from the weekly Ice Strength Chart issued by the CIS. Figure 4 shows a histogram plot of the average ice strength for each of the five surface conditions. There is a general trend of decreasing ice strength with increasing surface decay. However, the range of the data is not large and the trend is not monotonic. This indicates that the surface conditions cannot be reliably used to indicate the strength of the ice sheet.

Ground-Truthing of CIS Ice Charts

The data collected can be used to ground-truth the ice conditions forecasted by the CIS on the Daily Ice Charts. Figure 5 shows a histogram of the difference between the total ice concentration indicated on the CSI Ice Chart compared to that observed onboard the CCG vessels. Each data point corresponds to a particular latitude/longitude position and the concentration is compared to the last available Ice Chart for that location. The comparison shows that for total ice concentration, the CIS Charts agree with the observed to within ±1/10 in 60% of the cases. This agreement is quite remarkable considering that the comparison is a point observation on an Ice Charts that has a scale of 1:2-million. Other types of comparisons can also be made with the data.

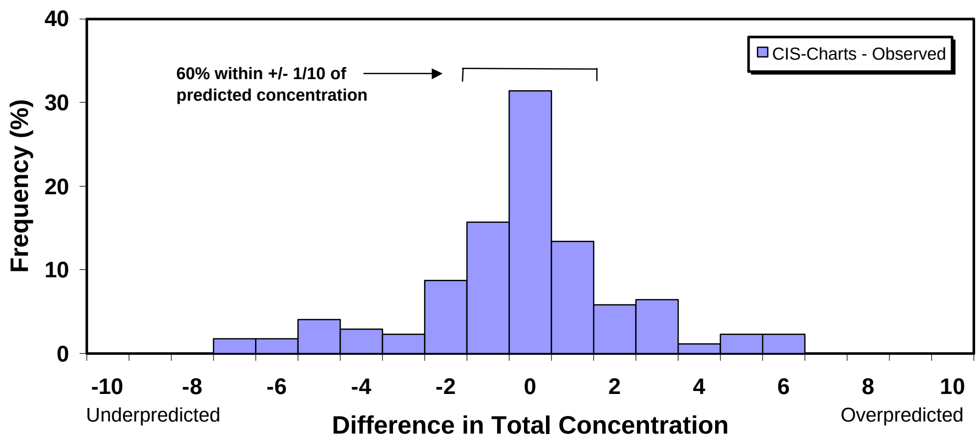

Figure 5: Histogram showing the difference between the total ice concentration from the CIS Ice Charts and the observed ice concentration.

Ice Numerals

In the Ice Regime System, the Ice Numeral must be based on the ice regime seen from the Bridge of the vessel. However, prior to transiting ice-covered waters, the CIS Ice Charts are often used for planning purposes and route selection. Since the Ice Charts were available to the Coast Guard, it is possible to compare the Ice Numerals calculated from the Bridge observations with those calculated from the CIS Ice Charts. Figure 6 shows the results for 172 events in which the Ice Chart information was available.

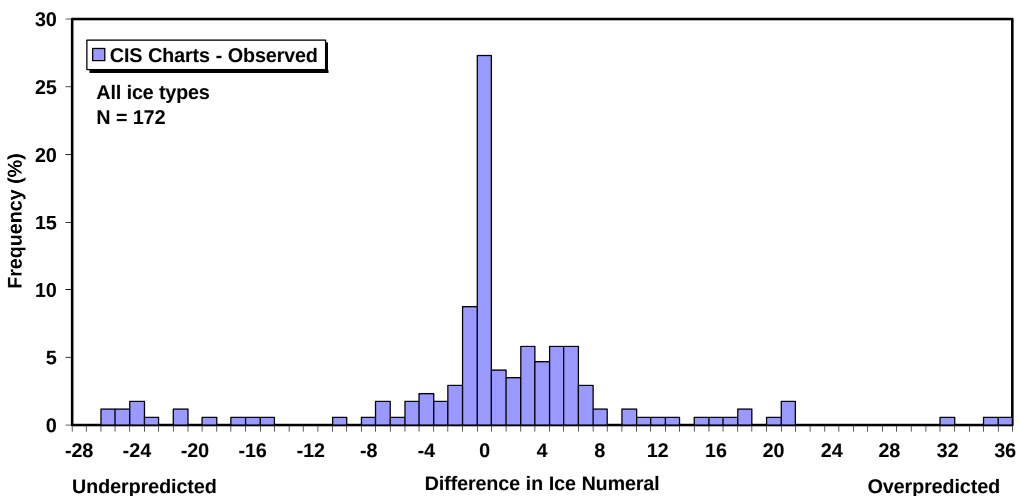

Figure 6: Comparison of the Ice Numeral as calculated from the CIS Ice Charts with those observed from the Bridge.

The analysis indicates that the Ice Numeral predicted from the CIS Ice Charts was in agreement with the Bridge observations in about 27% of the events. However, on average, the Ice Charts over predicts the Ice Numeral. This is a direct result of the finding from this study that the CIS Charts often under predict the amount of multi-year ice, especially for smaller multi-year floes.

Ice Numeral and Potential for Damage

A key part of this project was to obtain the input of the Officer of the Watch (OOW) on the severity of the ice regime and its potential for damage. Figure 7 shows a series of histograms of the number of responses for the damage potential as a function of the Ice Numeral. These plots integrate the responses from all of the vessels.

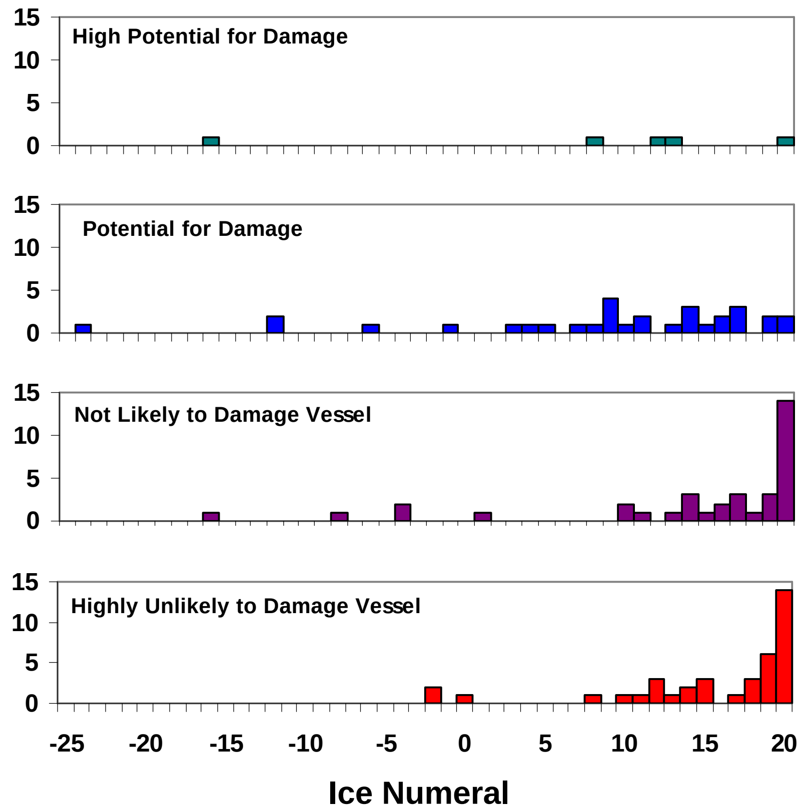

Figure 6: Histograms showing the number of response to the damage potential of the ice as a function of the Ice Numeral

In general, there is a favourable agreement between the potential for damage and the Ice Numeral. There are, however a few events that deserve particular attention. In the top histogram, there are five events in which the OOW indicated that the ice regime had High Potential for Damage. It would be expected that all of these events should have a negative Ice Numeral; however, four of the five events had a positive Ice Numeral. A closer examination of these events showed that they represented two different types of ice regimes. Three of the events involved 3-to-5-tenths multi-year ice and 3-tenths thick first-year ice, both heavily ridged. In these events, the vessels were CAC3 icebreakers travelling at speeds of 12 to 14 knots. The fourth event was Open Water with icebergs and heavy fog conditions.

SUMMARY

This data collection program was highly successful and provided a great deal of extremely useful information. The data have been used to evaluate the ease of application of the Ice Regime System, to investigate the ice surface properties and the state of the decay of the ice, to ground truth the Ice Charts, to investigate the use of the CIS Ice Charts in providing guidance for the Ice Regime System, and to apply the experience of the CCG Commanding Officers to the Ice Regime System.

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