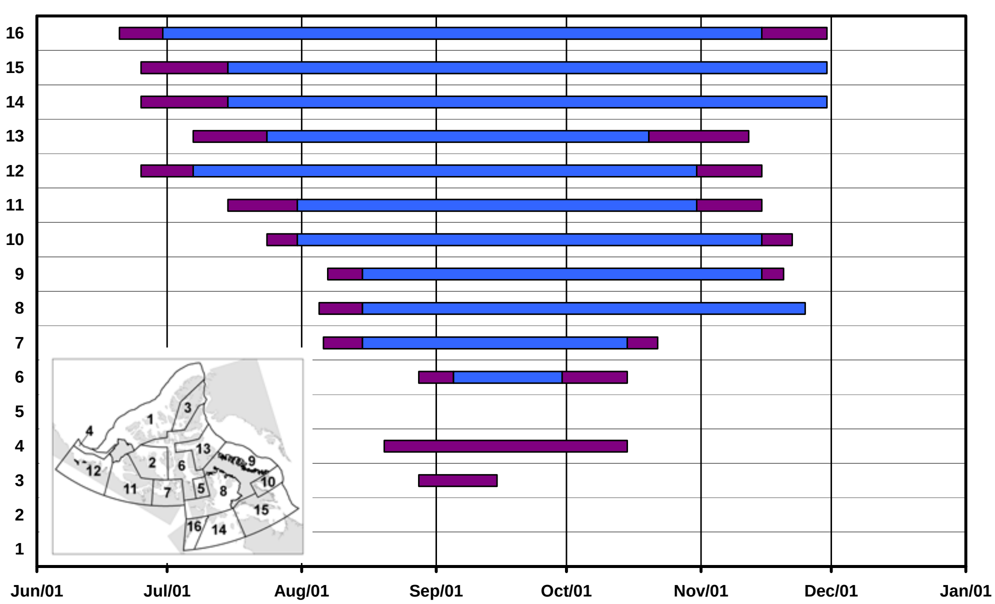
CHC CANADIAN HYDRAULICS CENTRE
CENTRE D'HYDRAULIQUE CANADIEN

TP 14894

Scientific Analysis of the ASPPR Hybrid System for Type B Vessels

G.W. Timco, A. Collins and I. Kubat

HYBRID SYSTEM 'TYPE B'



Technical Report CHC-TR-063

March 2009

National Research Council Canada
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G.W. Timco, A. Collins and I. Kubat
Canadian Hydraulics Centre
National Research Council of Canada
Ottawa, Ont., K1A 0R6
Canada

Prepared for

Transport Canada
330 Sparks St
Ottawa, Ont., K1A 0N8
Canada

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ABSTRACT

Significant research has shown that Transport Canada's Arctic Shipping Pollution Prevention Regulations (ASPPR) need to be modified and updated. The Canadian Hydraulics Centre of the National Research Council of Canada has been conducting research on methods to improve and update the system. This report provides information on a proposed revised approach (Hybrid System) for dealing with Type B vessels in Canada's Arctic waters. The proposed Hybrid System would redefine some of the existing Zone boundaries and allow mostly expanded windows for shipping using a combination of Ice Regime System Mandatory dates and Open Zone dates. The report is intended as a starting point for discussion with key Stakeholders of the ASPPR.

RÉSUMÉ

Des études ont clairement démontré que le Règlement sur la prévention de la pollution des eaux arctiques par les navires (RPPEAN), émanant de Transports Canada, requiert une mise à jour. Le Centre d'hydraulique canadien, du Conseil national de la recherche, a élaboré une méthodologie visant à améliorer ce règlement, notamment par l'entremise du « système hybride ». Ce système, qui s'applique au navire de type B circulant en eaux arctiques au Canada, prévoit la modification de l'étendue des zones existantes, ainsi qu'un élargissement de la période d'accès pour la navigation, en faisant intervenir des dates obligatoires pour le système des régimes des glaces et pour les aires ouvertes. Ce rapport se veut un point de départ pour une discussion entre les principaux intervenants intéressés au RPPEAN.

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1.0 INTRODUCTION

The Canadian Hydraulics Centre (CHC) of the National Research Council of Canada (NRC) has been investigating the scientific basis for Transport Canada's Arctic Shipping Pollution Prevention Regulations (ASPPR). The purpose of these Regulations is to minimize the likelihood that a ship will enter ice conditions that are beyond the ship's designed safe operating parameters. The Regulations are based on two completely different approaches for dealing with a vessel in different ice conditions at different times of the year. These systems are the Zone-Date System and the Ice Regime System.

The results of this research show that neither system is based on strong science. This suggests that a different system that can build on their strengths could provide a better method for the Arctic. Moreover, the International Association of Classification Societies (IACS) has recently agreed to harmonize their classifications for Arctic vessels and have developed standards for seven Polar Classes (Kendrick 1999; IMO 2002; Santos Pedro 2003: IACS 2007). These are not presently taken into account in the current Canadian Regulations but Transport Canada has indicated their intent to do so (see Appendix A). All of these factors suggest that this is a suitable time to revisit the Arctic Regulations. The authors wrote a Discussion Report (Timco and Kubat 2007a, 2007b) that outlined four possible options that would include Polar Class vessels, and may prove to be a more suitable means of pollution prevention in Canada's Arctic waters. This report was widely circulated to the Stakeholders through personal meetings, and at the CMAC-Northern meetings. [It is also available on the NRC-CHC website (www.chc.nrc.ca) under Cold Regions Technology/Reports]. Following this, the NRC-CHC organized a dedicated Consultation Workshop which was attended by key Stakeholders. The Workshop provided recommendations that the Hybrid System proposed by the NRC-CHC be further developed. This report outlines the approach that was used to develop the new Hybrid System for the ASPPR. Proposed changes are presented for both zone boundaries and entry/exit dates for each zone based on a scientific examination of the best available information of the ice conditions in the Arctic.

The contents of this report are based on a scientific analysis of the historical ice conditions in the Canadian Arctic. The authors have applied this analysis to suggest a potential approach for the ASPPR Hybrid System for Type B vessels. The intent is to use this as a starting point for discussions with all key Stakeholders of the ASPPR. This will be done during 20009/2010. It should be emphasized that the Hybrid Approach suggested here has not had input from any Stakeholder, including Transport Canada. Input from Stakeholders will be collected and presented at a Stakeholders meeting which will be arranged in the early part of 2010.

2.0 THE ZONE-DATE SYSTEM

In 1972, the Canadian Government drafted the Arctic Shipping Pollution Prevention Regulations (ASPPR) to regulate navigation in Canadian waters north of 60ºN latitude. These regulations include the Shipping Safety Control Zones (Figure 1), and the Date Table (Table 1), made under the Arctic Waters Pollution Prevention Act (see e.g. ASPPR 1989). Both of these are combined to form the "Zone/Date System" (ZDS) matrix that gives entry and exit dates for various ship types and classes. In this system, the ship types and classes, in descending order of ice capability are: Arctic Class: 10, 8, 7, 6, 4, 3, 2, 1A, 1 and Type Ships[1]: A, B, C, D, E.

The Arctic Class was normally but not accurately described as the thickness in feet of level ice that the vessel would have the power and strength to break. The Type ships represent the Classifications Societies' designation of ice-capable ships that are in turn equivalent to the Baltic Rules. The "Zone-Date System" is based on the premise that nature consistently follows a regular pattern year after year. It is a rigid system with little room for exceptions.

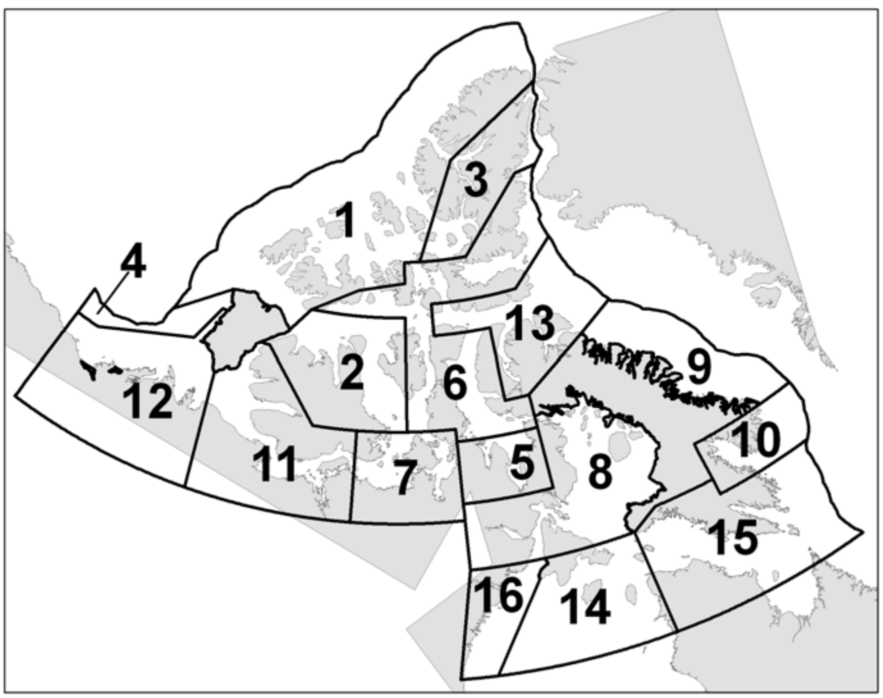

Figure 1: Map of northern Canada showing the Zones in the existing Zone-Date System. Zone #1 has the most severe ice conditions and Zone #16 has the lightest ice conditions.

[1] The 1972 tables reflect versions of the Baltic Rules that have been superseded. The current version of Type B is more structurally capable than the version assumed in the Canadian regulations (A. Kendrick, personal communication).

Kubat et al. (2005, 2006, 2007) has been investigating the veracity of the Zone-Date System for Transport Canada. They found that there are very large variations in the ice conditions from year-to-year. An examination of several years of data has shown that the Zone-Date System allows vessels into ice regimes which have a high potential to damage the vessel and it often restricts vessels from entering regions where the ice conditions are favourable for a safe passage. The large annual variations are not taken into account by this system - it has fixed (rigid) entry dates that often do not reflect the severity of the ice.

Table 1 : Zone-Date Table

Item	Category	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9	Zone 10	Zone 11	Zone 12	Zone 13	Zone 14	Zone 15	Zone 16
1.	**Arctic Class 10**	All Year	All Year	All Year	All Year	All Year	All Year	All Year	All Year	All Year	All Year	All Year	All Year	All Year	All Year	All Year	All Year
2.	**Arctic Class 8**	July 1 to	All Year	All Year	All Year	All Year	All Year	All Year	All Year	All Year	All Year	All Year	All Year	All Year	All Year	All Year	All Oct. 15
3.	**Arctic Class 7**	Aug. 1 to Sept. 30	Aug. 1 to Nov. 30	July 1 to Dec. 31	July 1 to Dec. 15	July 1 to Dec. 15	All Year	All Year	All Year	All Year	All Year	All Year	All Year	All Year	All Year	All Year	All Year
4.	**Arctic Class 6**	Aug. 15 to Sept. 15	Aug. 1 to Oct. 31	July 15 to Nov. 30	July 15 to Nov. 30	Aug. 1 to Oct. 15	July 15 to Feb. 28	July 1 to Mar. 31	July 1 to Mar. 31	All Year	All Year	July 1 to Mar. 31	All Year	All Year	All Year	All Year	All Year
5.	**Arctic Class 4**	Aug. 15 to Sept. 15	Aug. 15 to Oct. 15	July 15 to Oct. 31	July 15 to Nov. 15	Aug. 15 to Sept. 30	July 20 to Dec. 31	July 15 to Jan. 15	July 15 to Jan. 15	July 10 to Mar. 31	July 10 to Feb. 28	July 5 to Jan. 15	June 1 to Jan. 31	June 1 to Feb. 15	June 15 to Feb. 15	June 15 to Mar. 15	June 1 to Feb. 15
6.	**Arctic Class 3**	Aug. 20 to Sept. 15	Aug. 20 to Sept. 30	July 25 to Oct. 15	July 20 to Nov. 5	Aug. 20 to Sept. 25	Aug. 1 to Nov. 30	July 20 to Dec. 15	July 20 to Dec. 31	July 20 to Jan. 20	July 15 to Jan. 25	July 5 to Dec. 15	June 10 to Dec. 31	June 10 to Dec. 31	June 20 to Jan. 10	June 20 to Jan. 31	June 5 to Jan. 10
7.	**Arctic Class 2**	No Entry	No Entry	Aug. 15 to Sept. 30	Aug. 1 to Oct. 31	No Entry	Aug. 15 to Nov. 20	Aug. 1 to Nov. 20	Aug. 1 to Nov. 30	Aug. 1 to Dec. 20	July 25 to Dec. 20	July 10 to Nov. 20	June 15 to Dec. 5	June 25 to Nov. 22	June 25 to Dec. 10	June 25 to Dec. 20	June 10 to Dec. 10
8.	**Arctic Class 1A**	No Entry	No Entry	Aug. 20 to Sept. 15	Aug. 20 to Sept. 30	No Entry	Aug. 25 to Oct. 31	Aug. 10 to Nov. 5	Aug. 10 to Nov. 20	Aug. 10 to Dec. 10	Aug. 1 to Dec. 10	July 15 to Nov. 10	July 1 to Nov. 10	July 15 to Oct. 31	July 1 to Nov. 30	July 1 to Dec. 10	June 20 to Nov. 30
9.	**Arctic Class 1**	No Entry	No Entry	No Entry	No Entry	No Entry	Aug. 25 to Sept. 30	Aug. 10 to Oct. 15	Aug. 10 to Oct. 31	Aug. 10 to Oct. 31	Aug. 1 to Oct. 31	July 15 to Oct. 20	July 1 to Oct. 31	July 15 to Oct. 15	July 1 to Nov. 30	July 1 to Nov. 30	June 20 to Nov. 15
10.	**Type A**	No Entry	No Entry	Aug. 20 to Sept. 10	Aug. 20 to Sept. 20	No Entry	Aug. 15 to Oct. 15	Aug. 1 to Oct. 25	Aug. 1 to Nov. 10	Aug. 1 to Nov. 20	July 25 to Nov. 20	July 10 to Oct. 31	June 15 to Nov. 10	June 25 to Oct. 22	June 25 to Nov. 30	June 25 to Dec. 5	June 20 to Nov. 20
11.	**Type B**	No Entry	No Entry	Aug. 20 to Sept. 5	Aug. 20 to Sept. 15	No Entry	Aug. 25 to Sept. 30	Aug. 10 to Oct. 15	Aug. 10 to Oct. 31	Aug. 10 to Oct. 31	Aug. 1 to Oct. 31	July 15 to Oct. 20	July 1 to Oct. 25	July 15 to Oct. 15	July 1 to Nov. 30	July 1 to Nov. 30	June 20 to Nov. 10
12.	**Type C**	No Entry	No Entry	No Entry	No Entry	No Entry	Aug. 25 to Sept. 25	Aug. 10 to Oct. 10	Aug. 10 to Oct. 25	Aug. 10 to Oct. 25	Aug. 1 to Oct. 25	July 15 to Oct. 15	July 1 to Oct. 25	July 15 to Oct. 10	July 1 to Nov. 25	July 1 to Nov. 25	June 20 to Nov. 10
13.	**Type D**	No Entry	No Entry	No Entry	No Entry	No Entry	No Entry	Aug. 10 to Oct. 5	Aug. 15 to Oct. 20	Aug. 15 to Oct. 20	Aug. 5 to Oct. 20	July 15 to Oct. 10	July 1 to Oct. 20	July 30 to Sept. 30	July 10 to Nov. 10	July 5 to Nov. 10	July 1 to Oct. 31
14.	**Type E**	No Entry	No Entry	No Entry	No Entry	No Entry	No Entry	Aug. 10 to Sept. 30	Aug. 20 to Oct. 20	Aug. 20 to Oct. 15	Aug. 10 to Oct. 20	July 15 to Sept. 30	July 1 to Oct. 20	Aug. 15 to Sept. 20	July 20 to Oct. 31	July 20 to Nov. 5	July 1 to Oct. 31

3.0 THE ARCTIC ICE REGIME SHIPPING SYSTEM

Transport Canada, in consultation with stakeholders, made extensive revisions to the Arctic Regulations through the introduction of the Ice Regime System (ASPPR 1989; Canadian Gazette 1996; Equivalent Standards 1995; AIRSS 1996). The changes were 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 to determine transit.

The Arctic Ice Regime Shipping System (AIRSS) is based on a simple arithmetic calculation which produces an "Ice Numeral" that combines the ice regime and the vessel's ability to navigate safely through that ice regime. The "Ice Regime" is a region of generally consistent ice conditions. The Ice Numeral (IN) is based on the quantity of hazardous ice with respect to the ASPPR classification of the vessel. The Ice Numeral is calculated from

$$IN = [C_a \, x \, IM_a] \quad + \quad [C_b \, x \, IM_b] \quad + ... \qquad [1]$$

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" and Ship Category (ASPPR 1989). 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 ice types are based on the World Meteorological Organization classifications. The values of the Ice Multipliers (see Table 2) reflect the capability of the vessel class to operate in different ice conditions without damage. The multipliers are adjusted to take into account the decay or ridging of the ice. The Ice Numeral is therefore unique to the particular ice regime and ship operating within its boundaries.

The vessel class is defined in terms of vessels designed to operate in severe ice conditions for both transit and icebreaking (Canadian Arctic Class - CAC) as well as vessels designed to operate in more moderate first-year ice conditions (Type ships). In this system, the vessel classes, in descending order of ice capability are Canadian Arctic Class: CAC1, CAC2, CAC3, CAC4 and Type Ships: A, B, C, D, E.

The Ice Regime System determines whether or not 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 a qualified Ice Navigator (ASPPR, 1989) 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.

Table 2: Ice Multipliers in the Ice Regime System

Ice Types			Ice Multipliers						
			Type Vessels					CAC	
			E	D	C	B	A	4	3
MY	Old / Multi-Year Ice		- 4	- 4	- 4	- 4	- 4	- 3	- 1
SY	Second Year Ice		- 4	- 4	- 4	- 4	- 3	- 2	1
TFY	Thick First Year Ice	> 120 cm	- 3	- 3	- 3	- 2	- 1	1	2
MFY	Medium First Year Ice	70-120 cm	- 2	- 2	- 2	- 1	1	2	2
FY	Thin First Year Ice:								
	stage 2	50-70 cm	- 1	- 1	- 1	1	2	2	2
	stage 1	30-50 cm	- 1	- 1	1	1	2	2	2
GW	Grey-White Ice	15-30 cm	- 1	1	1	1	2	2	2
G	Grey Ice	10-15 cm	1	2	2	2	2	2	2
NI	Nilas, Ice Rind	< 10 cm	2	2	2	2	2	2	2
N	New Ice	< 10 cm	"	"	"	"	"	"	"
	Brash (ice fragments < 2 m across)		"	"	"	"	"	"	"
	Bergy Water		"	"	"	"	"	"	"
	Open Water		"	"	"	"	"	"	"

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.

Transport Canada sponsored the NRC-CHC to perform a considerable amount of research to investigate the scientific veracity of the Ice Regime System using a seven Task approach (Timco et al. 1997). Based on the research results and discussions with Stakeholders, a Discussion Paper was produced (Timco and Kubat 2002). This led to a Workshop of Stakeholders in Montreal in 2003 with the final outcome of a suggested modified Ice Regime System that better fit the empirical data (Timco et al. 2004).

4.0 FOUR ICE REGIME OPTIONS

The inadequacies of the Zone-Date System and the existing Ice Regime System combined with the new changes in international harmonization of Polar Class vessels indicate that changes to the Arctic Regulations for Canada's Arctic are required. However, the best approach to do this is not clear. The Regulations would have to have the following features:

- Have a strong scientific basis (i.e. not be based on *ad hoc* approach).
- Allow the operators sufficient opportunity to operate safely in the Arctic.
- Facilitate a means for operators to manage risk in a systematic way.
- Develop a quantifiable system that will allow improvements and innovation in rule making.
- Include the new IACS Polar Class vessels.

Based on these criteria, Timco and Kubat (2007a, 2007b) and Kubat et al. (2008) presented four different potential approaches: Modified Ice Regime System, Regimes Ice Chart System, Hybrid System, or the Arctic Certificate System. A consultation meeting was held in Montreal with all key Stakeholders to decide the general approach to take for the revision. It was decided that the Hybrid System, and perhaps the Arctic Certificate System is the best path forward (Kubat and Timco 2008).

The Hybrid System approach would make use of both the Zone-Date System and the (modified) Ice Regime System in a direct manner. In this case, the existing Zones and Dates would be re-evaluated and updated based on the historical data from the last twenty years or so. This would provide a framework for allowable entries into the zones. The question is: what is the best way to do this?

5.0 REANALYZING THE ZONE-DATE SYSTEM

It is important that the best available information be used to reanalyze the Zone-Date System. The authors considered various approaches but felt that making use of the Ice Charts supplied by the Canadian Ice Service (CIS) was clearly the best choice. The CIS have archived information on the ice conditions in the Arctic for a considerable length of time and this information forms the background for the analysis. The information is supplied for different geographic regions and represents the integration of information interpreted from satellite imagery, as well as on-ice observations. The conditions are summarized in terms of Egg Codes based on the WMO ice types (see e.g. MANICE 2005). This system is used internationally by all ice service organizations. The Ice Chart is subdivided into regions of more-or-less consistent ice conditions (or ice regimes). Each of these regions has a unique Egg Code associated with it. Figure 2 shows an example of an ice chart for the western Arctic on August 8, 2005, and the definition of the Egg Code. The ice information that is required for the re-analysis of the ZDS can be found in the Ice Charts and the Egg Code for each region. It is possible to use the ice information along with Equation [1] to determine the Ice Numeral for each region. This would be done for each vessel class in the Canadian system. It would define the regions where the vessel would be allowed and restricted for each Ice Chart (i.e. each geographic region and date). Of course there is considerable variation in the ice conditions from year-to-year and this must be included in the analysis. Thus, a method must be devised to integrate all of the information from the Ice Charts for the past 25 years. The approach to do this, developed by one of the authors (AC), is outlined below.

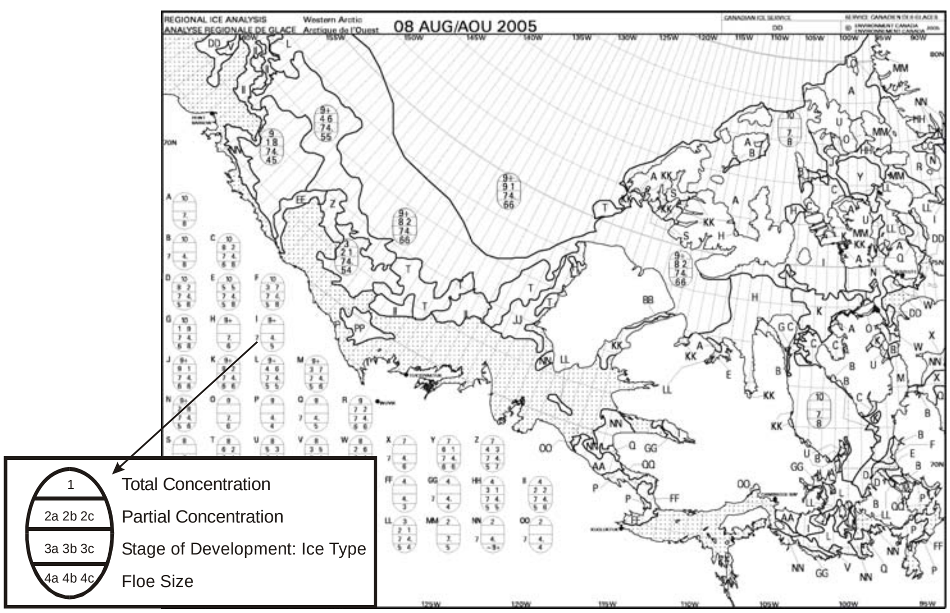

Figure 2: Illustrative Ice Chart of the Western Canadian Arctic and the definition of the Egg Code.

Figure 3 shows an example of a hypothetical offshore area which in Year 1 has two different regions of distinct ice conditions. These conditions are identified by the two Egg Codes. Using the information in the Egg Code (i.e. the ice type and ice concentration), it is possible to calculate the Ice Numeral (IN) for each region. This has been done for a Type B vessel in this example. In the following year on the same date, it is very likely that the same geographic area will have different ice conditions. Figure 4 shows the same area with two different ice regions for Year 2 and their corresponding Ice Numeral for a Type B vessel.

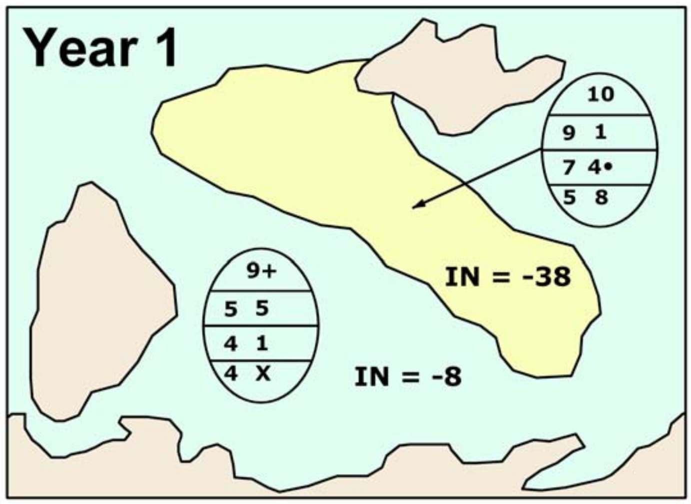

Figure 3: Illustration of two ice regions in a hypothetical offshore area for Year 1.

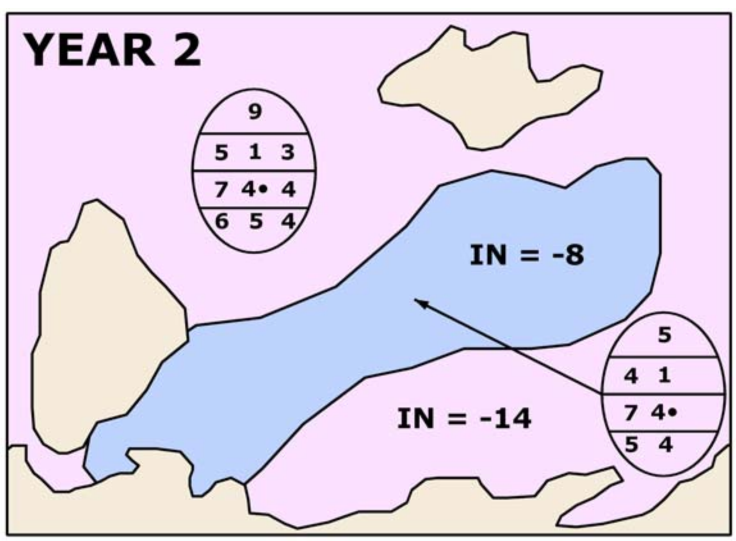

Figure 4: Illustration of two ice regions in a hypothetical offshore area for Year 2.

The question is: What are the average Ice Numerals for this geographic area based on these two years of information? Figure 5 shows the situation for a two-year period in this hypothetical example. Since the ice conditions were not the same for each year, it is necessary to delineate overlapping regions and this creates, in this case, six different ice regions (polygons). The average Ice Numeral can be calculated for these six regions by simply averaging the Ice Numeral determined from the two years of data. This process can be repeated for as many years as there are available Ice Charts. Of course, this example is very simple. The complexity and amount of the analyzed data dramatically increases using real Ice Charts and including many years of data. Nevertheless, using digital Ice Charts and using a Geographic Information Systems (GIS) approach, the analysis can be performed on a desktop computer.

This basic approach has been applied to define the boundaries (both zones and dates) for an updated Zone-Date System. Figure 6 shows the results of this approach for the week of August 7 to 13 from 1982 to 2007 for the Canadian western Arctic. As might be expected, the size of each polygon is very small. There are no artificial boundaries – the analysis is based solely on the regions of the ice regimes in each Ice Chart. The analysis for this chart generated 146,125 different polygon regions. It looks very much like a spaghetti chart.

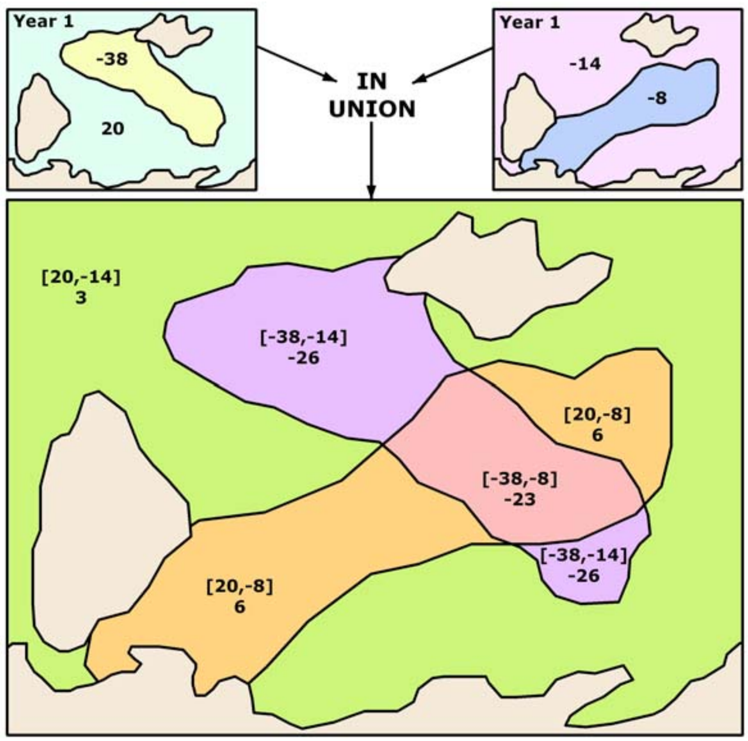

Figure 5: Schematic illustration showing the six ice regions (polygons) based on two years of data. The average Ice Numeral is shown for each polygon region.

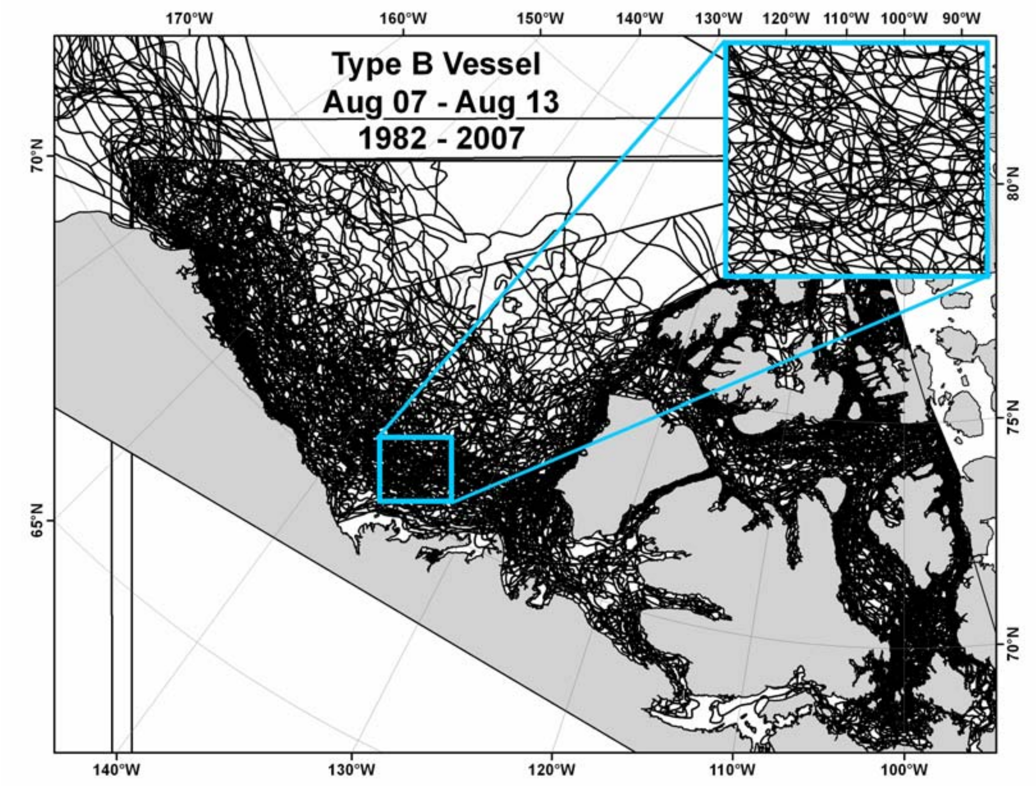

Figure 6: Analysis applied to the Canadian western Arctic for the week of August 7-23 for each year from 1982 to 2007.

It is possible to use colour coding to evaluate the ice severity of each of the polygon regions. This can be done by assigning a colour code to the average Ice Numeral for each polygon region. This has been done here for a Type B vessel. Average Ice Numerals with a value greater than five are given a dark green colour whereas an average IN between zero and five is given a light green colour. These are regions that would allow navigation at this time of the year for a Type B vessel. For IN values below zero, the polygons are coloured yellow, to pink to red for increasing ice severity and risk of damage to a vessel (i.e. increasingly more negative Ice Numerals). The extra levels of colour were included to help to identify those transition regions that are close to the IN=0 (go, no go) boundary of the Ice Regime System. This added information will be helpful in evaluating the regions where the CHC modified Ice Regime System (Timco et al. 2004) would aid the navigator.

Figure 7 shows the results of this overall analysis. This is an extremely striking figure, especially when compared to that of Figure 6. It shows very dramatic and clear trends where safe shipping and hazardous shipping would be encountered at this time of year for a Type B vessel. It shows clear evidence of historical regions of severe ice conditions (red regions) as well as regions where shipping should be allowed (green regions). It also shows the transitions regions. Clearly, this is a very powerful approach to dealing with the revisions to the Zone-Date System.

It is possible to argue that this approach represents only the average value and other factors come into play. Of course that is correct. However the data can be easily analyzed to look at regions where there are high standard deviations. These are the regions where there is considerable variation from year-to-year. This variability must be considered in the revised ZDS. There is considerable talk about the lessening of the ice conditions in the Arctic over the past few years. Again, this approach can be performed using, say, six-year windows to see if there are any definite trends due to climate warming. All of these factors will be considered in this development of the overall revised system.

This approach can be used to define the boundaries (both zones and dates) for all the vessel classes considered in the new Canadian Arctic regulations. This will be done by first assigning unique Ice Multipliers for each vessel class (Kendrick 2005), including all seven of the Polar Class vessels as well as the Baltic Type A and Type B vessels.

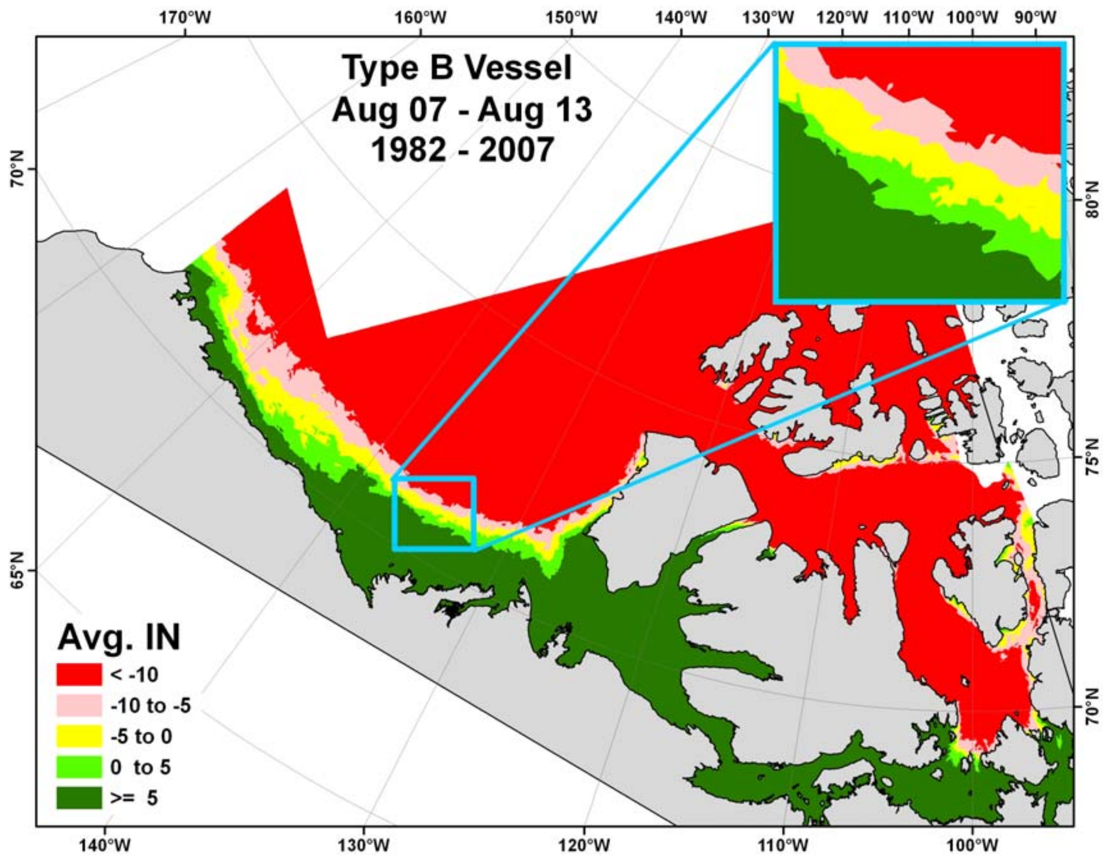

Figure 7: Results of the analysis showing the regions where navigation is allowed (given by the green colours) and those where it is not allowed (given by the yellow, pink and red colours) for a Type B vessel in the western Arctic during the second week of August.

6.0 HYBRID SYSTEM: APPLICATION TO TYPE B VESSELS

The NRC-CHC has applied this technology to examine the ice conditions in the Canadian Arctic for the last 25 years. As a first step towards the development of the new Hybrid System, the existing Ice Multipliers for Type B vessels were used to evaluate the severity of the ice conditions throughout the year. The maps of the Arctic showing the ice severity for Type B vessels are presented in Appendix B. They will not be discussed in detail here. The following discussions are based on these maps.

6.1 Proposed Changes to Zone Boundaries

Examination of the maps showed that there were two regions where the existing definition for the Zone boundaries did not agree with the ice conditions. These Zones were Zones 4 and Zone 5. Each will be discussed in turn.

6.1.1 Zone 4

The region west of Banks Island in the western Arctic was not well represented by the existing Zone boundaries. An examination of the Arctic Type B maps (Appendix B) for this region showed that there were regions where the ice was too severe for a Type B vessel, yet the vessels were allowed to enter the regions through the existing Zone-Date System. Further, this region was characterized by extremely large seasonal variations that could not be properly handled by the rigid ZDS. Figure 8 shows the proposed changes for the boundaries for Zone 4. These changes to the boundaries also affect the boundaries for Zones 1 and Zones 12. Figure 9 illustrates that there are significant changes to the ice condition in this region throughout the summer. Thus, the use of the Modified Ice Regime System is mandatory at all times when entry into this Zone is allowed.

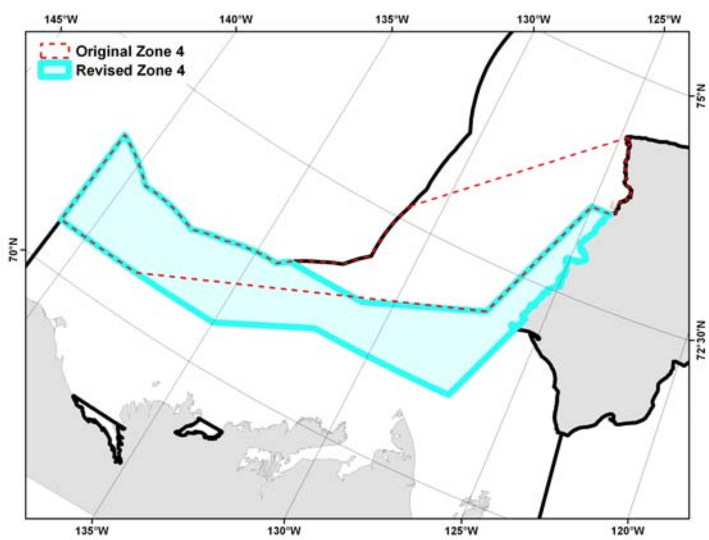

Figure 8: Proposed new boundaries for Zone 4 based on an analysis of Type B vessels.

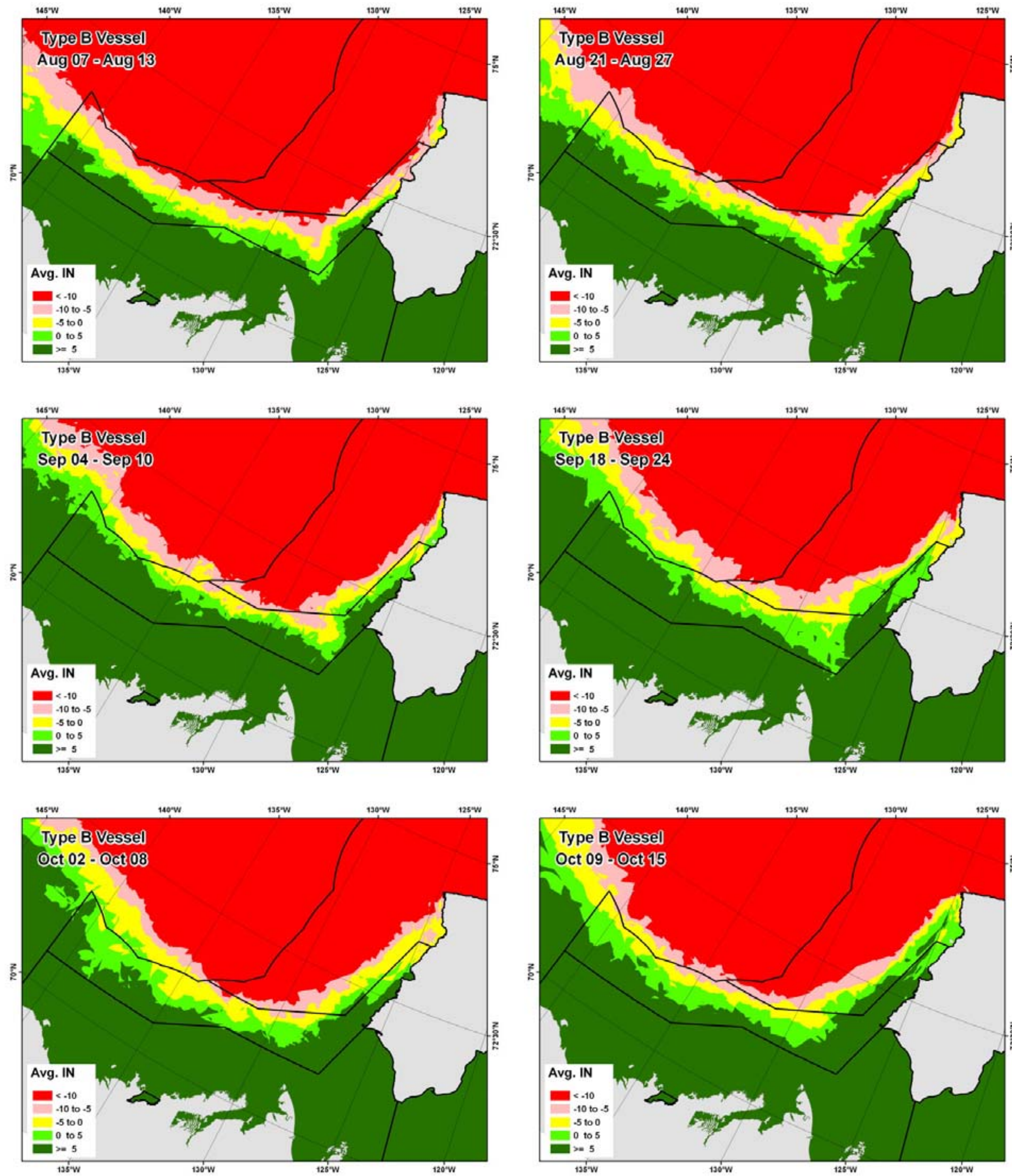

Figure 9: Illustration of the ice conditions in the new Zone 4 throughout the summer and autumn seasons.

6.1.2 Zone 5

The existing Zone-Date System does not allow entry into Zone 5 at any time of the year. Examination of the Type B Arctic maps clearly showed that there was a large difference in the ice conditions in this region. In the eastern part of the Zone (Committee Bay), the average ice conditions were too severe for a Type B vessel and the current no-entry policy well represented this region. However, in the western part of Zone 5 (Pelly Bay), the ice conditions were generally less severe and there were time-windows where safe navigation was possible. Examination of this regions showed that the ice conditions were generally consistent with those in Zone 6. Therefore it is proposed that the western section of Zone 5 become part of Zone 6. Figure 10 shows the proposed boundary for Zone 5. As mentioned, this change also affects the boundaries for Zone 6. Figure 11 illustrates that the new Zone 5 has severe ice conditions for Type B vessels throughout the year.

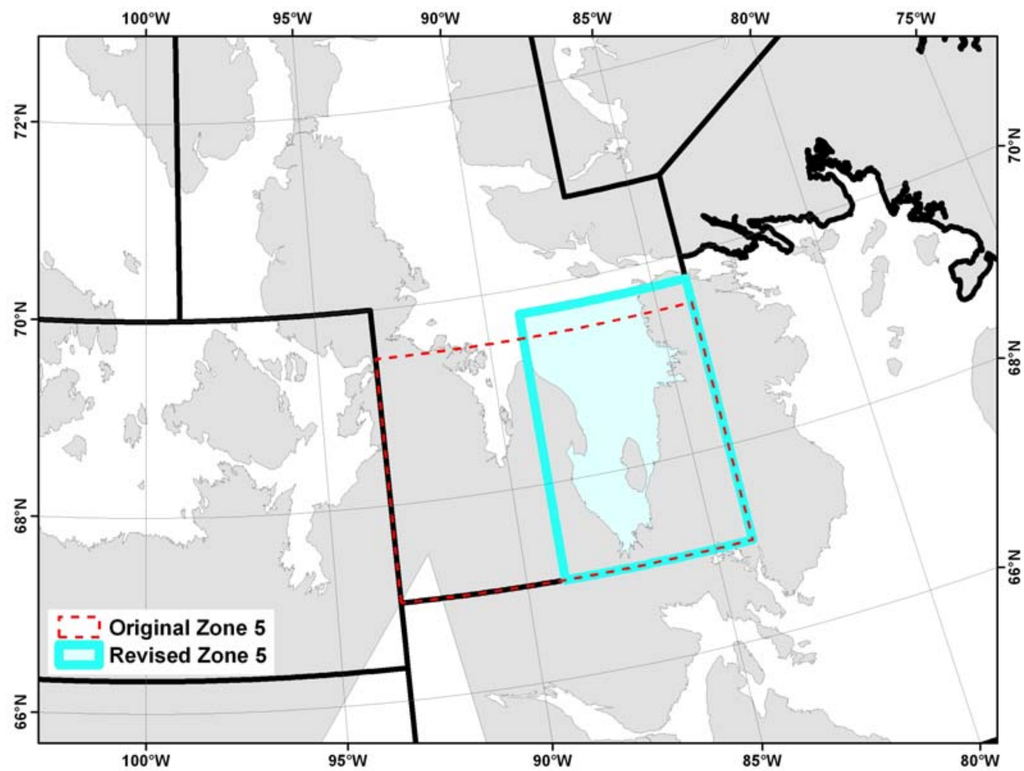

Figure 10: Proposed new boundaries for Zone 5 based on analysis of Type B vessels.

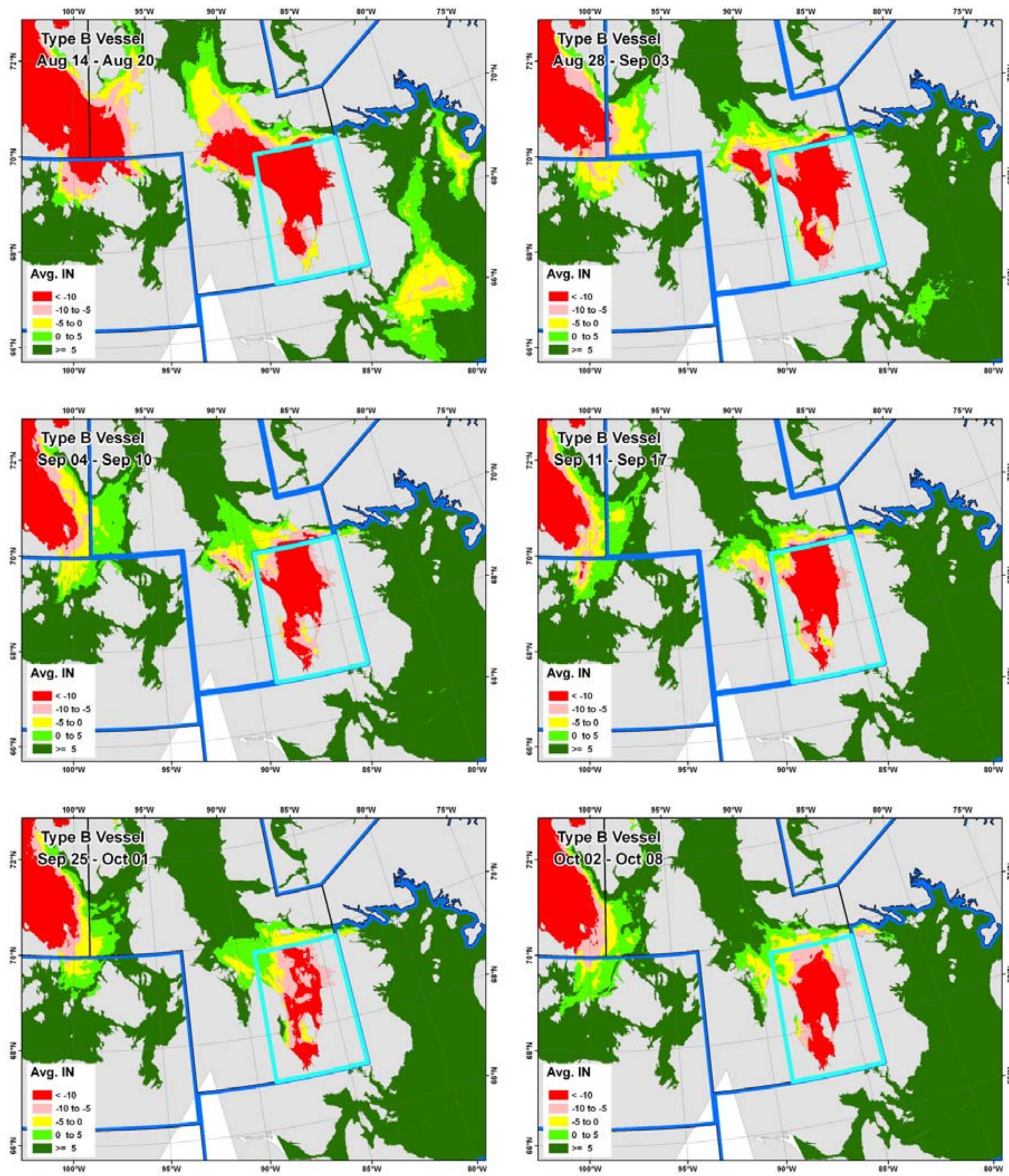

Figure 11: Illustration of the ice conditions in the new Zone 5 throughout the summer and autumn seasons. Type B vessels are not allowed at any time into Zone 5.

6.1.3 Other Zones

There are a few other potential regions that should be examined in more detail. They are mentioned here for detailed discussions with Stakeholders.

- The section of Zone 3 and Zone 6 along the eastern edge of Ellesmere Island through Nares Strait, Kane Basin and Smith Sound are significantly different in ice conditions than the rest of these zones. The ice severity looks similar to that of Zone 1 (i.e. many large multi-year ice floes) and it is suggested that this region be moved into Zone 1.
- Parts of Zone 6 have high variability of ice conditions from year-to-year. Some years show conditions that are very severe for a Type B vessel. One approach to deal with this variability would be to sub-divide the zone into sub-zones (i.e. Zone 6a, 6b, etc) which would require the use of the Modified Ice Regime System even if the rest of Zone 6 was an Open Zone period.

6.1.4 Hybrid Zone Map

The changes in boundaries to Zone 4 and 5 also affected several other zones, as discussed above. Figure 12 presents a view of the proposed Hybrid Zone boundaries[2].

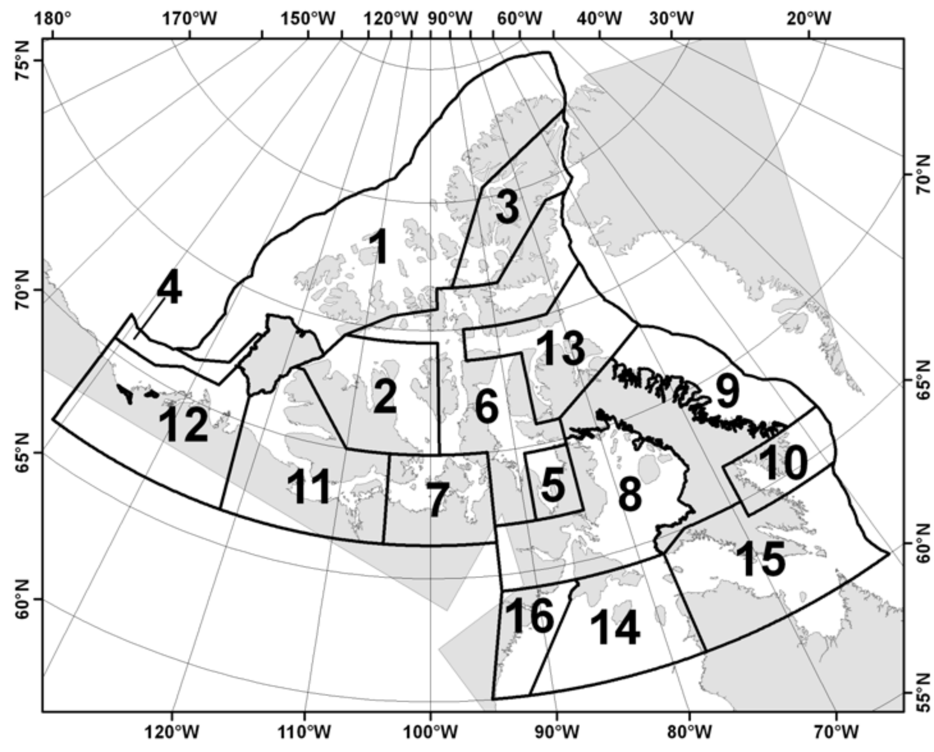

Figure 12: Proposed Zone boundaries in the Hybrid System.

[2] It should be noted that these suggested changes were made based only on the analysis of a Type B vessel. These and possibly other zone boundaries may change once other vessel classes have been considered.

6.2 Proposed Changes to the Zone Dates

Examination of the Type B Arctic maps (Appendix B) clearly showed that the existing dates for a Type B vessel were not well represented by the existing Zone-Date System. The large annual variations as well as the variations in ice conditions within a zone clearly showed that the simple Zone-Date System was not suitable. However, it was evident that a Hybrid System would provide a more suitable approach for dealing with the ice conditions in the Regulations. It was clear that a combination of a simple Zone-Date System along with using the Modified Ice Regime System was a better approach.

The Hybrid System uses the Modified Ice Regime System during the times of the season where there are generally highly variable ice conditions, either within a zone, or from seasonal variations. When the ice conditions were more consistent and favourable for navigation for a Type B vessel, the formal use of an Ice Regime System would not generally be required. During these periods, navigation would be considered as an Open Zone (OZ). Due care and diligence of the navigator[3] is required.

The details for defining the individual dates for each zone will not be discussed in detail here. However, maps of the ice conditions for Type B vessels are presented in Appendix B. These maps can be consulted for information pertaining to the ice conditions in each zone throughout the year. The proposed dates for the Hybrid System for a Type B vessel are given below. They are grouped according to the times when the Modified Ice Regime System is Mandatory (MIRSM) and the dates when it is an Open Zone (OZ). Information on the existing dates for each zone is also given for comparison.

Zone 1 (new boundaries)

Existing ZDS	No entry
Hybrid System	No entry

Zone 2

Existing ZDS	No entry
Hybrid System	No entry

Zone 3

Existing ZDS	Aug 20 to Sept 5
Hybrid System	MIRSM Aug 28 to September 15

Zone 4 (new boundaries)

Existing ZDS	Aug 20 to Sept 15
Hybrid System	MIRSM Aug 20 to Oct 15

Zone 5 (new boundaries)

Existing ZDS	No entry
Hybrid System	No entry

[3] Of course due care and diligence of the Navigator is also required when using the Ice Regime System.

Zone 6 (new boundaries)

Existing ZDS	Aug 25 to Sept 30
Hybrid System	MIRSM Aug 28 to Sept 5
	OZ Sept 6 to Sept 30
	MIRSM Oct 1 to Oct 15

Zone 7

Existing ZDS	Aug 10 to Oct 15
Hybrid System	MIRSM Aug 6 to Aug 15
	OZ Aug 15 to Oct 15
	MIRSM Oct 16 to Oct 22

Zone 8

Existing ZDS	Aug 10 to Oct 31
Hybrid System	MIRSM Aug 5 to Aug 15
	OZ Aug 16 to Nov 25

Zone 9

Existing ZDS	Aug 10 to Oct 31
Hybrid System	MIRSM Aug 7 to Aug 15
	OZ Aug 16 to Nov 15
	MIRSM Nov 16 to Nov 20

Zone 10

Existing ZDS	Aug 1 to Oct 31
Hybrid System	MISRM July 24 to July 31
	OZ Aug 1 to Nov 15
	MIRSM Nov 16 to Nov 22

Zone 11

Existing ZDS	July 15 to Oct 20
Hybrid System	MIRSM July 15 to July 31
	OZ Aug 1 to Oct 31
	MIRSM Nov 1 to Nov 15

Zone 12 (new boundaries)

Existing ZDS	July 1 to Oct 25
Hybrid System	MIRSM June 25 to July 7
	OZ July 8 to Oct 31
	MIRSM Nov 1 to Nov 15

Zone 13

Existing ZDS	July 15 to Oct 15
Hybrid System	MIRSM July 7 to July 24
	OZ July 25 to Oct 20
	MIRSM Oct 21 to Nov 12

Zone 14

Existing ZDS	July 1 to Nov 30
Hybrid System	MIRSM June 25 to July 15
	OZ July 16 to Nov 30

Zone 15

Existing ZDS	July 1 to Nov 30
Hybrid System	MIRSM June 25 to July 15
	OZ July 16 to Nov 30

Zone 16

Existing ZDS	June 20 to Nov 10
Hybrid System	MIRSM June 20 to June 30
	OZ July 1 to Nov 15
	MIRSM Nov 15 to Nov 30

Figure 13 shows the proposed Hybrid System for a Type B vessel. It can be seen that most regions have a combination of the Modified Ice Regime System and an Open Zone. It is interesting to compare this to the existing dates for the existing Zone-Date System (see Figure 14). Clearly there are more opportunities for navigation using the Hybrid System. However, in some Zones (for example Zones 3 and 4), the Modified Ice Regime System must be used at all times during the allowable entry times for the Zone.

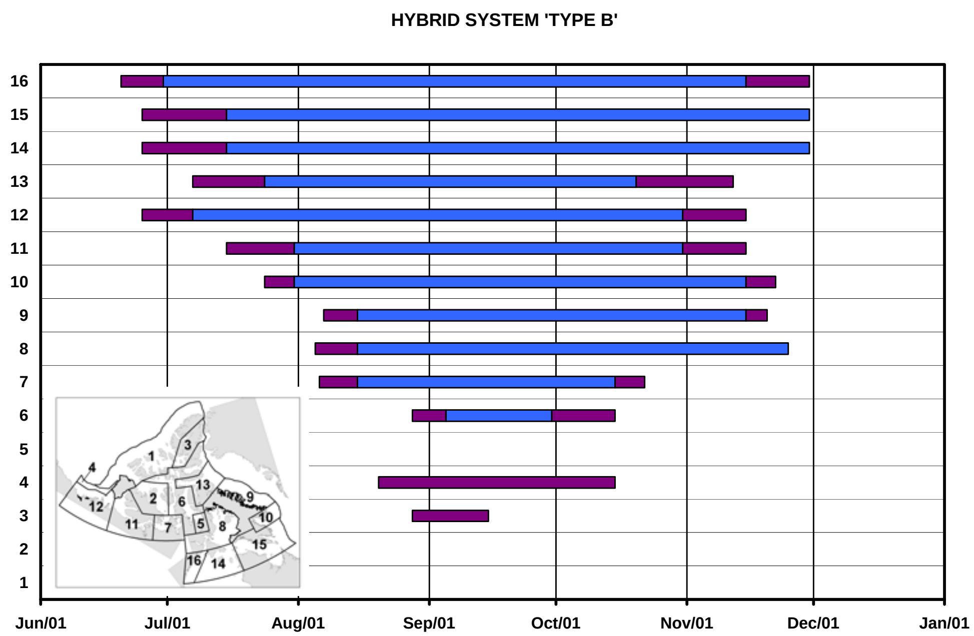

Figure 13: Entry/Exit dates for Type B vessel in the Hybrid System. The Blue bars represent Open Zone and the burgundy bars represent dates when the Modified Ice Regime System must be used.

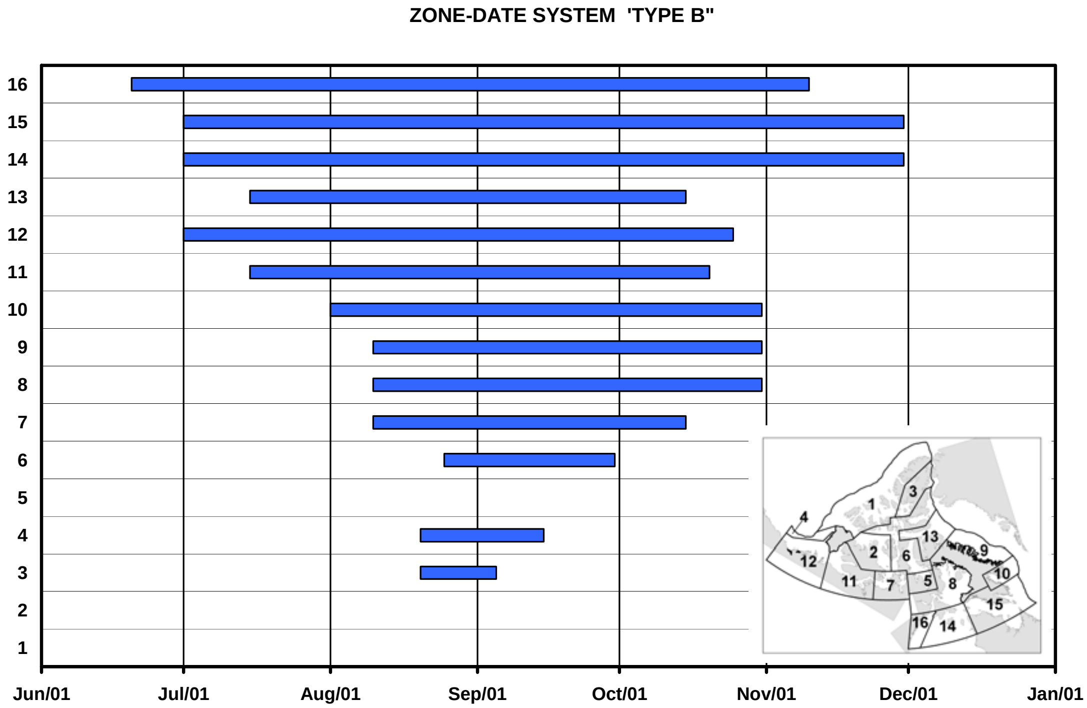

Figure 14: Entry/Exit dates for a Type B vessel in the existing Zone-Date System. The Blue bars represent Open Zone dates.

7.0 MODIFIED ICE REGIME SYSTEM

The Modified Ice Regime System would have the same basic format as the existing System. That is, each vessel class would be assigned unique Ice Multipliers and the Ice Numeral would be calculated according to Equation 1. The IN=0 go/no-go would still be used to determine whether a vessel can enter a specific ice regime. However, there would be some significant changes compared to the existing Ice Regime System. These changes are summarized as follows:

7.1 Ice Categories

There would only be two ice categories used in the Modified System. These are first-year sea ice and Old Ice. In the existing system, Old ice is subdivided into second-year ice and multi-year ice. However research by the NRC-CHC (Johnston and Timco, 2008) has clearly illustrated that even experienced ice specialists have uncertainty on differentiating between these two ice types. Therefore they would not be subdivided in the modified system and ice older than one season would be treated as Old Ice.

7.2 Ice Thickness

The existing Ice Regime System is based on the ice thickness as defined by the World Meteorological Organization (WMO) and detailed in MANICE (2005). These definitions are related to **growing** sea ice and they do not apply to sea ice that is decaying. Therefore it is proposed that the Ice Numeral would be calculated based on the actual ice thickness and not by the WMO definitions. However, the same thickness boundaries as used by the WMO would be used for defining the Ice Multipliers.

7.3 Summer Bonus

The NRC-CHC (Timco and Johnston 2003; Timco et al 2004) has shown that the existing Ice Regime System can be modified to accommodate summer ice conditions with better correlation to empirical data. The NRC-CHC has suggested that this Summer Bonus should be granted to vessels if they meet all of the following criteria:

1. Summer ice conditions are in effect – These conditions would commence if the ice has decayed to the rotten stage (thaw holes throughout the full-thickness of ice)[4]. The summer decay bonus should be removed as soon as there is Thin First-year ice (or thicker ice) in the ice regime in the autumn during ice growth (Timco and Johnston 2003).
2. Ice Navigation Equipment – Vessels with high quality equipment for identifying ice features to aid in safe navigation have the ability to anticipate and avoid unsafe ice conditions. The criteria for sufficient Ice Navigation Equipment must be decided by Transport Canada with input from key Stakeholders.
3. Experienced Captains - Vessels with experience Captains and personnel often have a better appreciation for unsafe ice conditions and safe speeds in different

[4] The Canadian Ice Service has been developing an Ice Strength Chart (Gauthier et al 2002; Langlois et al. 2003). If this is available, the summer bonus would commence as soon as the strength of the first-year ice is less than 15% of its mid-winter strength.

ice conditions. The criteria for sufficient Experience must be decided by Transport Canada with input from key Stakeholders.

The Ice Multipliers for all first-year ice types (including Open Water) should be increased by +1 for vessels that qualify for the Summer Bonus[5].

7.4 No Decay Bonus for Old Ice

Significant research (Johnston et al, 2002, 2003; Johnston 2004; Johnston and Timco 2008; Timco and Johnston 2002) has shown that multi-year ice does not decay in the same manner as first-year sea ice. The research has shown that first-year ice strength decreases quite rapidly such that it is approximately 15% of its mid-winter strength in early July. Multi-year ice does not decay to this extent. Therefore, there is little justification for applying a decay bonus for Old Ice. The Ice Multipliers for Old Ice will be the same throughout the year.

7.5 Ice Navigator

An experienced Ice Navigator is required to implement the Modified Ice regime System. The criteria for sufficient qualifications for an Ice Navigator must be decided by Transport Canada with input from key Stakeholders.

7.6 Reporting to NORDERG

Reporting requirements need to be sufficient to allow a Pollution Prevention Officer (PPO) to make an initial assessment of whether the vessel is in potentially safe conditions and is being operated safely (position and speed). The current Ice Regime System also requires vessels to report their experience to NORDREG. It is suggested that this detailed reporting (i.e. after-action reports) would not be a requirement with the Modified Ice Regime System. However, the vessel must keep sufficient records to justify navigation during the date periods when the Modified Ice Regime System is mandatory[6].

7.7 Ice Multipliers

Table 3 provides the Ice Multipliers for Type B vessels in the Modified Ice Regime System.

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[5] The NRC-CHC proposed an Arctic Certificate approach for summer conditions as one of the potential options (Timco and Kubat 2007a, 2007b). This approach could be pursued to simplify the implementation of the Summer Bonus.

[6] The NRC-CHC would be very interested to receive copies of this information to further refine the Modified Ice Regime System.

Table 3: Table of Proposed Ice Multipliers for Type B Vessels

	Thickness Range	Ice Multiplier	Summer Bonus Ice Multiplier
Old Ice	all	- 4	- 4
First-Year Ice			
(TFY)	> 120 cm	- 2	- 1
(MFY)	70 - 120 cm	- 1	0
(FY)	50 - 70 cm	1	2
(FY)	30 - 50 cm	1	2
(GW)	15 - 30 cm	1	2
(G)	10 - 15 cm	2	3
(N)	< 10 cm	2	3
Open Water		2	3

8.0 SUMMARY AND CONCLUSIONS

This report has outlined the approach that was used to develop the Hybrid System for the Canadian Arctic waters. It was then applied to develop a proposed system for Type B vessels. The astute reader will have noticed that the authors did not provide detailed justification for the proposed changes. This was done intentionally. The authors realize that although the Ice Charts provide valuable information, input from experienced Captains is also essential to these revisions. Thus, these proposed revised zone boundaries and dates are meant as a starting point for discussion. The authors will meet and discuss these proposed changes with many of the Stakeholders of the ASPPR. These include Transport Canada; Canadian Coast Guard; Canadian Ice Service; governments of Nunavut, Northwest Territories and the Yukon Territories; northern ship owners, operators and Captains; and the marine arm of the oil and gas industry.

The authors invite comments/suggestions/criticisms/endorsements of the approach outlined in this report. Interested readers should provide comments to the first author at:

Dr. Garry Timco
Canadian Hydraulics Centre
National Research Council of Canada
1200 Montreal Rd.,
Ottawa, ON K1A 0R6 Canada
Phone 613-993-6673
Fax 613–952-7679
Email – garry.timco@nrc.gc.ca

It is anticipated that these discussions and feedback will further refine this proposed system. A one-day Stakeholders meeting will be held in the early part of 2010 to discuss these changes. The NRC-CHC will be developing the new Hybrid System boundaries for the remaining vessel classes in the Hybrid System.

9.0 ACKNOWLEDGMENTS

The authors would like to acknowledge the interest and financial support of Transport Canada, especially Victor Santos-Pedro, Ross MacDonald and Peter Timonin for this research. Comments from Andrew Kendrick, Bob Gorman and Tim Keane are also appreciated.

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Appendix A

Transport Canada Ship Safety Bulletin 04/2009

IACS UNIFIED REQUIREMENTS FOR POLAR CLASS SHIPS
Application in Canadian Arctic Waters

SHIP SAFETY BULLETIN

Bulletin No.: 04/2009
RDIMS No.: 3908731
Date: 2009-08-17
Y - M - D

Ship Safety Bulletins provide safety-related information to the marine community.
All bulletins are available at: www.tc.gc.ca/marinesafety

Subject: **IACS UNIFIED REQUIREMENTS FOR POLAR CLASS SHIPS**
Application in Canadian Arctic Waters

Purpose

This Bulletin explains Transport Canada's policy towards the application of new rules respecting structural and machinery requirements for polar ships, promulgated by the International Association of Classification Societies (IACS), as referenced from an International Maritime Organization (IMO) document.

Background

IACS Unified Requirements (URs) for Polar Class Ships (UR I1, I2 and I3) took effect in March 2008. New ships built to these URs will be assigned a Polar Class (PC) notation ranging from PC1 to PC7. A Polar Class notation may also be assigned to an existing vessel by applying to an IACS member to have the vessel assessed in accordance with the URs for Polar Class Ships.

Under authorities vested by the *Arctic Waters Pollution Prevention Act* (AWPPA), Transport Canada administers several regulations and standards that are aimed at preventing pollution and damage to the Arctic marine environment. Currently, these regulations and standards are based on a mix of unique Canadian Arctic Categories (AC & CAC), and Types that are based on the Finnish-Swedish (Baltic) Rules. Vessels designed to any other ice class are only considered for equivalency on a case-by-case basis. Vessels with the new Polar Class notations will be treated as described in this Bulletin.

The IACS URs for Polar Class Ships were developed as a result of international efforts originating at IMO to harmonize the many systems of requirements for polar ice-classed vessels. Working groups were set up, including representatives from national administrations, classification societies, industry, academia, and research organizations. In order to represent Canadian Arctic interests, Transport Canada provided a leading role at these IMO meetings and strongly supported the harmonization initiative.

Keywords:

1. Unified Requirements
2. Polar Class
3. Ice-covered waters

Questions concerning this Bulletin should be addressed to:

AMSR
V. M. Santos-Pedro
613-991-3160
shipshape@tc.gc.ca

Transport Canada
Marine Safety
Tower C, Place de Ville
11th Floor, 330 Sparks Street
Ottawa, Ontario K1A 0N8

To add or change your address, contact us at: marinesafety-securitemaritime@tc.gc.ca or 613-991-3135.
Owners of commercial vessels automatically receive Bulletins.

It was agreed that IMO would develop overall guidelines for ships operating in ice-covered waters. The resulting document was published by IMO as a joint Circular MSC 1056/MEPC 399 - Guidelines for Ships Operating in Arctic Ice-covered Waters in December 2002. It was also agreed that details of hull and machinery construction would be coordinated through IACS, and the (then draft) URs are referenced in the IMO Guidelines. The Guidelines and URs both utilize the seven Polar Classes - PC 1 through PC 7. PC 1 is the most capable class, capable of year-round operation in all ice conditions. PC 6/7 are for use in summer/autumn operations in medium/thin first-year ice, which may include old ice inclusions. The IMO Guidelines are currently under review for updates and application in all Arctic and Antarctic waters.

The development of the URs incorporates a great deal of Canadian operational experience, field data, research and development. Transport Canada has a full understanding of the technical background to the requirements, and remains a partner in ongoing development work.

Transport Canada Policy

Transport Canada supports the full implementation of the URs and of other relevant state-of-the-art knowledge incorporated in the IMO Guidelines through appropriate revisions to the *Arctic Shipping Pollution Prevention Regulations* (ASPPR) and to other related standards. Implementation will follow the Government of Canada's regulatory process including consultation and various forms of impact and benefit/cost analysis.

As an interim measure for navigation purposes, Transport Canada will consider that PC 6 and 7 vessels will be allowed to operate as Type A and B vessels (Baltic 1AS and 1A construction) respectively. This approach is valid both for access under the current ASPPR Zone/Date system and also under the Arctic Ice Regime Shipping System (AIRSS) Standards defined in Transport Publication (TP) 12259. The PC vessels are intended to be more suited to polar operations than are their Baltic equivalents, so this approach is conservative, and it may be revised for full implementation, giving access advantage to PC vessels.

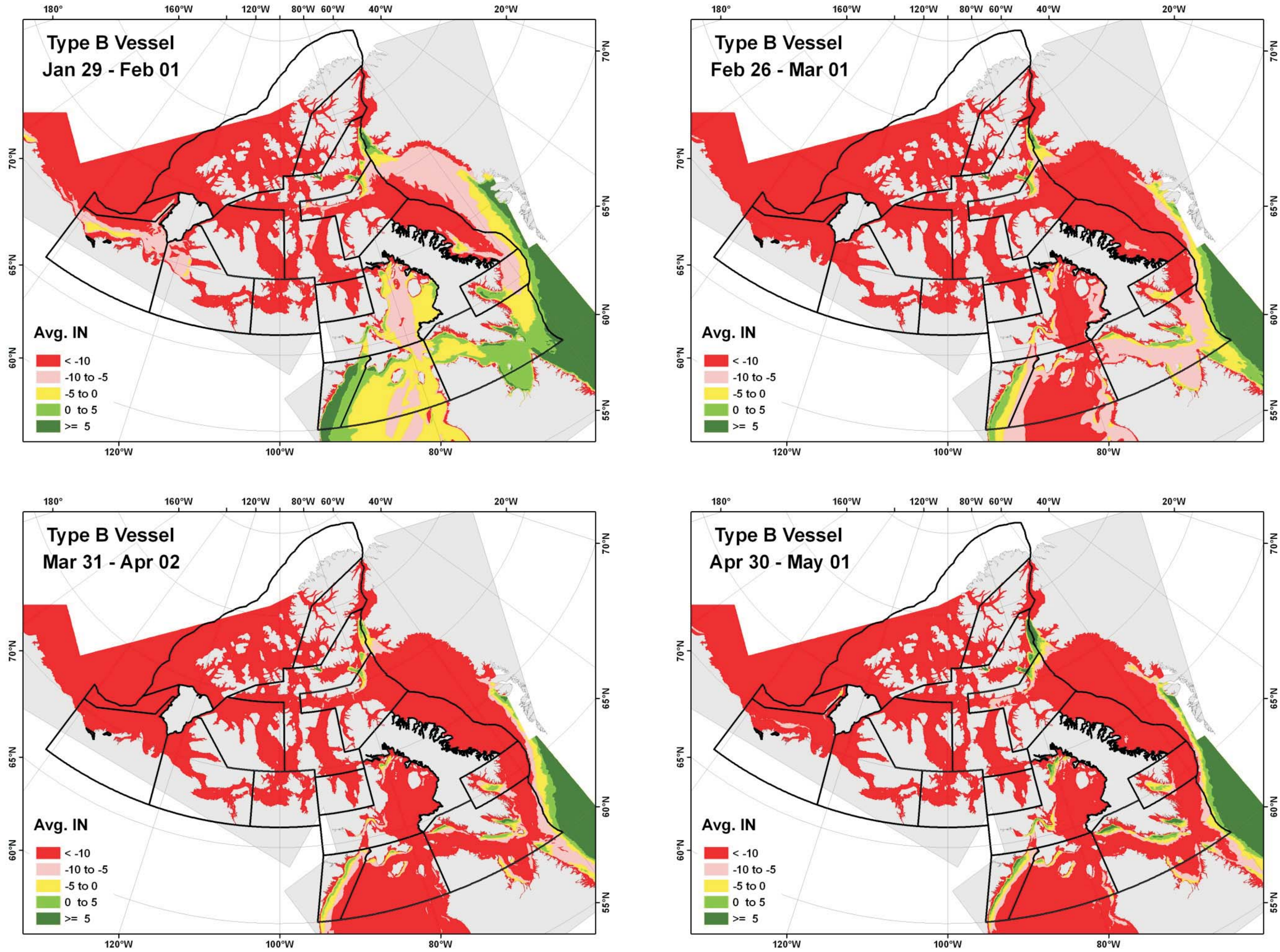
For other Polar Class vessels, the two highest classes - PC 1 and PC 2 - will be permitted to operate throughout the Arctic at any time of the year, provided they comply with other provisions of the Standard TP 12259 and with the damaged stability, subdivision, and pollutant segregation requirements of the current Canadian regulations and Equivalent Standards, or the IMO Guidelines. This approach corresponds to the access granted to vessels of Canadian Arctic Categories CAC 1 and CAC 2 under the current system.

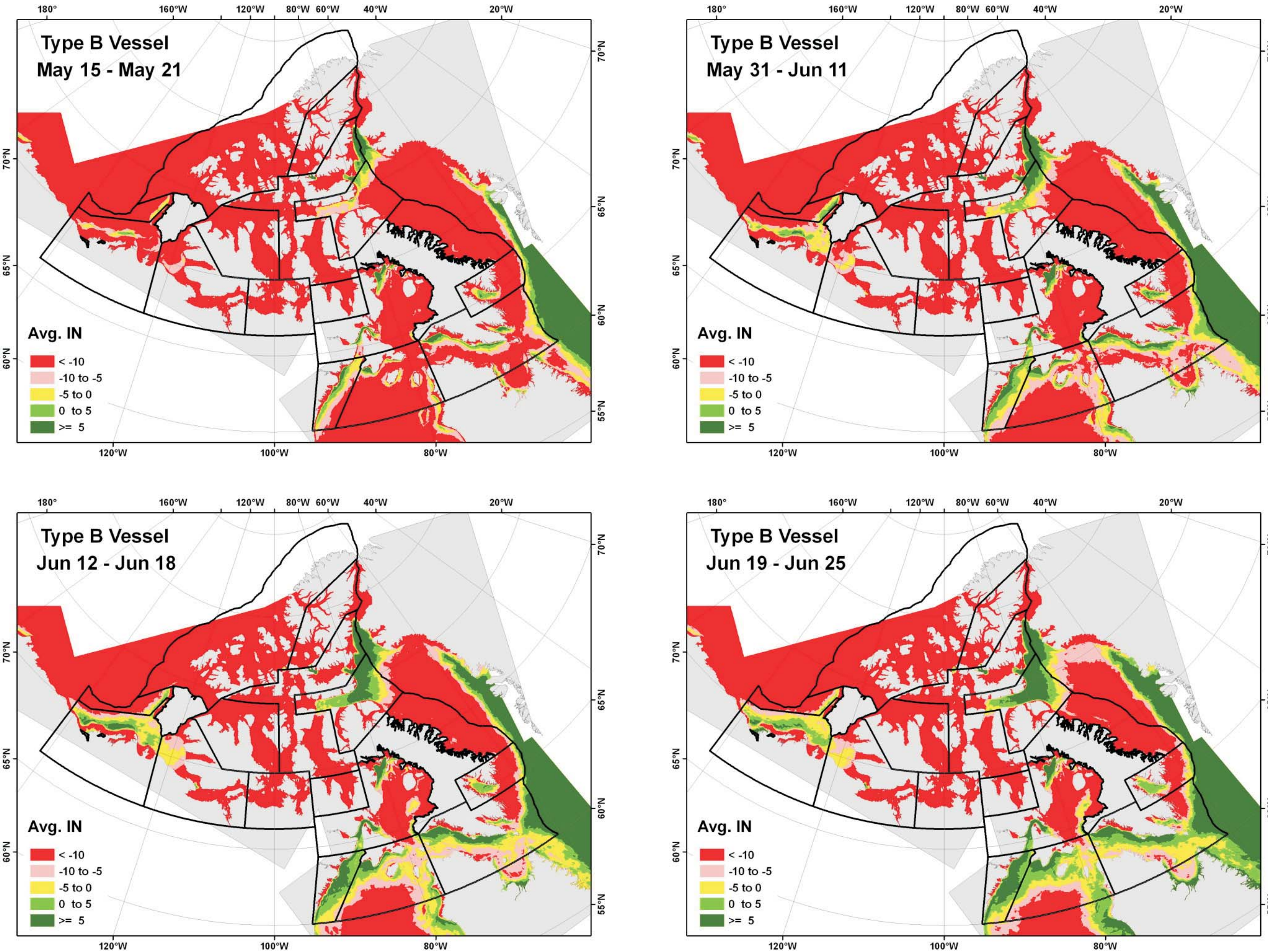
Vessels constructed as PC 3, 4, and 5 will also be permitted to operate under the AIRSS (TP 12259) subject to compliance with damaged stability, subdivision, and pollutant segregation. In the interim, it will be necessary to assign ice multipliers on a case-by-case basis, subject to the general principle that a PC 3's multipliers and resulting ice numerals will be no more onerous than those for CAC 3, and those for PC 4 will be no more onerous than those for CAC 4. PC 5 vessels will be expected to have multipliers between those for CAC 4 and Type A. No modifications will be made to the Zone/Date system to address PC 3, 4, and 5 vessels during the interim period, but such PC vessels will be permitted access during Type A seasons without needing to comply with the requirements of the Standard TP 12259. Verification of AIRSS ice multipliers for PC 3, 4, and 5 vessels will be undertaken by Transport Canada, Marine Safety based on submissions from vessel owners.

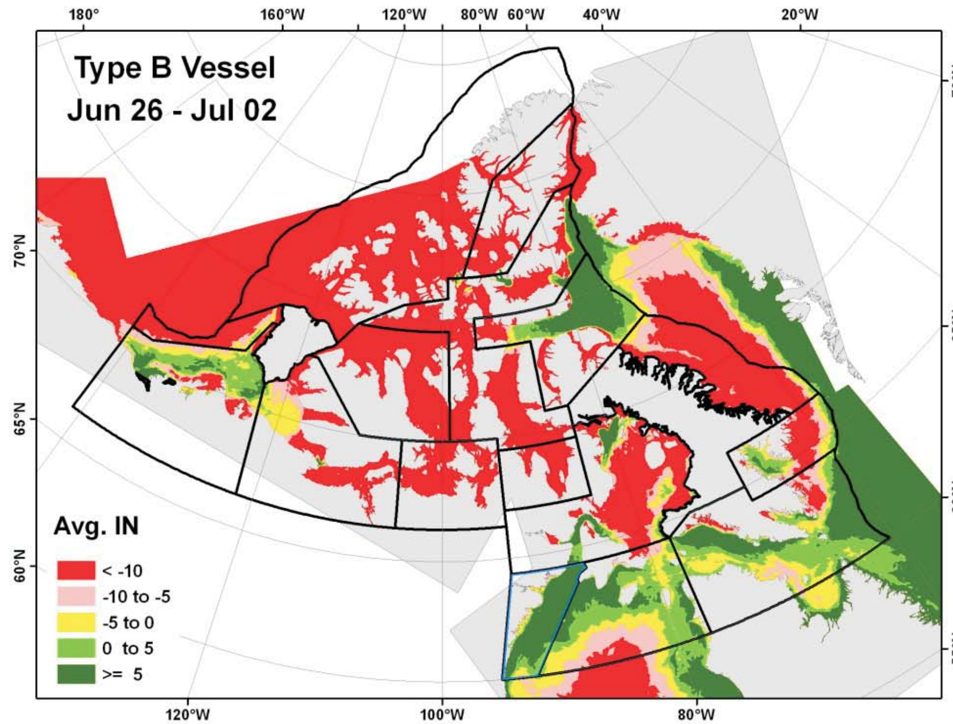
The choosing and assignment of an appropriate PC notation for new and existing vessels is the responsibility of vessel owners and their preferred IACS member classification society.

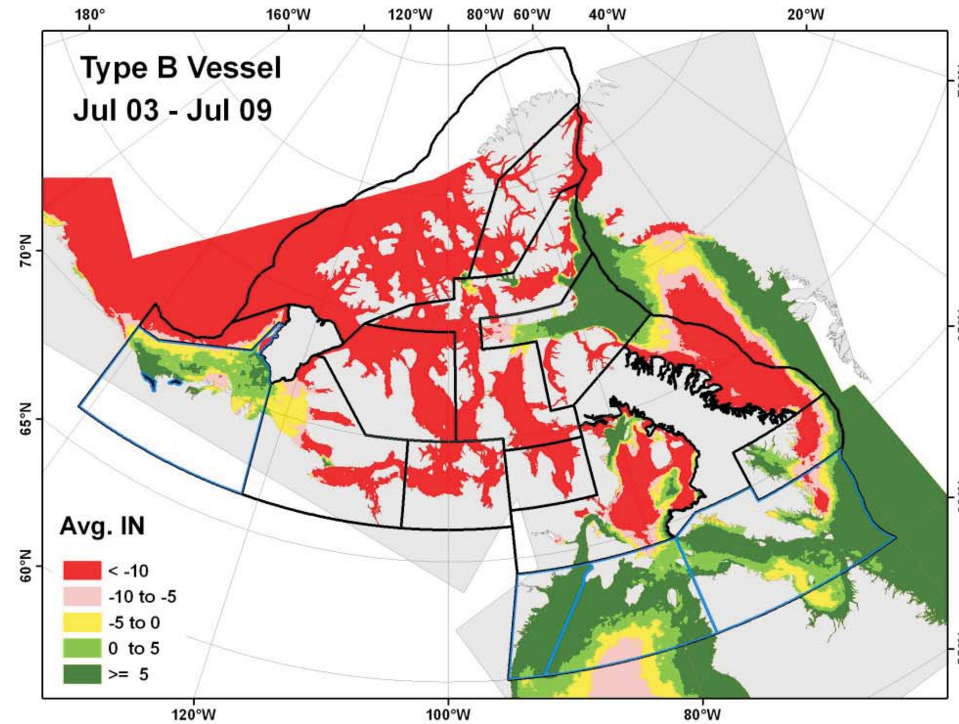
Appendix B

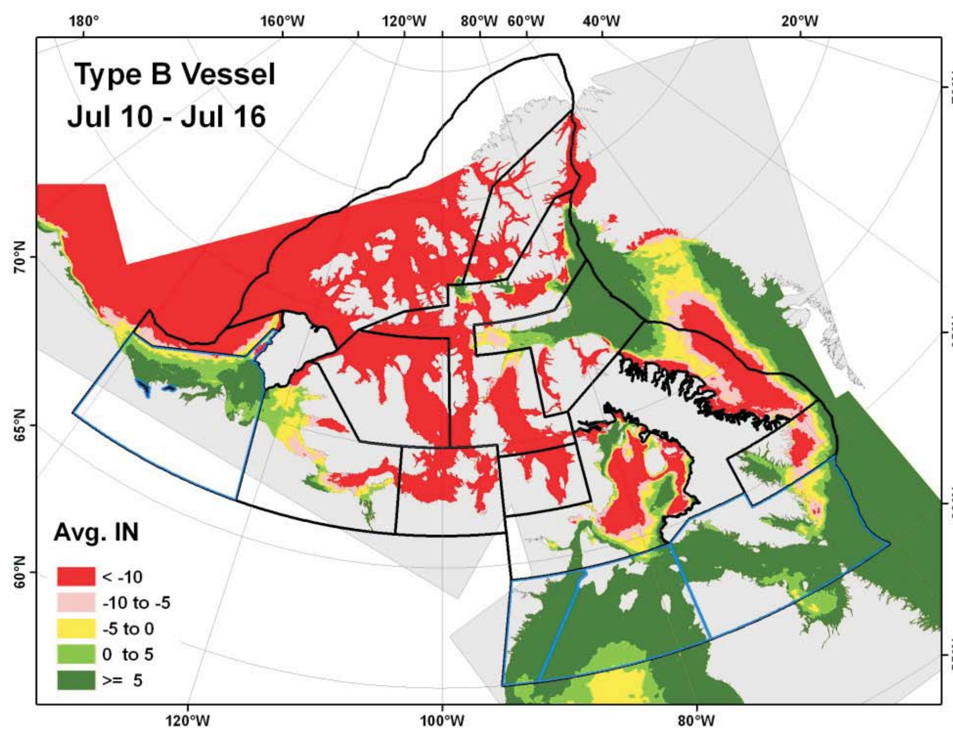
Ice Severity Maps for Type B Vessels

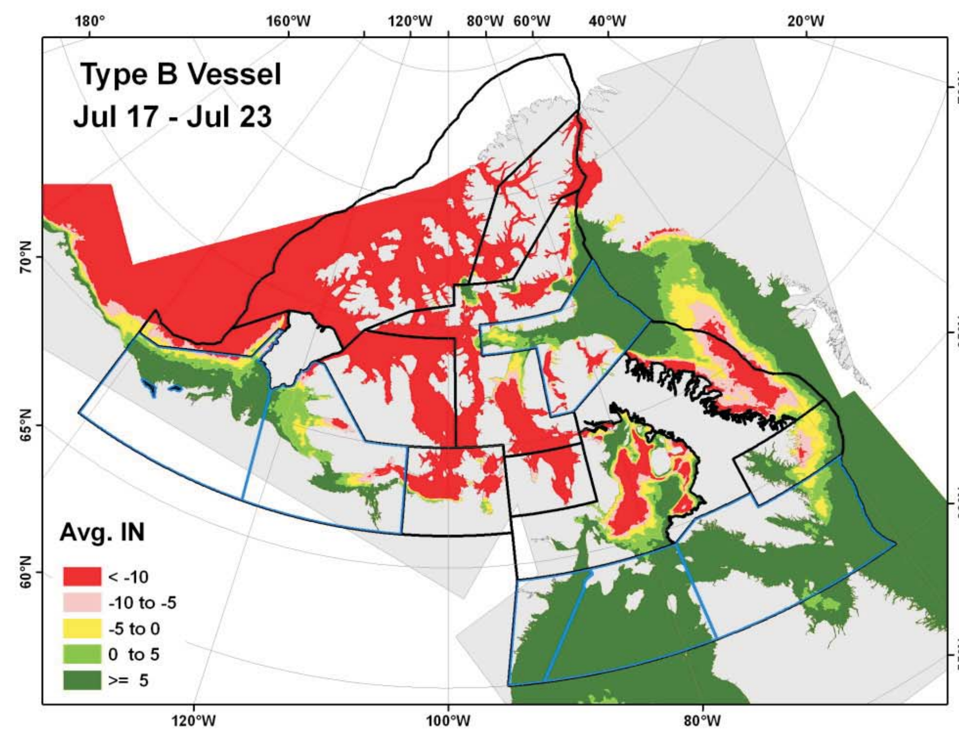

Type B Vessel
Jan 29 - Feb 01
Avg. IN
< -10
-10 to -5
-5 to 0
0 to 5
>= 5
180°
160°W
120°W
80°W
60°W
40°W
20°W
70°N
65°N
60°N
55°N
120°W
100°W
80°W
Type B Vessel
Feb 26 - Mar 01
Avg. IN
< -10
-10 to -5
-5 to 0
0 to 5
>= 5
Type B Vessel
Mar 31 - Apr 02
Avg. IN
< -10
-10 to -5
-5 to 0
0 to 5
>= 5
Type B Vessel
Apr 30 - May 01
Avg. IN
< -10
-10 to -5
-5 to 0
0 to 5
>= 5

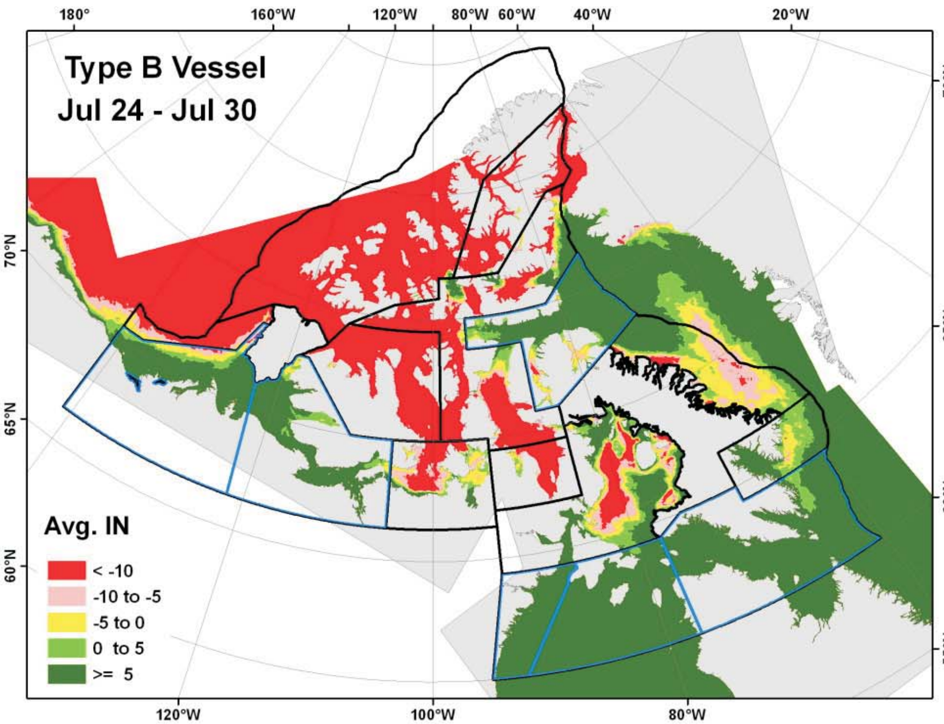

Type B Vessel
May 15 - May 21
Avg. IN
< -10
-10 to -5
-5 to 0
0 to 5
>= 5
Type B Vessel
May 31 - Jun 11
Avg. IN
< -10
-10 to -5
-5 to 0
0 to 5
>= 5
Type B Vessel
Jun 12 - Jun 18
Avg. IN
< -10
-10 to -5
-5 to 0
0 to 5
>= 5
Type B Vessel
Jun 19 - Jun 25
Avg. IN
< -10
-10 to -5
-5 to 0
0 to 5
>= 5
180°
160°W
120°W
80°W
60°W
40°W
20°W
120°W
100°W
80°W
70°N
65°N
60°N
55°N

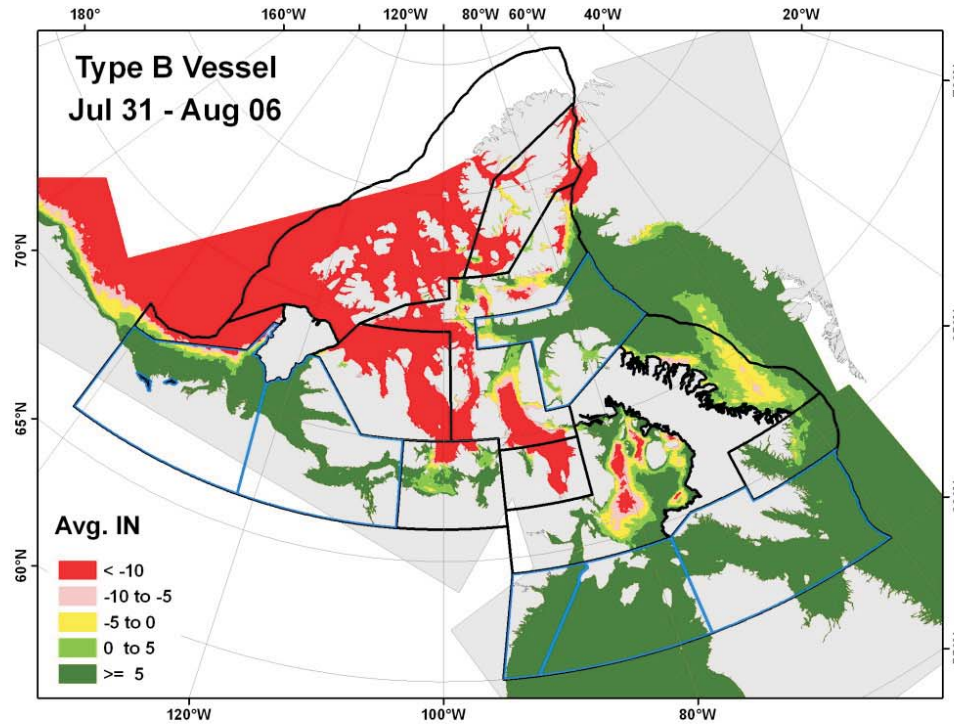

Type B Vessel
Jun 26 - Jul 02
Avg. IN
< -10
-10 to -5
-5 to 0
0 to 5
>= 5
180°
160°W
120°W
80°W
60°W
40°W
20°W
70°N
65°N
60°N
55°N
100°W

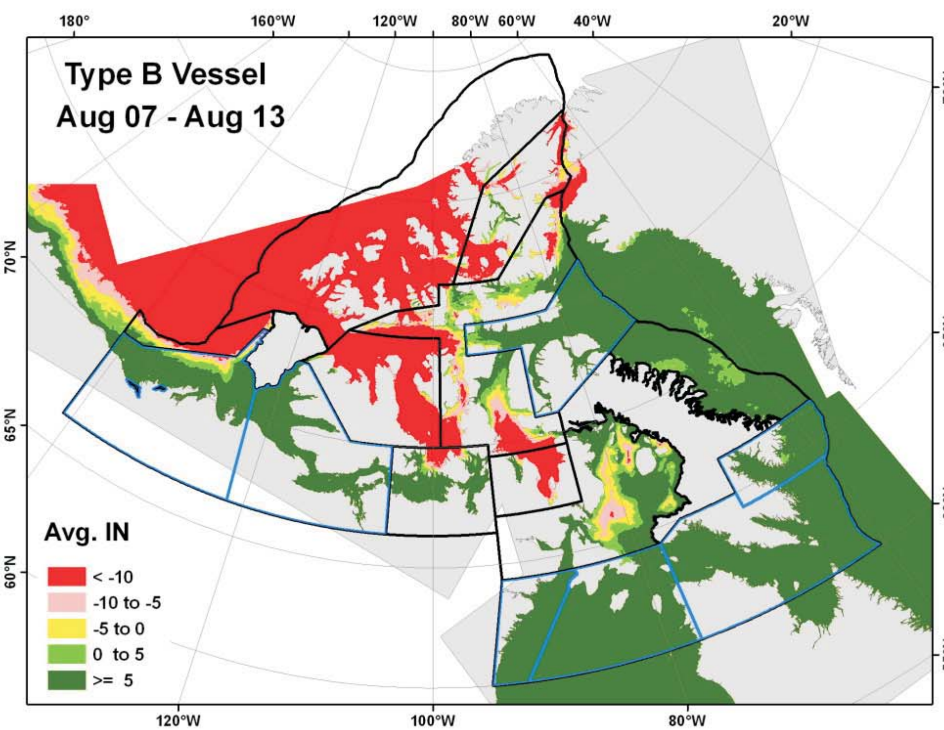

Type B Vessel
Jul 03 - Jul 09
Avg. IN
< -10
-10 to -5
-5 to 0
0 to 5
>= 5
180°
160°W
120°W
80°W
60°W
40°W
20°W
70°N
65°N
60°N
55°N
100°W


Type B Vessel
Jul 10 - Jul 16
Avg. IN
< -10
-10 to -5
-5 to 0
0 to 5
>= 5
180°
160°W
120°W
80°W
60°W
40°W
20°W
70°N
65°N
60°N
55°N
100°W


Type B Vessel
Jul 17 - Jul 23
Avg. IN
< -10
-10 to -5
-5 to 0
0 to 5
>= 5
180°
160°W
120°W
80°W
60°W
40°W
20°W
70°N
65°N
60°N
55°N
100°W


Type B Vessel
Jul 24 - Jul 30
Avg. IN
< -10
-10 to -5
-5 to 0
0 to 5
>= 5
180°
160°W
120°W
80°W
60°W
40°W
20°W
70°N
65°N
60°N
55°N
120°W
100°W
80°W


Type B Vessel
Jul 31 - Aug 06
Avg. IN
< -10
-10 to -5
-5 to 0
0 to 5
>= 5
180°
160°W
120°W
80°W
60°W
40°W
20°W
70°N
65°N
60°N
55°N
120°W
100°W
80°W


Type B Vessel
Aug 07 - Aug 13
Avg. IN
< -10
-10 to -5
-5 to 0
0 to 5
>= 5
180°
160°W
120°W
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60°N
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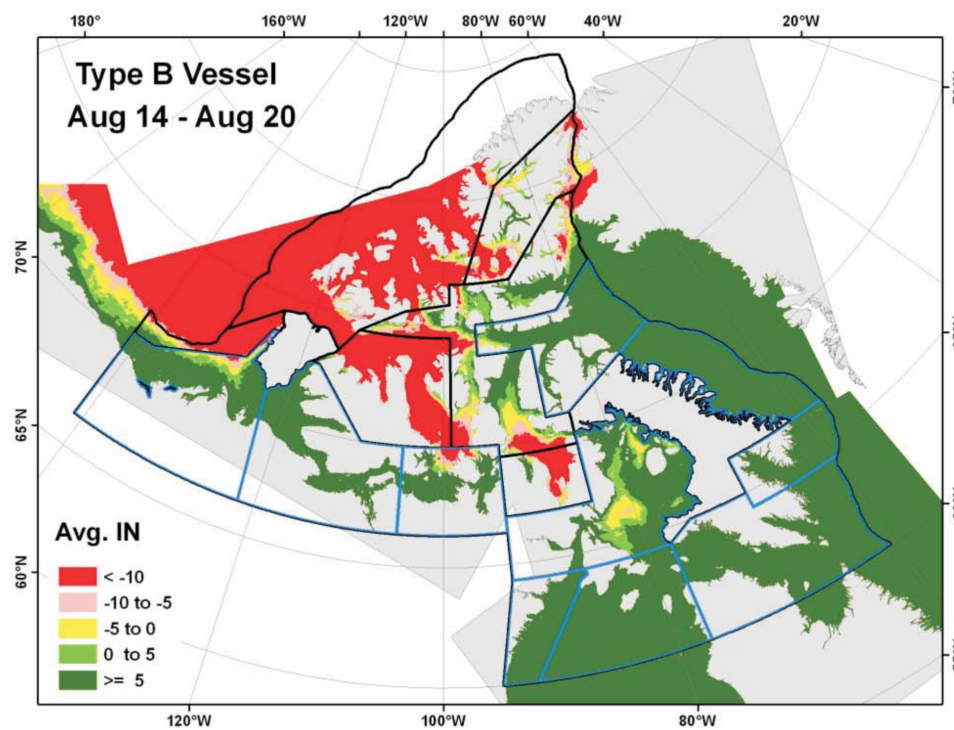
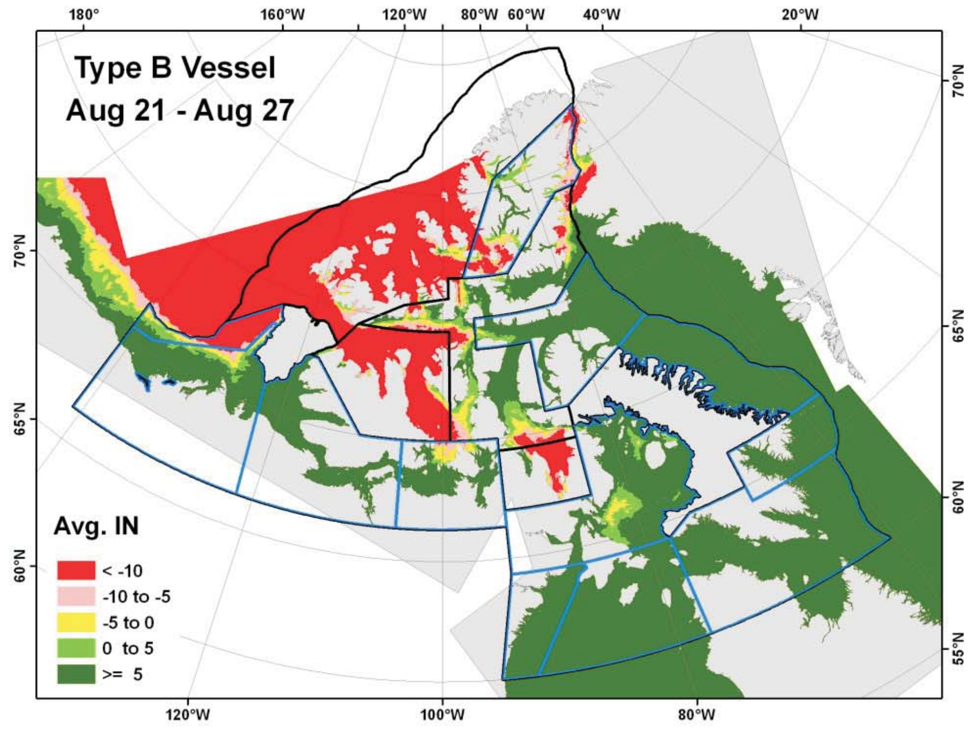
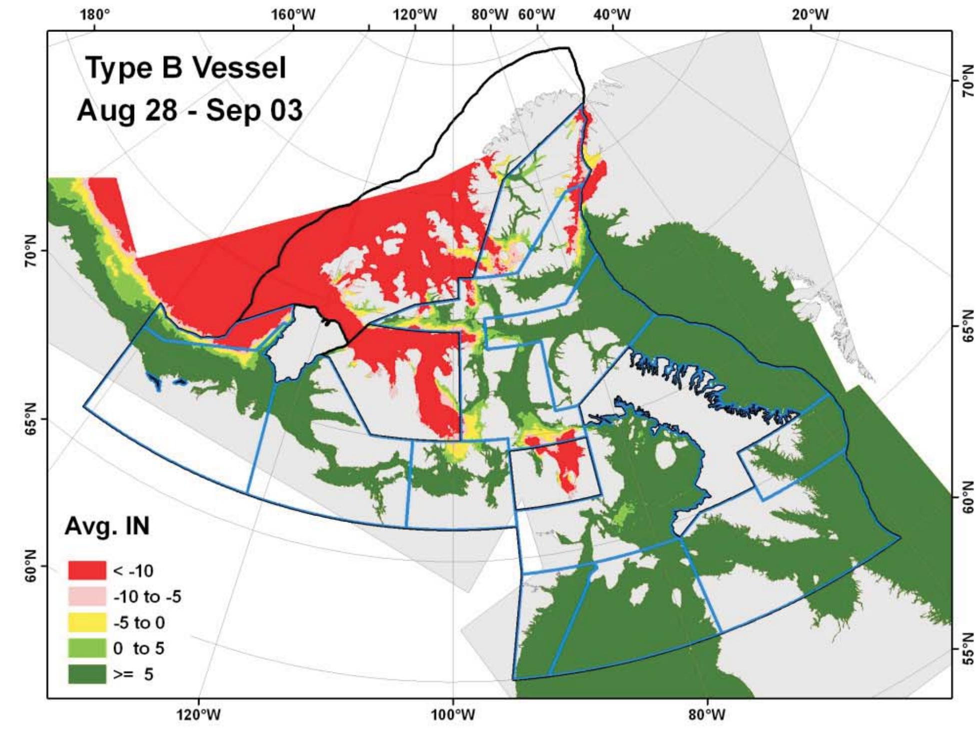
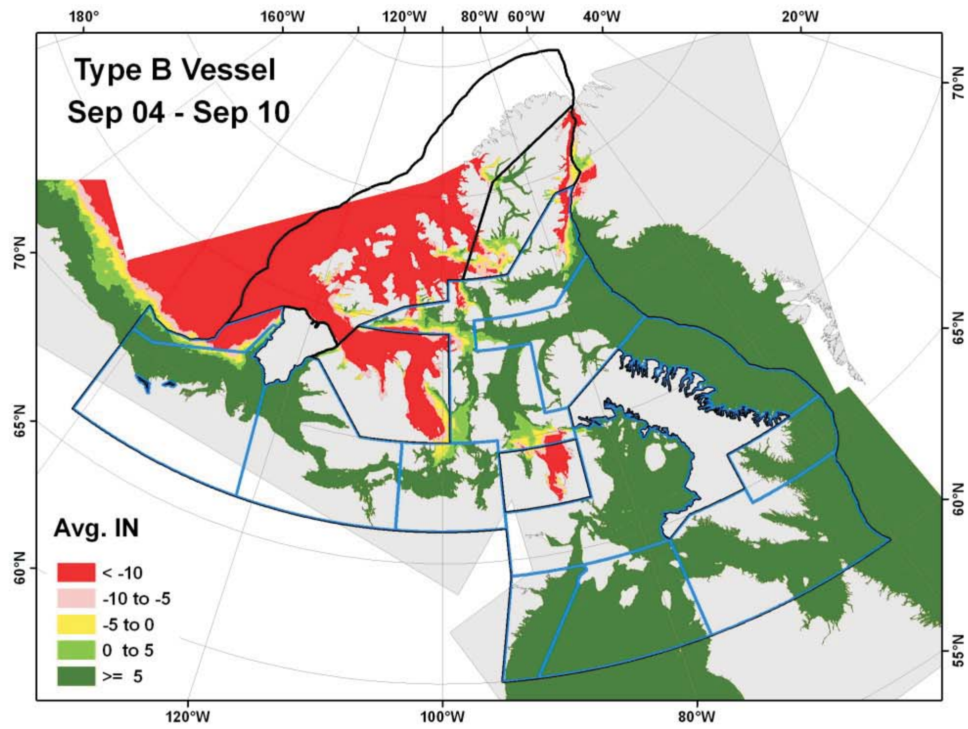
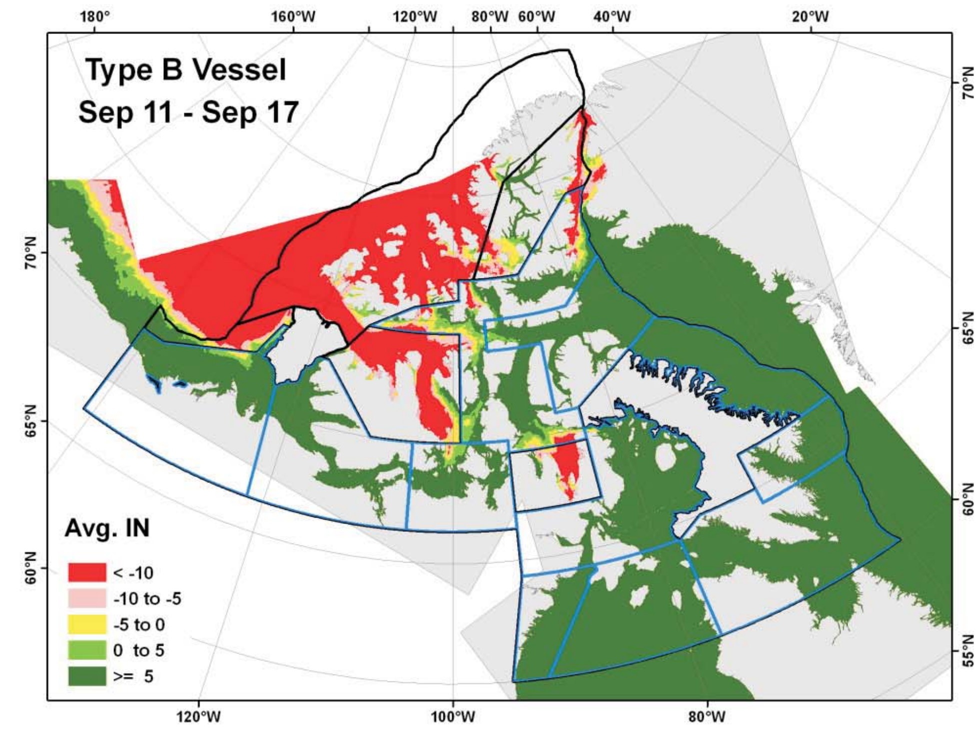
120°W
100°W
80°W

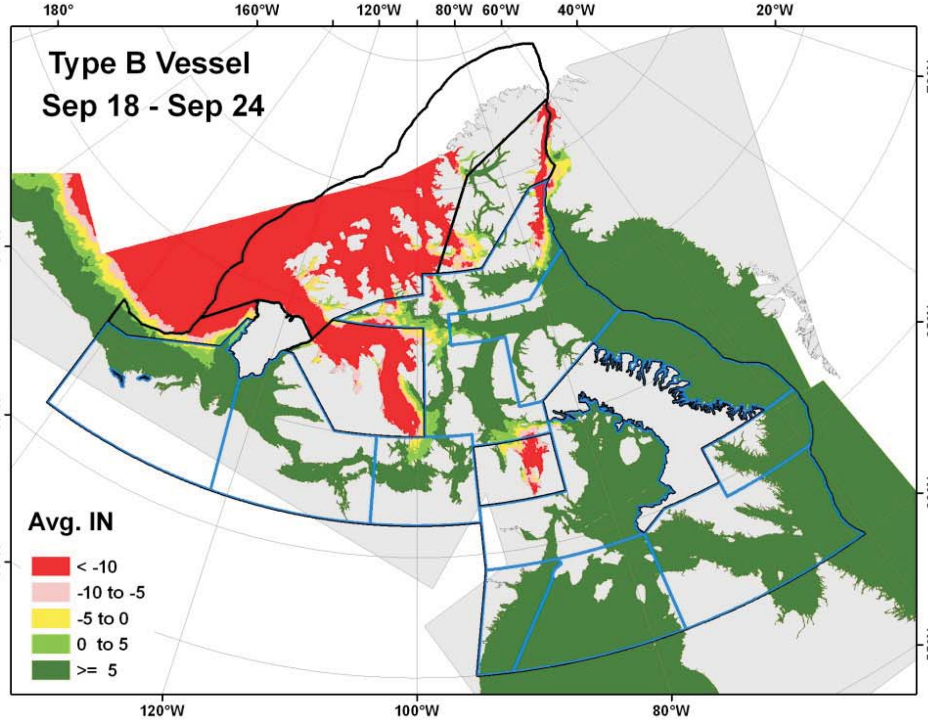

Type B Vessel
Aug 14 - Aug 20
Avg. IN
< -10
-10 to -5
-5 to 0
0 to 5
>= 5
180°
160°W
120°W
80°W
60°W
40°W
20°W
70°N
65°N
60°N
55°N
120°W
100°W
80°W

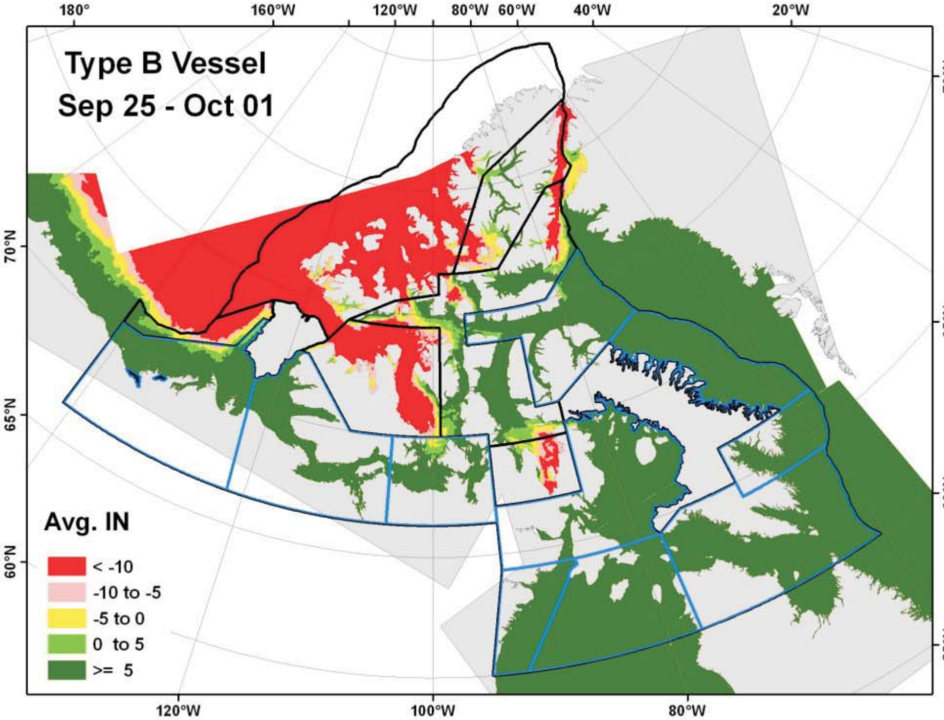

Type B Vessel
Aug 21 - Aug 27
Avg. IN
< -10
-10 to -5
-5 to 0
0 to 5
>= 5

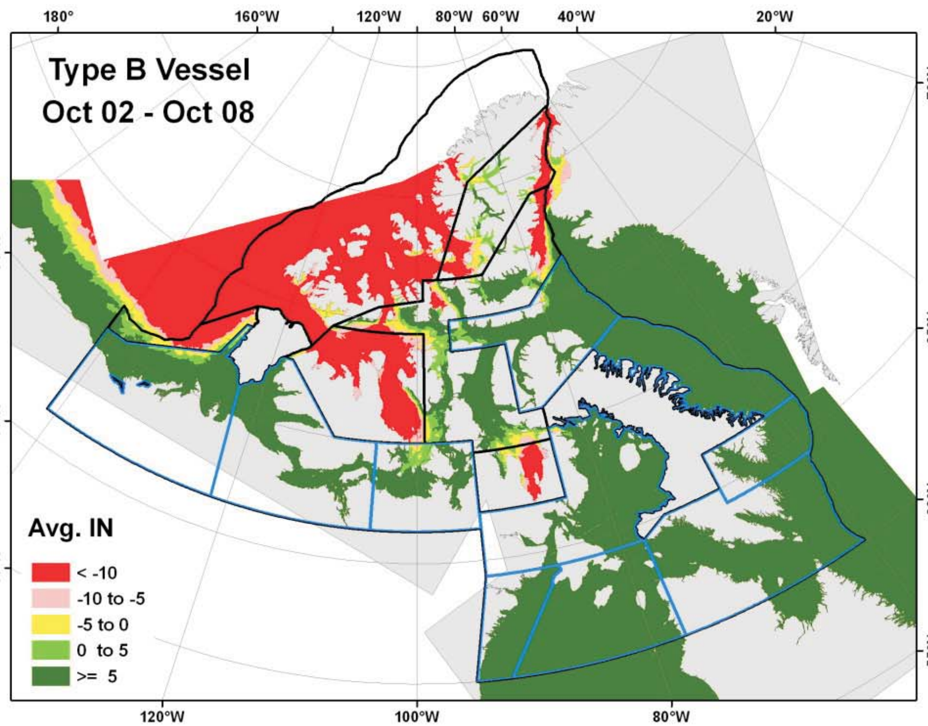

Type B Vessel
Aug 28 - Sep 03
Avg. IN
< -10
-10 to -5
-5 to 0
0 to 5
>= 5

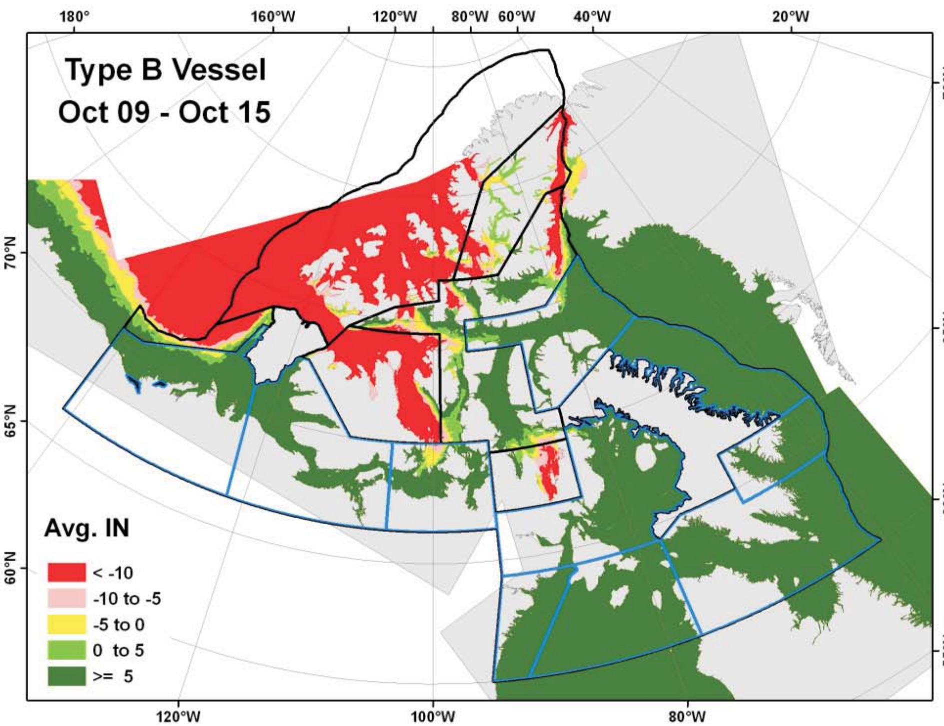

Type B Vessel
Sep 04 - Sep 10
Avg. IN
< -10
-10 to -5
-5 to 0
0 to 5
>= 5

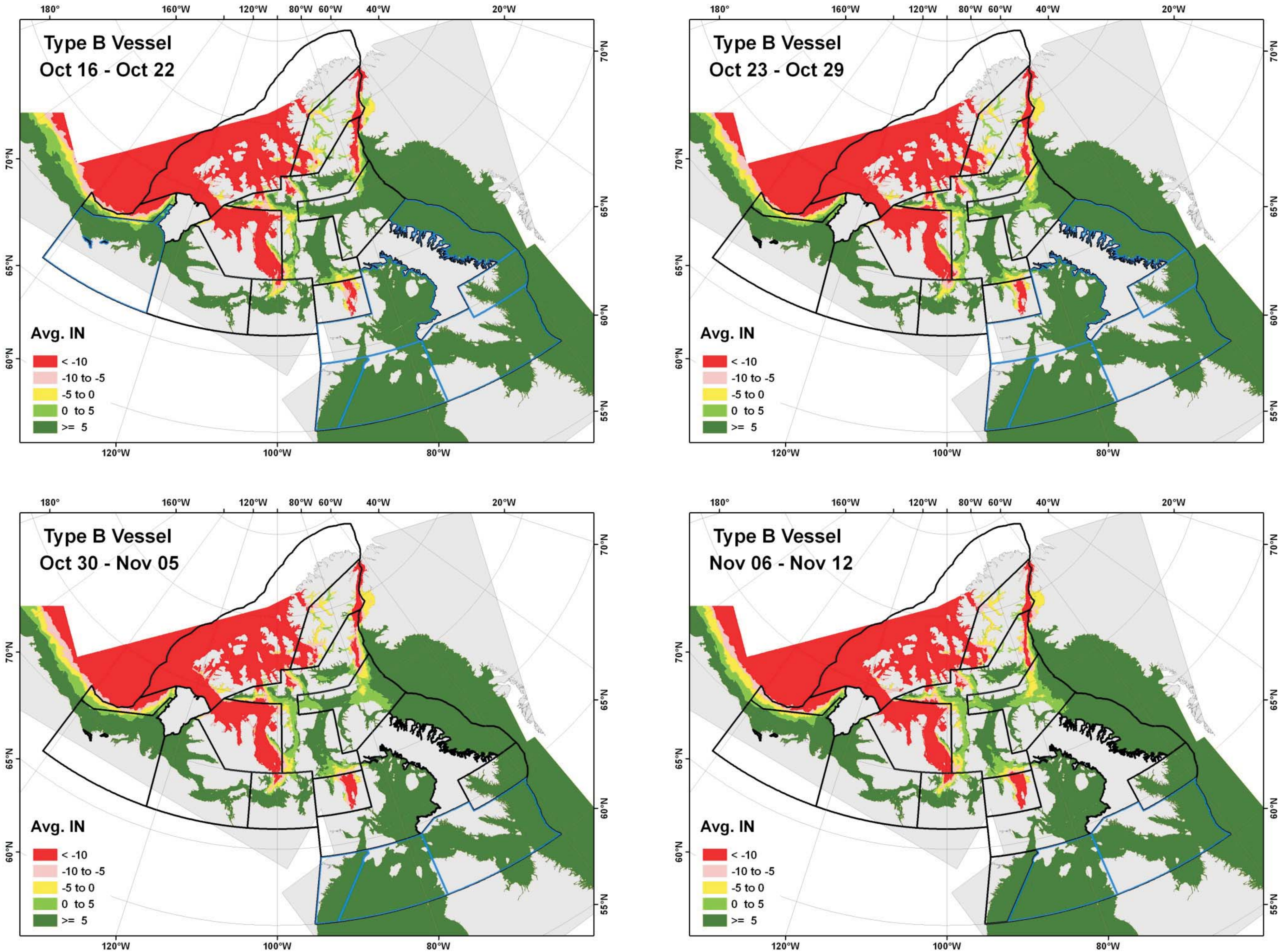

Type B Vessel
Sep 11 - Sep 17
Avg. IN
< -10
-10 to -5
-5 to 0
0 to 5
>= 5

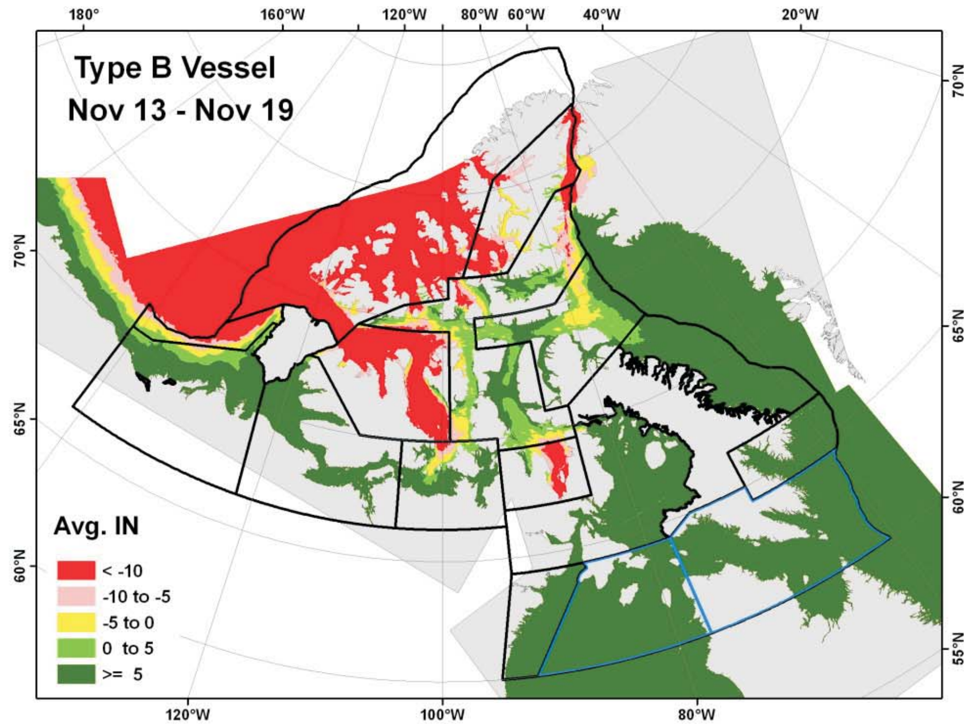

Type B Vessel
Sep 18 - Sep 24
Avg. IN
< -10
-10 to -5
-5 to 0
0 to 5
>= 5
180°
160°W
120°W
80°W
60°W
40°W
20°W
120°W
100°W
80°W
70°N
65°N
60°N
55°N

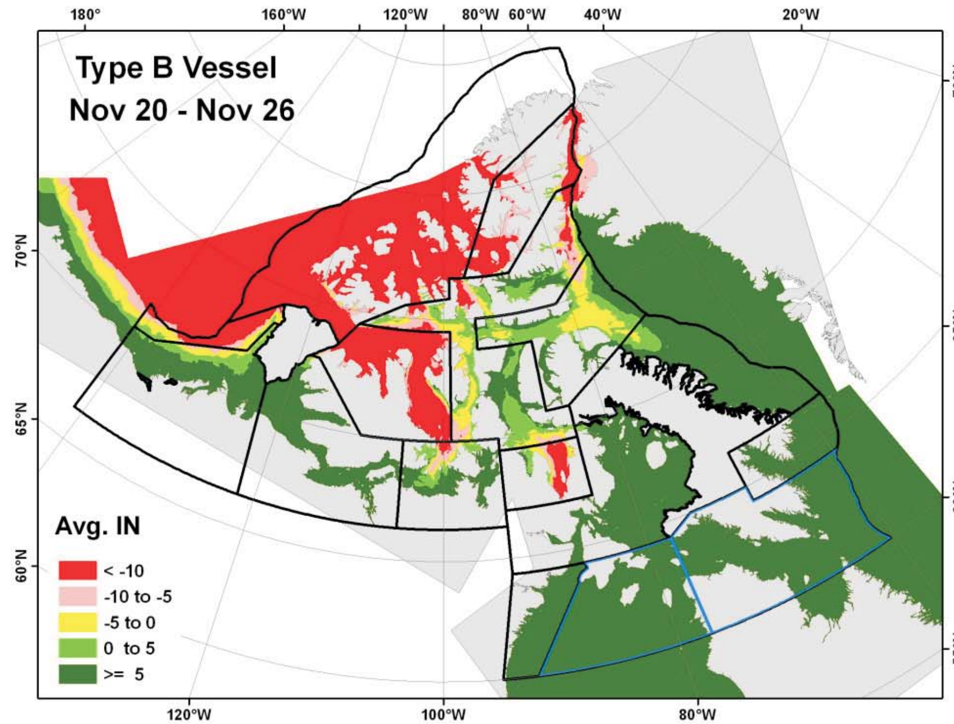

Type B Vessel
Sep 25 - Oct 01
Avg. IN
< -10
-10 to -5
-5 to 0
0 to 5
>= 5
180°
160°W
120°W
80°W
60°W
40°W
20°W
120°W
100°W
80°W
70°N
65°N
60°N
55°N

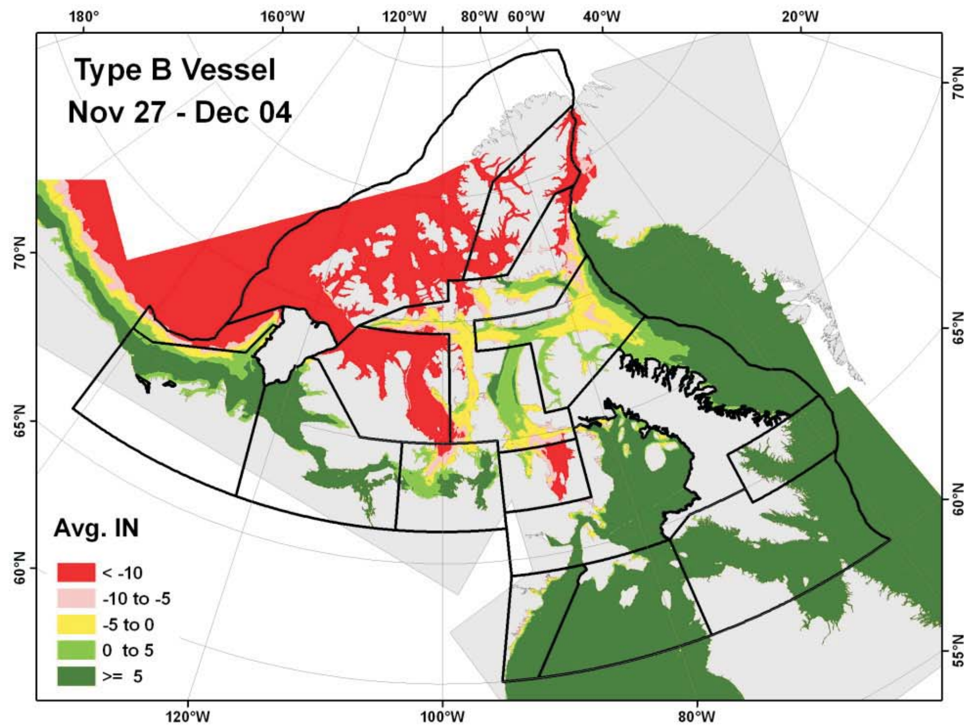

Type B Vessel
Oct 02 - Oct 08
Avg. IN
< -10
-10 to -5
-5 to 0
0 to 5
>= 5
180°
160°W
120°W
80°W
60°W
40°W
20°W
120°W
100°W
80°W
70°N
65°N
60°N
55°N

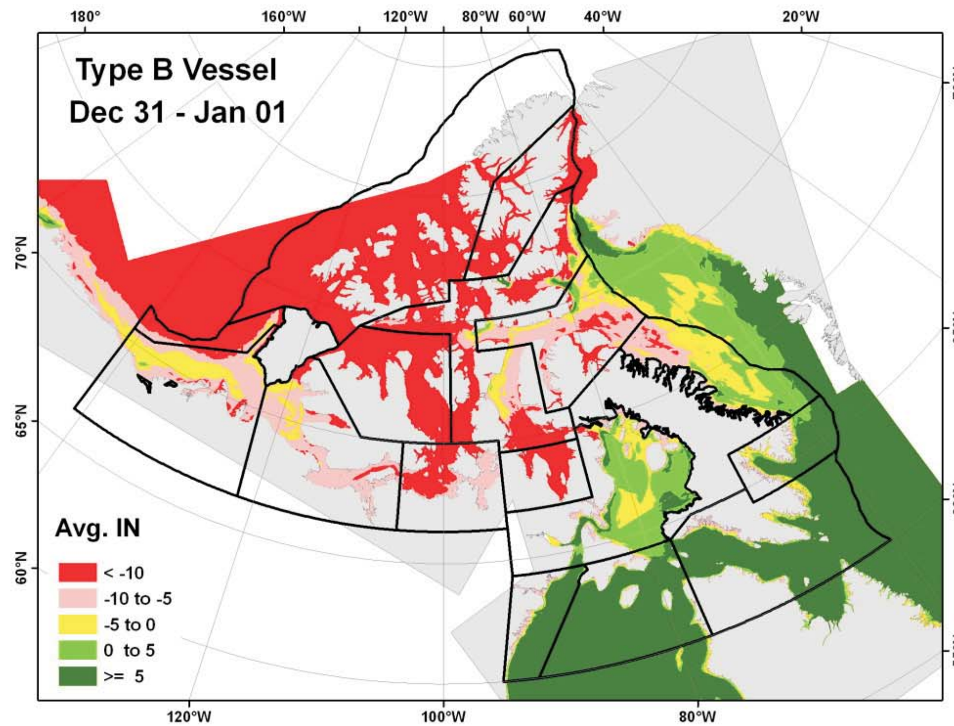

Type B Vessel
Oct 09 - Oct 15
Avg. IN
< -10
-10 to -5
-5 to 0
0 to 5
>= 5
180°
160°W
120°W
80°W
60°W
40°W
20°W
120°W
100°W
80°W
70°N
65°N
60°N
55°N


Type B Vessel
Oct 16 - Oct 22
Avg. IN
< -10
-10 to -5
-5 to 0
0 to 5
>= 5
Type B Vessel
Oct 23 - Oct 29
Avg. IN
< -10
-10 to -5
-5 to 0
0 to 5
>= 5
Type B Vessel
Oct 30 - Nov 05
Avg. IN
< -10
-10 to -5
-5 to 0
0 to 5
>= 5
Type B Vessel
Nov 06 - Nov 12
Avg. IN
< -10
-10 to -5
-5 to 0
0 to 5
>= 5
180°
160°W
120°W
80°W
60°W
40°W
20°W
100°W
70°N
65°N
60°N
55°N


Type B Vessel
Nov 13 - Nov 19
Avg. IN
< -10
-10 to -5
-5 to 0
0 to 5
>= 5
180°
160°W
120°W
80°W
60°W
40°W
20°W
120°W
100°W
80°W
70°N
65°N
60°N
55°N


Type B Vessel
Nov 20 - Nov 26
Avg. IN
< -10
-10 to -5
-5 to 0
0 to 5
>= 5


Type B Vessel
Nov 27 - Dec 04
Avg. IN
< -10
-10 to -5
-5 to 0
0 to 5
>= 5


Type B Vessel
Dec 31 - Jan 01
Avg. IN
< -10
-10 to -5
-5 to 0
0 to 5
>= 5