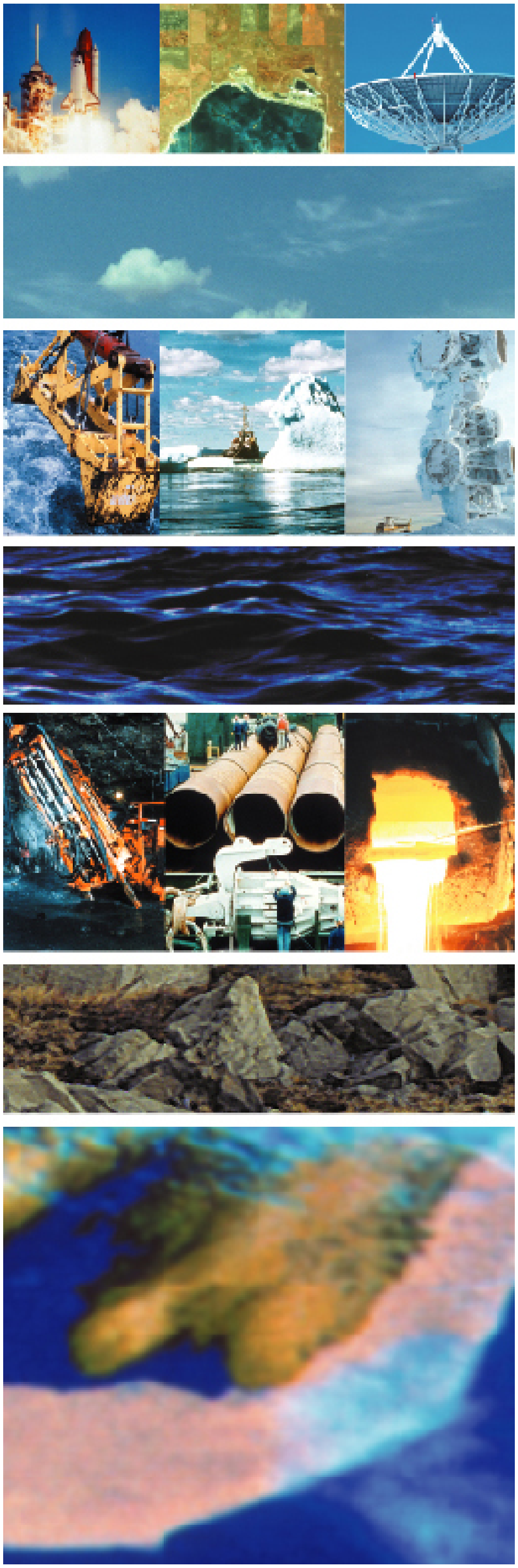

CHARACTERIZATION OF ICE-FREE SEASON FOR OFFSHORE NEWFOUNDLAND

May 2005

C-CORE Report R-04-093-341

C-CORE

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CHARACTERIZATION OF ICE-FREE SEASON FOR OFFSHORE NEWFOUNDLAND

Version 2

Prepared for:

C-NOPB

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R-04-091-341

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Foreword

This report has been prepared by C-CORE for the Canada-Newfoundland Offshore Petroleum Board (C-NOPB). The primary purpose of the report is to assist the C-NOPB in assessing the feasibility of allowing certain types of drilling installations (in particular, jack-ups) to operate in the Newfoundland offshore area on a seasonal basis.

It should be understood by all users of this report that the information in this report is **not** to be interpreted as the approved operating season for jack-up drilling installations.

Due to the high variability of ice conditions offshore Newfoundland, the C-NOPB has determined that the acceptable operating periods for jack-ups will be made on a season-by-season basis, based on actual ice conditions (and other factors) and not necessarily on historical ice data information. The determination of a suitable window of operations for jack-ups will be based on the proposed geographical area of operations and the results from the ice surveillance program for that particular year, taking into account actual (observed) as well as forecasted pack ice and iceberg conditions, as well as weather conditions.

Nevertheless, the results of this report may be very helpful for general planning purposes and in gaining a better understanding of pack ice and iceberg conditions in the Newfoundland offshore area.

EXECUTIVE SUMMARY

An analysis was conducted to establish an ice-free season when, on average, the influence of iceberg and pack ice on ice-sensitive operations may be considered negligible for areas of offshore Newfoundland where exploration activities are likely. Figure 1 shows the region considered, with areas of particular interest indicated.

Iceberg data derived from International Ice Patrol and Canadian Ice Service iceberg charts, as well as the PERD (2004) Iceberg Sighting Database were considered as data sources. The PERD (2004) data covered the longest time span and provided the largest number of sightings over the greatest number of months, and thus was considered most appropriate for the analysis. Pack ice data for the analysis was derived from Canadian Ice Service regional ice charts. The iceberg and pack ice data used in the analysis covered time spans of 44 and 36 years, respectively.

In order to define a month as “typically” being ice-free, it was necessary to establish criteria. If icebergs (or pack ice in concentrations greater than $1/10^{th}$) were observed, on average, less than once in five years in a given degree-square during a particular month, then that month in that degree square was designated as being ice-free. The ice-free seasons are indicated in Figure 1, and are given for the four areas of particular interest in Table 1. The presence of icebergs dictated the duration of the ice-free season off the east and south coasts, while off the west coast pack ice dominated. Further analysis was conducted on the iceberg data to further define iceberg presence in terms of light, moderate or heavy iceberg seasons. Improvements in the long-term forecasting of ice season severity would allow more effective planning for ice-sensitive operations and better enable the CNOPB to authorize commencement of these operations during a given year based on the expected severity of the season (light, moderate or heavy).

These estimates of the duration of the ice-free season are intended to be conservative. A variety of strategies (long-range detection and forecasting, evasive maneuvers, etc.) would serve to mitigate risk and extend the effective ice-free season. For analysis of ice risk or the ice-free season in other areas with potential for exploration or production activities (i.e. Labrador), ongoing, long-term comprehensive monitoring programs are recommended to provide the required environmental data.

Table 1 Ice-free season based on long-term average conditions

Region	Ice-Free Season
Jeanne d'Arc (46°-47° N, 48°-49° W)	August - January
South Whale (44°-45° N, 52°-53° W)	July – March
Laurentian (45°-46° N, 55°-56° W)	July - March
Port-au-Port (48°-49° N, 59°-60° W)	May - December

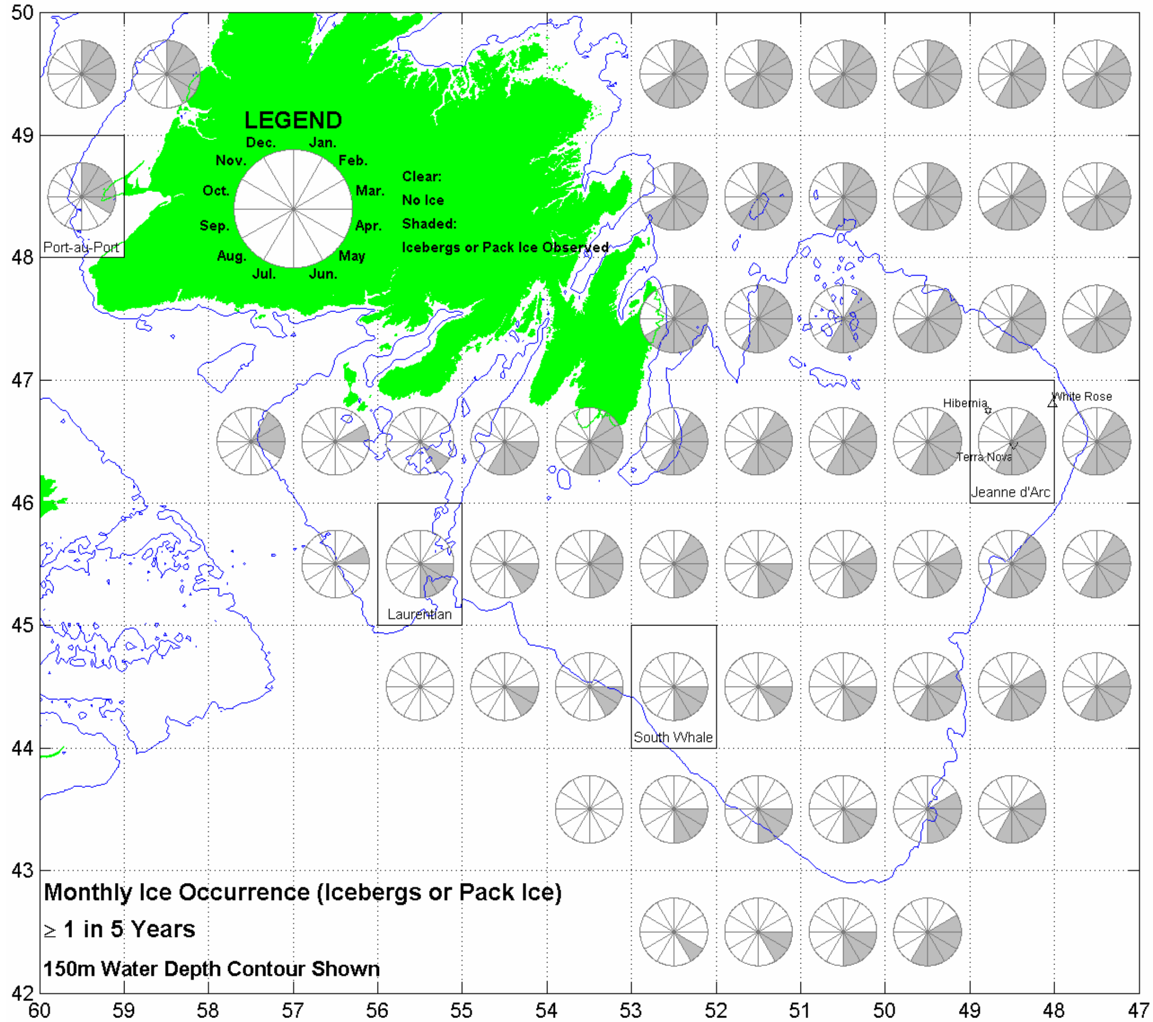

Figure 1 Typical ice-free season (no shading) based on ice occurrence once in 5 years

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1 INTRODUCTION

1.1 Background

While icebergs and pack ice are important considerations for exploration and development activities for offshore Newfoundland, they do not occur on a year-round basis, or even on an annual basis. Routine activities are generally conducted on a year-round basis, with ice-related risks mitigated using conventional surveillance and ice management techniques. However, it may be desirable to perform certain operations during ice-free periods. C-CORE has been contracted by the Canada-Newfoundland Offshore Petroleum Board (CNOPB) to perform an analysis to determine when the Newfoundland offshore can be considered free of ice.

This report was not intended to be a probability-based analysis of iceberg or pack ice impact frequencies or loads. Rather, it is a general guide documenting the months when the influence of ice on offshore operations are negligible. For specific operations within a given year, the decision whether an ice-sensitive operation proceeds at a given time resides with the CNOPB. These decisions would not be constrained in any way by the contents of this report.

1.2 Objectives

The primary objectives of this study were to:

- characterize the presence of icebergs and pack ice for offshore Newfoundland in regions where exploration or development activities, or both, are likely; and
- use these data to define an “ice-free” season where the influence of icebergs and pack ice on offshore activities may be considered negligible.

The areas considered (the shaded area shown in Figure 1-1) covers most of the offshore region south of 50° N. Degree squares covering areas of particular interest (Jeanne d’Arc, South Whale, Laurentian and Port-au-Port) are also indicated.

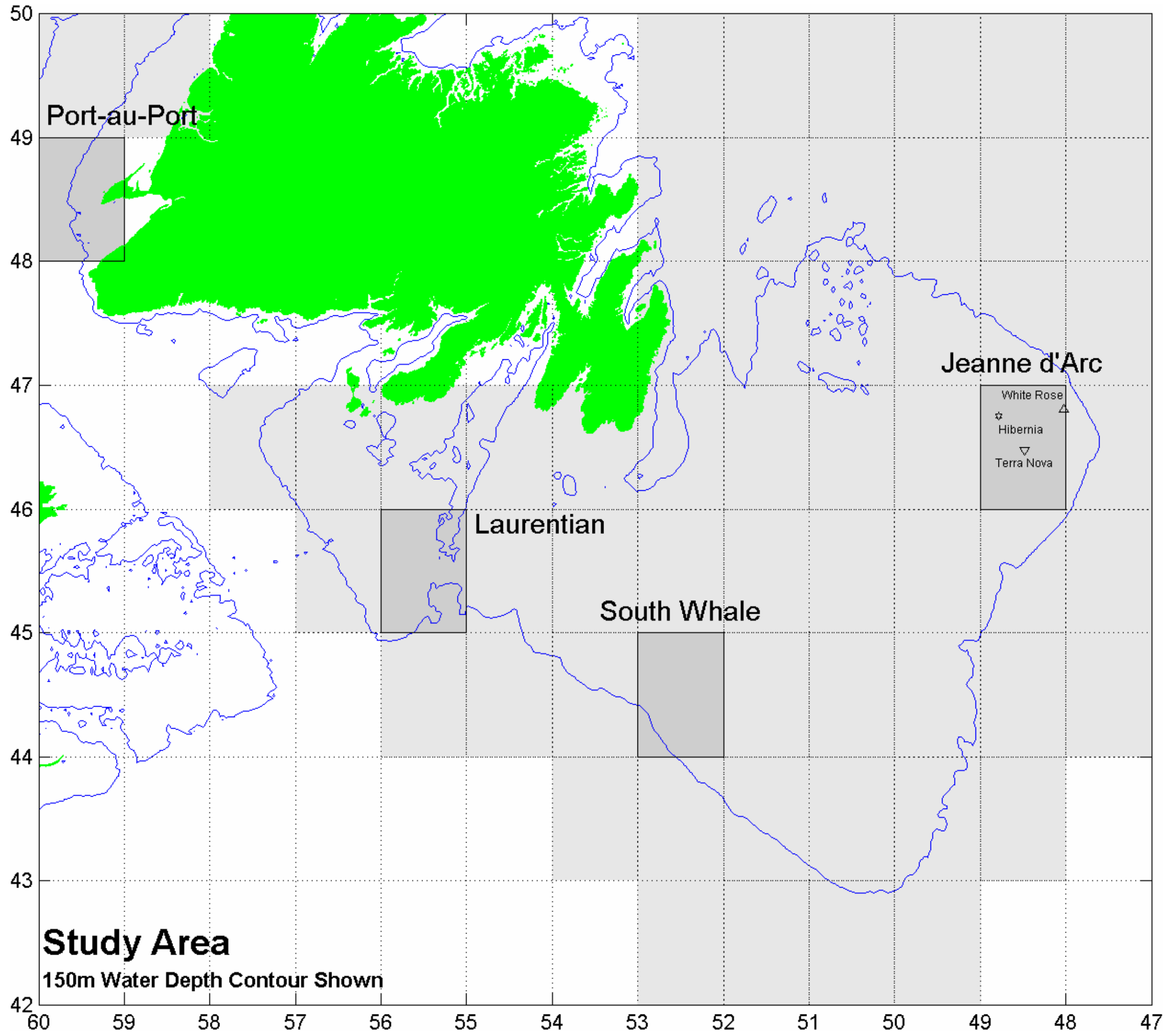

Figure 1-1 Area covered by ice analysis (lightly shaded) with areas of particular interest indicated (Jeanne d'Arc, South Whale, Laurentian and Port-au-Port)

2 DATA SOURCES

2.1 Iceberg Data

Iceberg sighting data from a variety of sources were used to determine the ice-free season for offshore Newfoundland. The primary sources of data were the International Ice Patrol (IIP), the Canadian Ice Service (CIS), and the PERD (2004) Iceberg Sighting Database.

The International Ice Patrol (IIP), formed primarily in response to the Titanic disaster in 1912, conducts surveys to define the Limits of All Known Ice (LAKI) in order to alert transatlantic mariners of potential risk of collisions with icebergs. IIP iceberg charts (see Figure 2-1) from 1960 to 2004 were reviewed to discern patterns in iceberg occurrence. The data in these charts have also been incorporated into Memorial University Iceberg Database (Jordaan et al, 1999) to allow iceberg areal densities to be calculated. The IIP also give the monthly and annual number of icebergs drifting south of 48°N (IIP, 2005), as shown in Figure 2-2. The IIP also documents iceberg sighting in a database that gives iceberg position, size, shape, sighting source, and various other data. It is important to note that the database includes sightings not documented in the IIP charts. If iceberg conditions are such that no risk is posed to transatlantic mariners (i.e. icebergs limited to the northern Grand Banks, but still south of 48°N) charts are unlikely to be produced. Therefore, while Figure 2-2 (bottom) shows icebergs drifting south of 48°N in October, November and December, IIP charts have been produced in these months.

The Canadian Ice Service (CIS), a branch of the Meteorological Service of Canada (MSC), specializes in data on Canada's navigable waters. Iceberg (and pack ice) charts are available on-line daily (CIS, 2005). CIS iceberg charts dating back to 1988 were used for comparison with other data sources for this report. A sample CIS iceberg chart is shown in Figure 2-3, where it can be seen that the area covered extends further north than on IIP charts. The CIS and IIP exchange information, although analysis and interpretation are performed independently. When ice extends south of 48°N, the IIP becomes responsible for establishing the LAKI.

The PERD Grand Banks Iceberg Database (PERD, 2004) contains over 200,000 iceberg sightings and is the largest available source of iceberg sighting data. This database and documentation is available online (PERD, 2005) and is a compilation of sighting data from a variety of sources, including the International Ice Patrol, industry iceberg surveillance data (which includes data from Provincial Airlines Environmental Services dating back to 1973), sighting data from ships and lighthouses, and iceberg locations dating as far back as 1619 from the Ship Ice Collision Database (Hill, 2004). Iceberg sightings offshore Newfoundland from the PERD database are shown in Figure 2-4.

IIP survey data from 1960 to 1998 were extracted from the Memorial University Iceberg Database (Jordaan et al, 1999) and updated to 2004 using charts provided by the IIP. These charts give iceberg counts per degree square on a monthly or biweekly basis. Available CIS charts from 1988 to 2004 were manually processed for analysis. Charts at approximately 1 week intervals were manually input into spreadsheets, with more than 500 iceberg charts processed. The iceberg sighting data in the PERD (2004) database was processed to give the number of iceberg sightings per degree square per month. Since sighting data prior to 1960 were infrequent, these data were discarded.

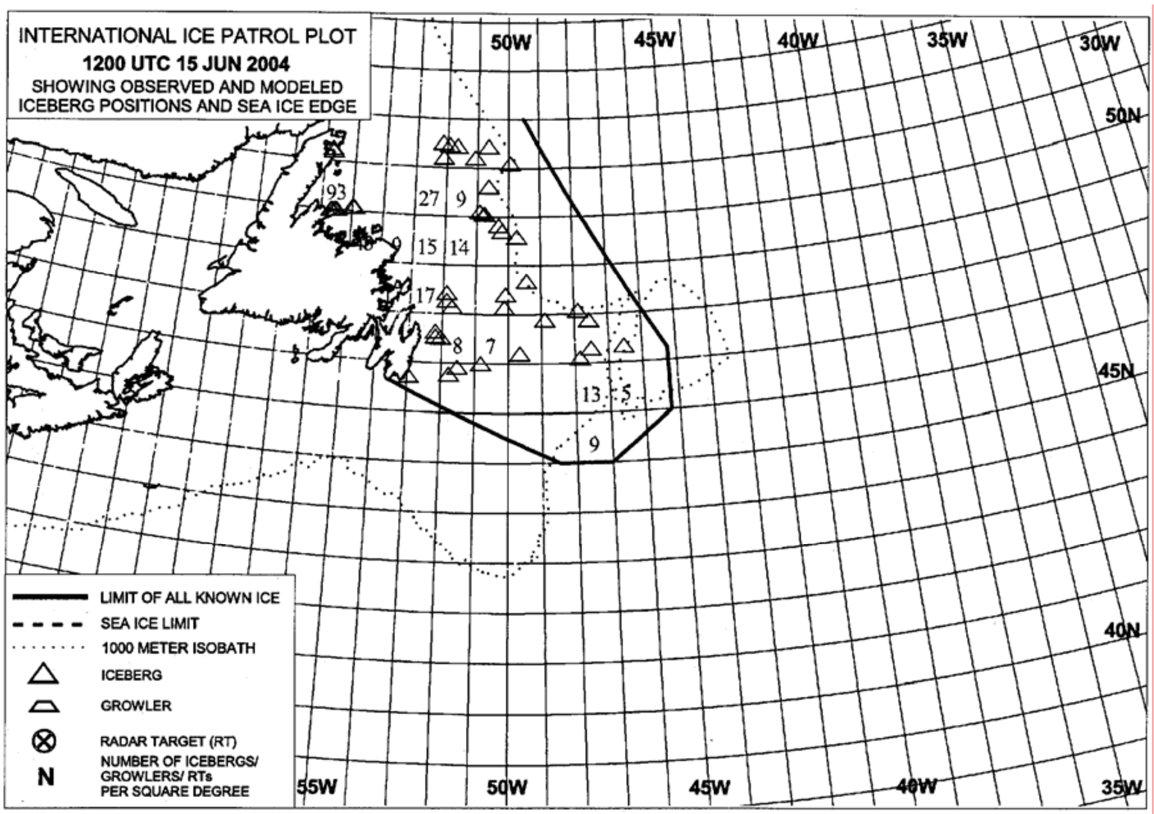

Figure 2-1 Sample iceberg chart issued by International Ice Patrol

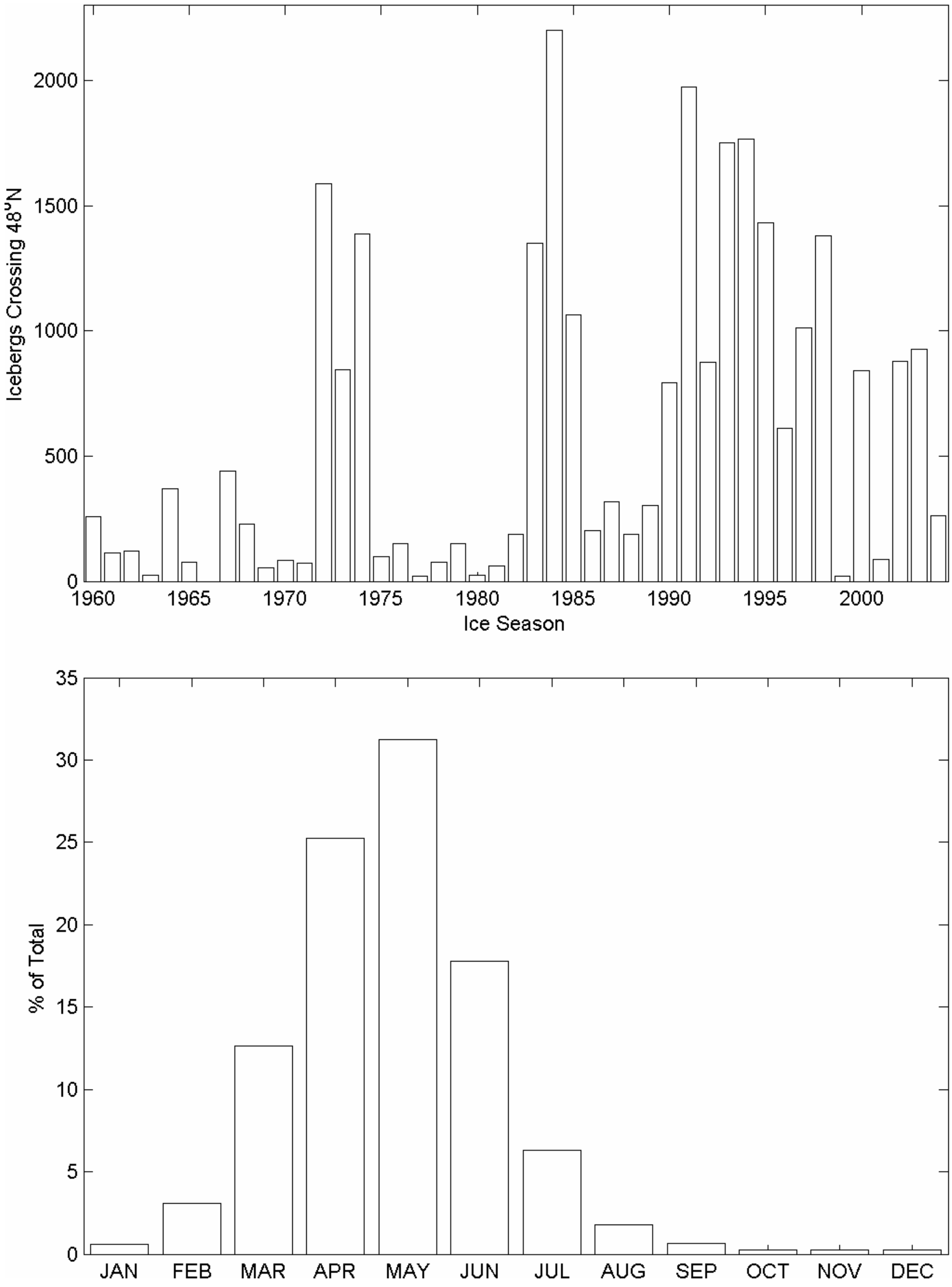

Figure 2-2 Annual and monthly icebergs drifting south of 48°N (IIP, 2005)

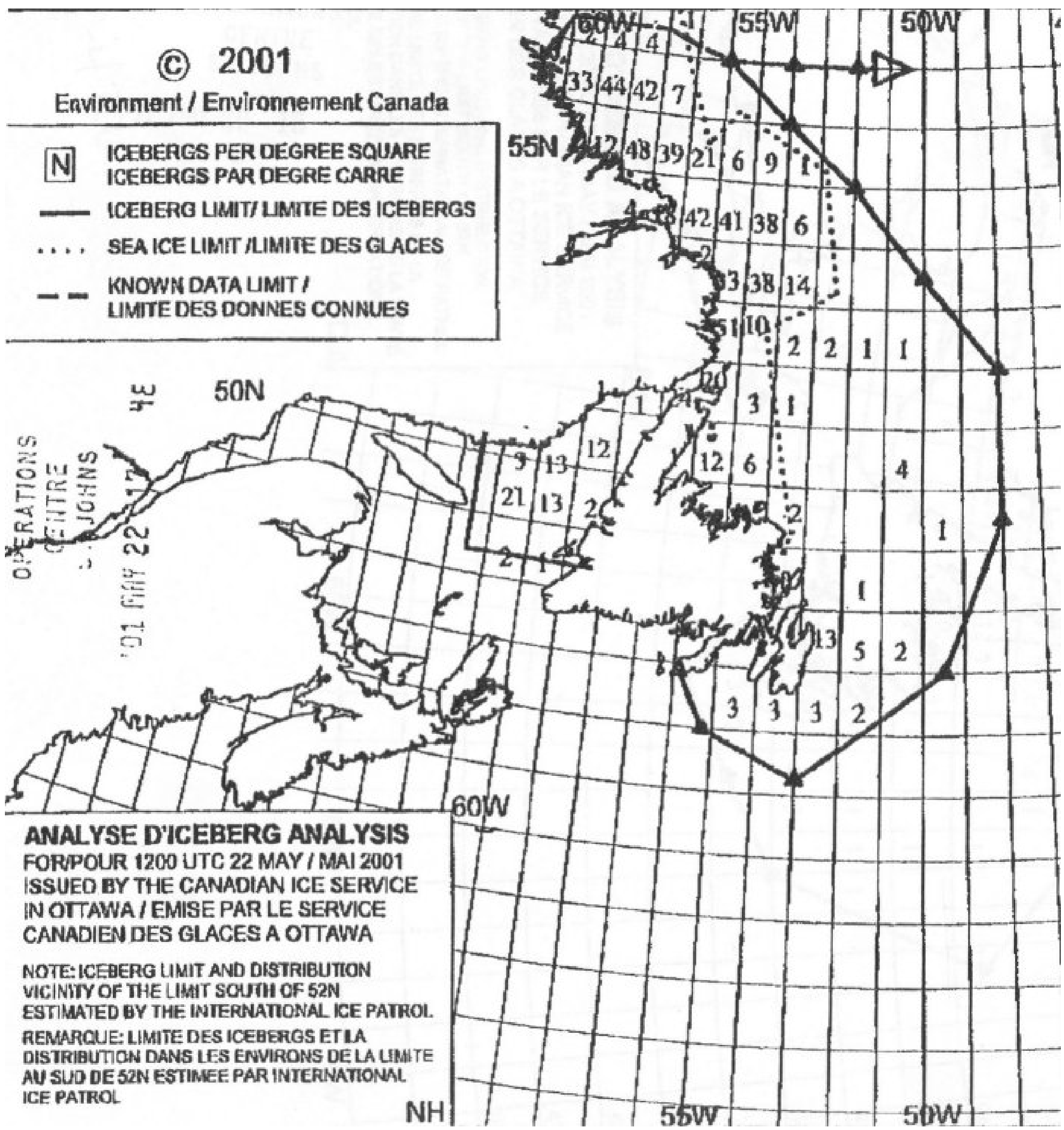

Figure 2-3 Canadian Ice Service iceberg chart

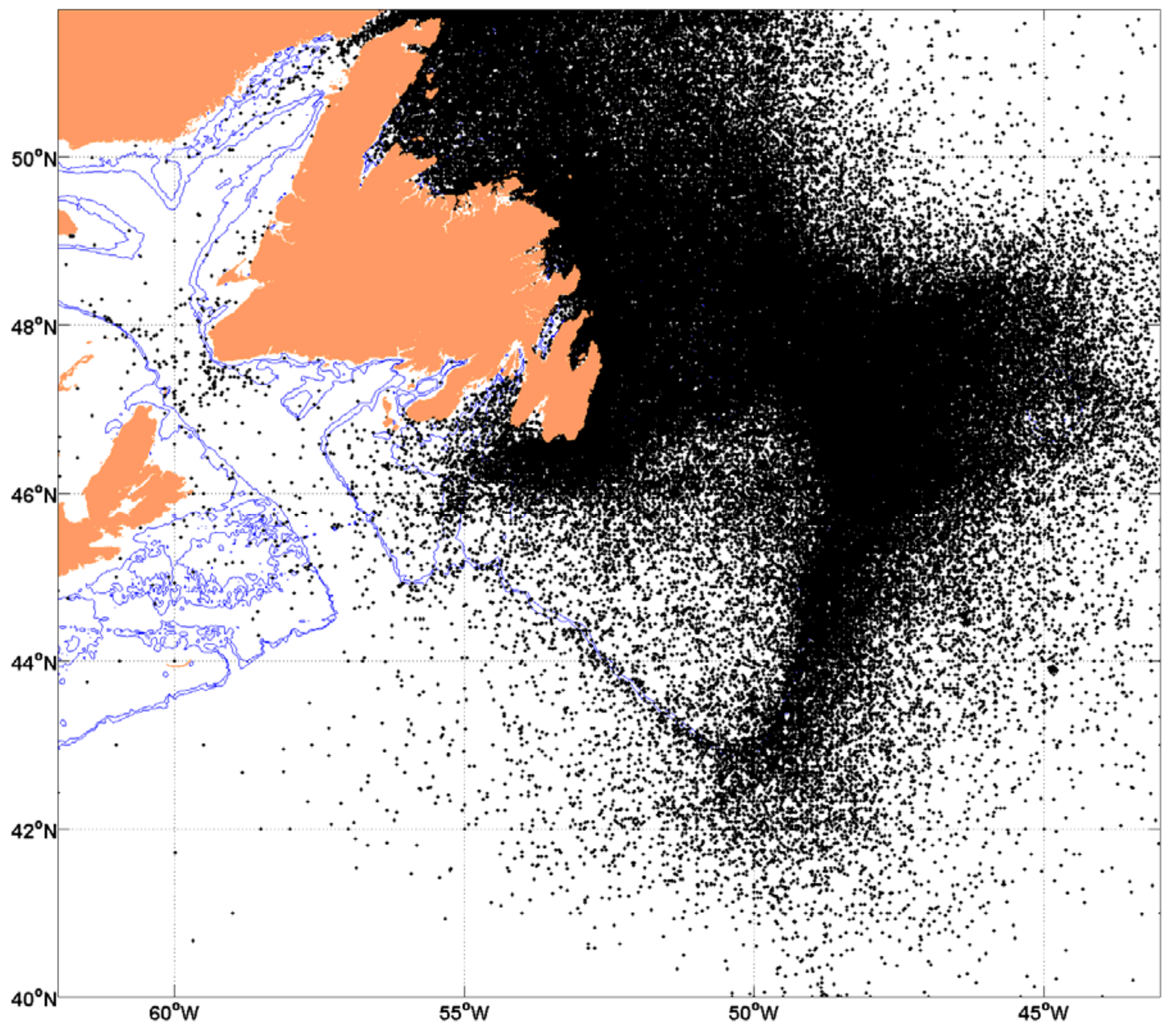

Figure 2-4 Iceberg sightings from the PERD Grand Banks Iceberg Database

2.2 Pack Ice Data

The sole source of data used in the analysis of pack ice occurrence and concentrations were regional ice charts for the Canadian East Coast (CIS, 2005). These charts show the estimated ice conditions for the region encompassing the Gulf of St. Lawrence as well as the eastern and southern coasts of Newfoundland and Labrador, as shown in Figure 2-5. They are based on an analysis and integration of all available data on ice conditions, including weather and oceanographic information, visual observations from shore, ship and aircraft, airborne radar, and satellite imagery. Ice concentration, stage of development (including thickness), and form of the predominant ice type are presented in the Egg Code format using the World Meteorological Organization (WMO) Standard (CIS, 2005). The charts are produced on a weekly basis from December to July, typically, and are available from 1969 to present. The pack ice analysis in this document used all data up to the end of the 2004 ice season.

The regional ice charts, from 1969 to 1998, were also available in a SIGRID-2 digital raster format (WMO, 1994) produced by the CIS. This enabled the timely extraction of pack ice concentration data, at 0°15' intervals in both longitude and latitude directions, covering the Grand Banks, Newfoundland South Coast and Newfoundland West Coast regions, using the ***ICE'98*** computer program (Canatec, 1999). Data beyond 1998 was not available in the SIGRID-2 format as the standard is undergoing a major revision to change from raster based data to vector based data. For the period 1999 to 2004, pack ice concentration data were extracted manually from the regional charts at the same 0°15' intervals.

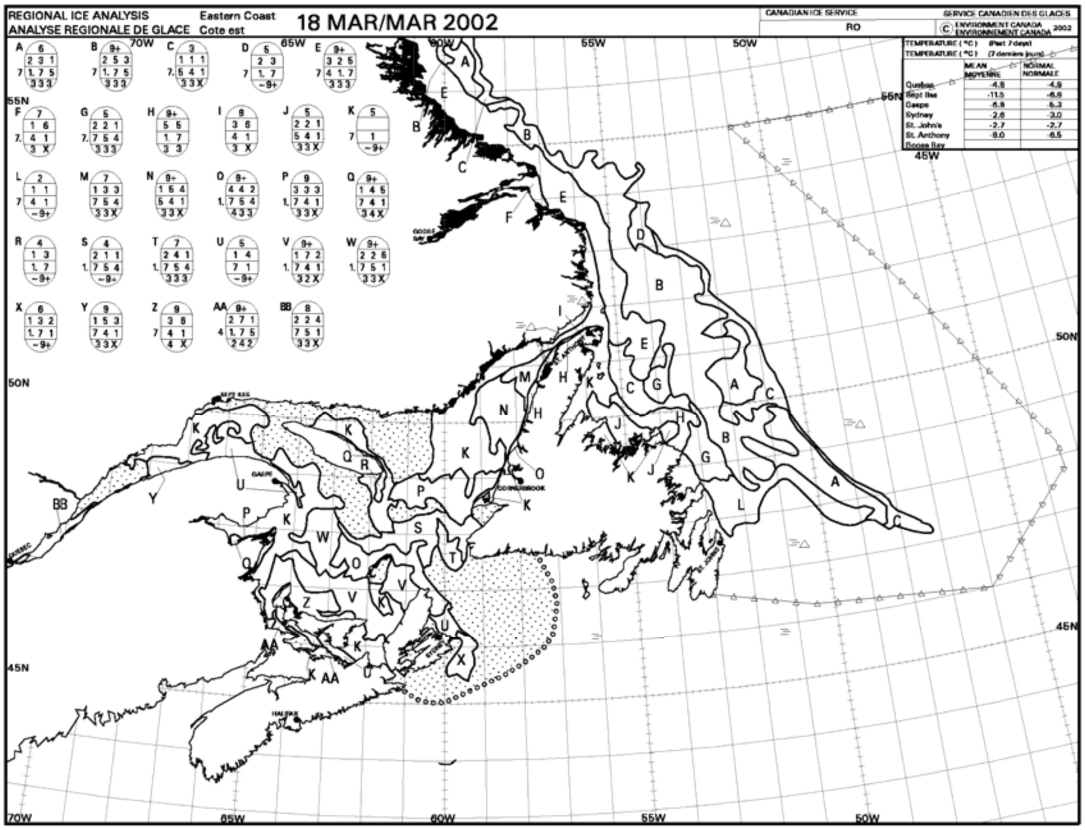

Figure 2-5 Sample CIS regional ice chart for East Coast Region

3 ANALYSIS PROCEDURE

3.1 Analysis of Iceberg Data

The International Ice Patrol, Canadian Ice Service and PERD (2004) data were processed to allow presentation in the same format. Iceberg data were presented to show whether icebergs were present in a specific degree square during a given month in the form of a "pie-chart" as shown in Figure 3-1. The 12 sections of the circle represent months, with each section clear or shaded, depending on whether icebergs were observed, using a variety of criteria. The criteria for indicating the presence of icebergs for a specified month and degree square were:

- any icebergs observed over duration of data record;
- icebergs observed in frequencies greater than, or equal to, 1 in 5 years during each month; and
- icebergs observed in light, moderate and heavy icebergs seasons in frequencies greater than, or equal to, 1 in 5 years during each month.

To verify the conservatism of the one in five year criterion for discriminating the typical presence or absence of ice, the probability of iceberg contact was calculated for a structure or facility performing a procedure of limited duration (i.e. 1 month) when the probability of an iceberg entering the degree square in which the operation is being conducted is 20% (once in five years during that month). The resultant contact probability was on the order of 10^{-4} (1 in 10,000). Based on this analysis, it was concluded that defining a degree square as "ice-free" when the likelihood of an iceberg entering the degree is less than 1 in 5 years within a given month is a reasonable criterion.

Iceberg seasons were defined as light, moderate or heavy based on the number of icebergs that drifted south of 48° N. Light iceberg seasons typically have longer ice-free seasons than moderate or heavy iceberg seasons. The criteria used by Marko et al. (1994), which is consistent with local industry practice (Pip Rudkin, PAL, Personal Communication), are given in Table 3-1. This is compatible with industry practice of forecasting upcoming ice seasons as light, moderate or heavy. A comparison of the results for the various data sets using the various criteria were used to determine the best representative data set and criteria as presented in Section 4.1 and in Appendix A.

In all cases the data were processed to determine, based on monthly intervals, whether or not icebergs were observed in each degree square. The number of icebergs present, which would be of concern in calculation of iceberg densities for calculation of collision probabilities, was not considered since the present analysis is concerned with defining an ice-free season only.

Table 3-1 Criteria used to define light, moderate and heavy iceberg seasons (Marko et al., 1994)

Ice Season	Icebergs Drifting South of 48°N
Light	< 200
Moderate	≥ 200 & ≤600
Heavy	> 600

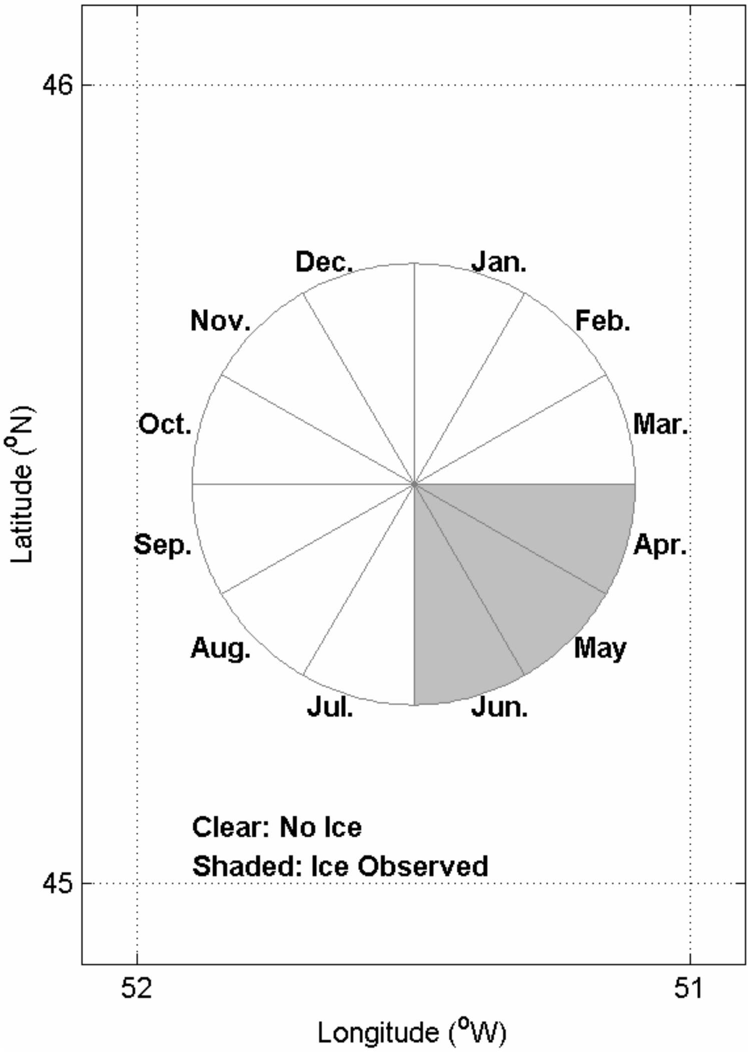

Figure 3-1 Format used for showing monthly occurrence of ice per degree square

3.2 Analysis of Pack Ice Data

Weekly pack ice concentration data, covering the Grand Banks, St. Pierre Banks and West Coast of Newfoundland, were extracted from the CIS pack ice data set, described in the previous chapter, for grid points spaced at 0°15' intervals in both latitude and longitude directions (see Figure 3-2). The data spanned 36 years, from 1969 to 2004 inclusive.

Data analysis consisted of calculating the likelihood of encountering **any** pack ice in concentrations greater than $1/10^{th}$, on a monthly basis, at each grid point. Using an ice concentration exceeding $1/10^{th}$ produces a very conservative result as operations in concentrations up to $5/10^{ths}$ using ice classed vessels is common.

An example describing the method used for calculating the average ice occurrence rate, at a single point, for a single month, is shown in Table 3-2. Only the existence of any ice during any portion of the month was considered in the calculation, not the duration for which pack ice existed within the month. A single, representative, occurrence rate was then assigned to each degree-square in the study region based on the maximum calculated occurrence rate of all grid points located on or within the degree-square boundary.

A degree-square was then defined as "ice-free", for any given month, if it was free of pack ice, for example, four out of every five years on average.

Table 3-2 Example calculation showing monthly pack ice occurrence rate

Grid Point X, Month 2:					
Year	Observed Ice Concentration (tenths)				Was Ice Present during Month?
	Week 1	Week 2	Week 3	Week 4	
1	0	0	0	0	No
2	0	0	0	0	No
3	4	5	5	5	Yes
4	0	0	0	0	No
5	0	0	0	0	No
6	8	0	0	0	Yes
7	0	9	5	0	Yes
8	0	0	0	0	No
Total number of years ice observed in month 2					3
Pack ice occurrence rate in month 2					0.375 (or 3 in 8 years)

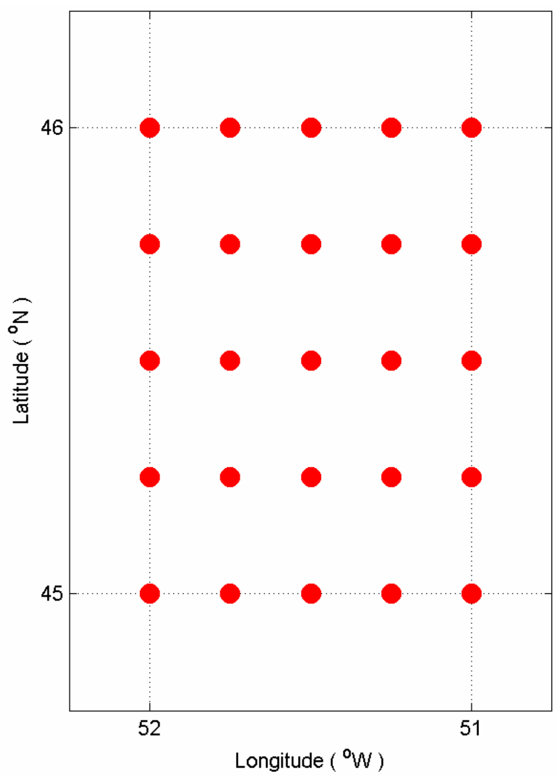

Figure 3-2 Example showing 0°15′ grid spacing for pack ice data points

4 RESULTS

4.1 Icebergs

A comparison of the various sources of iceberg data was required to ensure the best representation of iceberg occurrence. A single data set was not appropriate for all regions considered, requiring the use of different data sets for characterizing different areas.

Icebergs occasionally pass through the Strait of Belle Isle and drift into the Gulf of St. Lawrence. The IIP's primary concern is protecting transatlantic mariners off the east and southeast coast, so the normal operations area spans 40°N to 52°N, and 39°W to 57°W, and excludes the Gulf of St. Lawrence. Therefore, IIP charts do not show icebergs off Newfoundland's west coast. It is likely that icebergs shown on some IIP charts (see Figure 4-1) between Newfoundland and Cape Breton, and on the Scotian Shelf, drifted through the Gulf of St. Lawrence. The PERD (2004) database shows icebergs off Newfoundland's west coast (Figure 2-4), but these date mostly from the 1960's. CIS charts show occasions where there were significant numbers of icebergs near the Port au Port Peninsula on the west coast as recently as 2001 (Figure 2-3), but these are not documented in the PERD (2004) database. Canatec (1997) used IIP and CIS data to calculate iceberg frequency off the Port-au-Port Peninsula, and Sandwell (1998) used these data to generate iceberg impact loads. Inquiries were made to residents of the Port-au-Port area, and there were no reports of iceberg appearing in the area. In one case, a retired fisherman (born 1925) reported never seeing an iceberg in the vicinity of the Port-au-Port Peninsula (Roy Gaudon Sr., 2005, personal communication), suggesting that icebergs in that region should be, at best, treated as an infrequent event. The PERD (2004) and CIS data were used to determine the months during which any icebergs were observed, while the CIS data was used (over the 1988 to 2004 period) to determine monthly iceberg frequency with 1 in 5 year return periods (Appendix A, Figure A.7). Since iceberg presence off the west coast appeared to be unrelated to the number of icebergs drifting south of 48°N on the east coast, these data were not considered using the light, moderate and heavy iceberg season criteria.

Figure 4-2 shows the months during which icebergs were recorded in the various data sets. Iceberg data collected outside the area bounded by 42°N to 50°N and 47°W to 60°W were discarded. It can be seen that the majority of iceberg sightings from the IIP data were collected in the span from March to July, which, as shown in Figure 2-2 (bottom), are the months during which the majority of icebergs drift south of 48°N. The PERD (2004) data shows iceberg sightings recorded over a 12 month span for a number of years. While the CIS data shows icebergs in all 12 months during some years, the period covered by the data set is substantially less than either the IIP or PERD (2004) data.

Figure 4-3 shows the months where any icebergs were recorded in the PERD (2004) database for the region. It should be noted that some months in this figure are designated as having icebergs present on a basis of a single iceberg sighting, and this is responsible for some degree squares having icebergs in all 12 months, or an iceberg present in one month, with preceding and following months ice-free (i.e. November in the degree square centered on 49°30′N, 49°30′W). This emphasizes the need to define ice-free on a probabilistic basis. Corresponding figures for the IIP and CIS data are shown in Appendix A. The number of months when icebergs are recorded on the northeast Grand Banks in the degree square containing Terra Nova ranges from 7 months for the IIP data to a full 12 months for the PERD (2004) data, indicating the PERD (2004) data represent the best and most conservative data source (with the exception of the west coast). For almost all other degree squares under consideration the same can be concluded. Thus, any further analysis presented here is based on the PERD (2004), except for the west coast, since these data would produce the most conservative results (shortest ice-free season). Figure 4-4 shows the months when icebergs are recorded in each degree square equal to or greater than 1 in 5 years.

Results for specific regions of interest are given in Table 4-1. The locations of the degree squares corresponding to these locations are shown in Figure 1-1. In this analysis, an "iceberg free season" was defined as a period of three or more consecutive months that meet the criterion of "iceberg free". The 1 in 5 year criterion is used here to characterize "typical" or "average" conditions. The ice-free season corresponding to this condition was further refined by breaking the data set down into light, moderate and heavy iceberg season based on the number of icebergs drifting south of 48° N (see Section 3.1). The data are also shown in Figure 4-5, Figure 4-6 and Figure 4-7, and the corresponding iceberg-free seasons are given in Table 4-2. Appendix A gives results based on CIS and IIP data. The CIS data covered insufficient numbers of light or moderate ice seasons (3 and 2, respectively) to apply the 1 in 5 year criterion.

Table 4-1 Iceberg free season for selected areas in study region as defined by iceberg occurrence threshold

Region	Iceberg Free Season: 3 or More Consecutive Ice-Free Months	
	Any Icebergs	Less than once in 5 years per month
Jeanne d'Arc 46-47° N & 48-49°W	None	August – January
South Whale 44°-45° N & 52°-53° W	September – November	July - March
Laurentian 45°-46° N & 55°-56° W	August – January	July - March
Port-au-Port 48°-49° N & 59°-60° W	June - January	All Year

Table 4-2 Iceberg free season for selected areas in study region as defined by iceberg occurrence threshold on basis of light, moderate or heavy ice seasons

Region	Iceberg Free Season: ≥ 3 Consecutive Ice-Free Months		
	Light Season, less than once in 5 years per month	Moderate Season, less than once in 5 years per month	Heavy Season, less than once in 5 years per month
Jeanne d'Arc 46-47° N & 48-49°W	July – February	August – January	None
South Whale 44°-45° N & 52°-53° W	June-April	July - April	July - March
Laurentian 45°-46° N & 55°-56° W	All Year	June - March	July - March
Port-au-Port 48°-49° N & 59°-60° W	N.A.	N.A.	N.A.

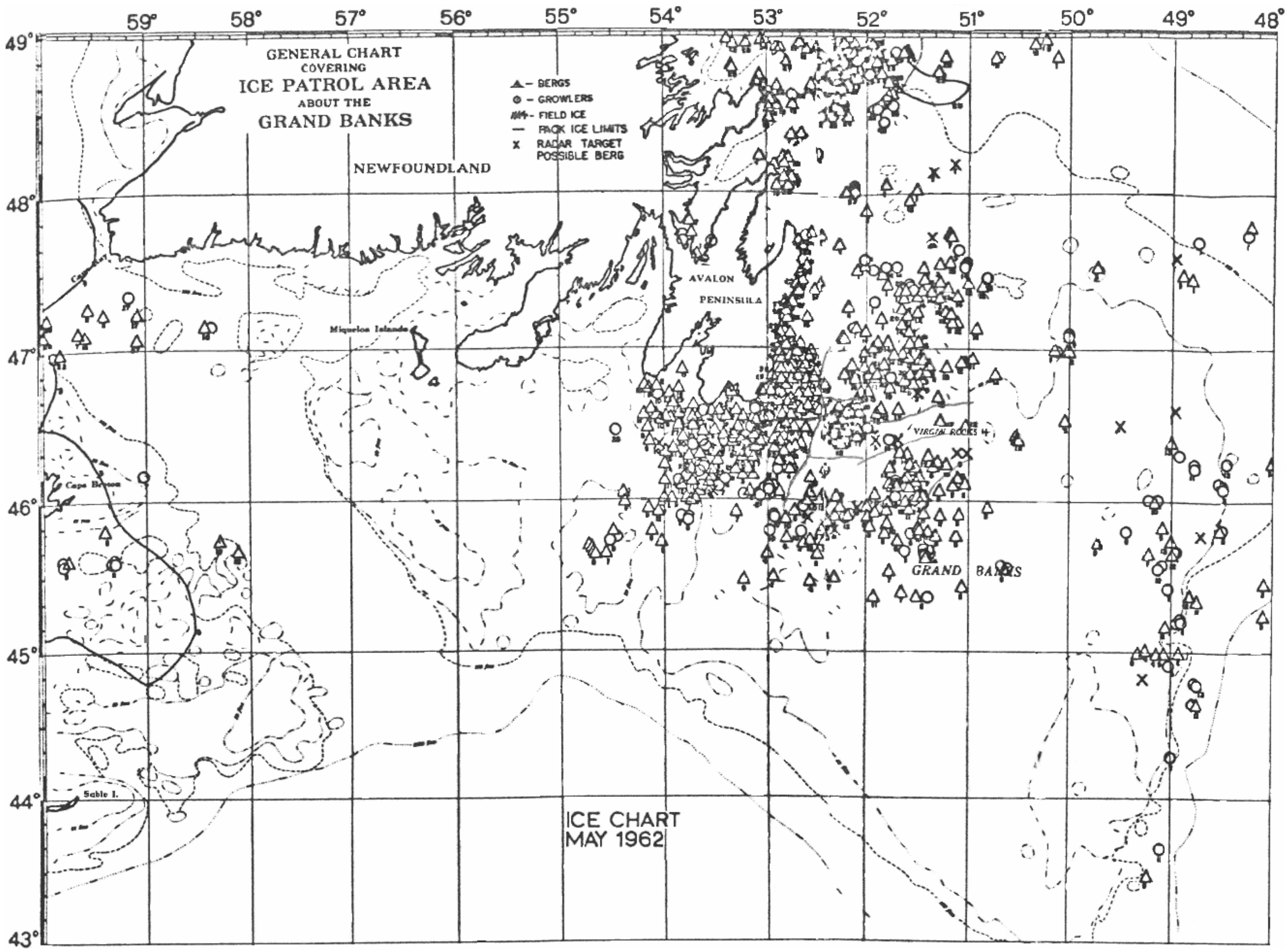

Figure 4-1 IIP iceberg chart showing icebergs likely to have drifted through the Gulf of St. Lawrence

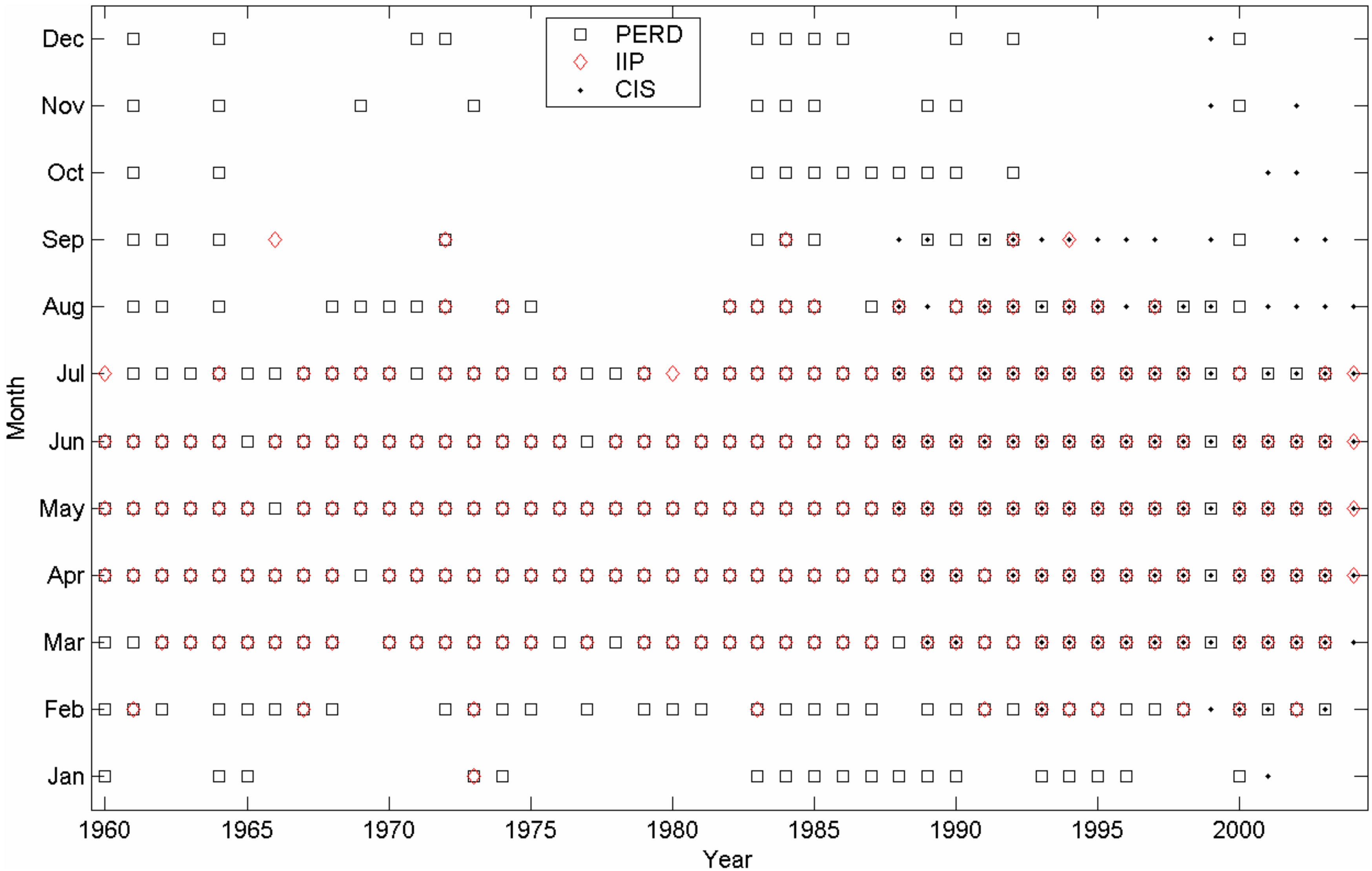

Figure 4-2 Months and years during which icebergs observed in study area

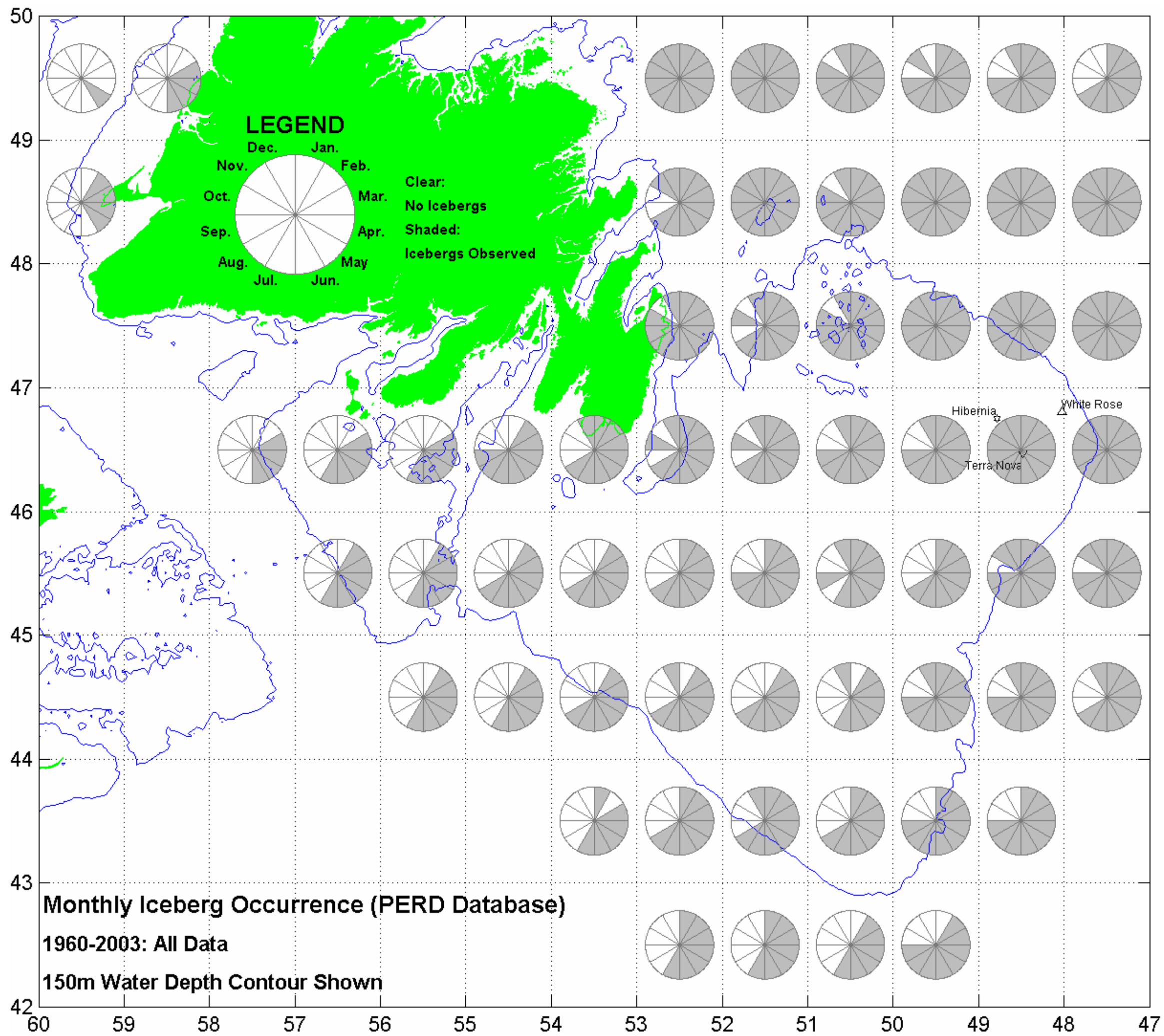

Figure 4-3 Months when any icebergs were recorded in PERD (2004) database

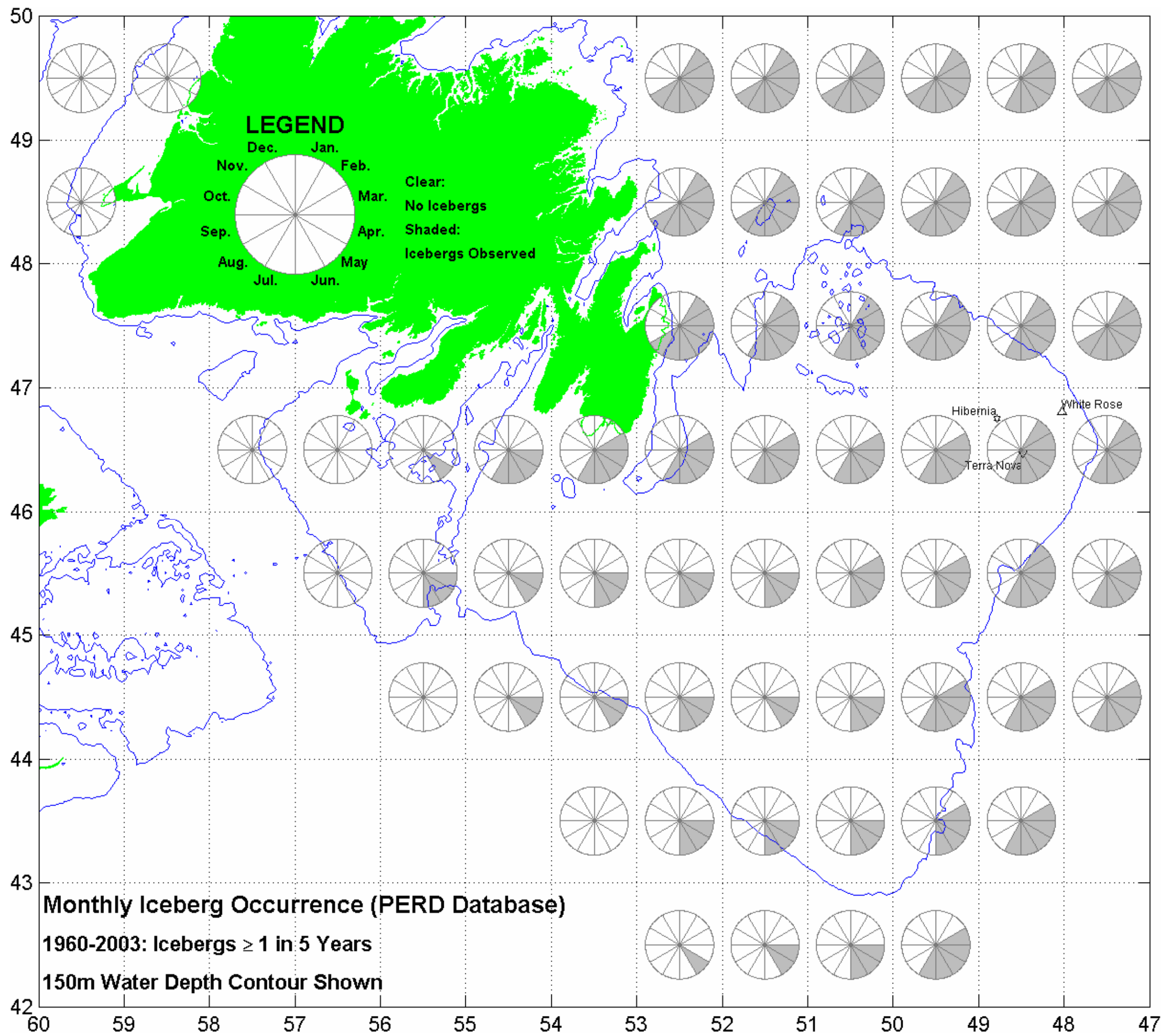

Figure 4-4 Months when icebergs were recorded in PERD (2004) database ≥ 1 in 5 years

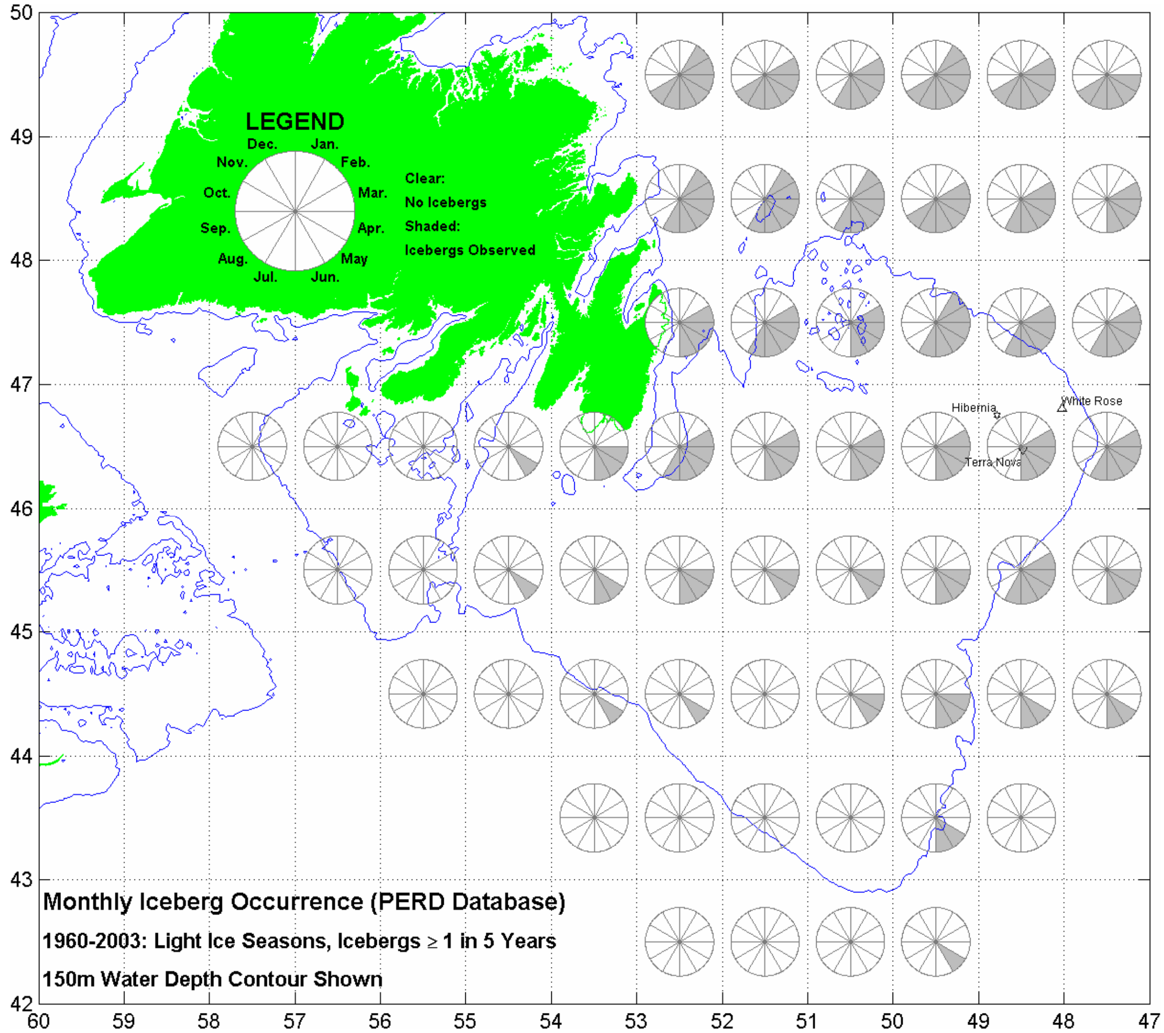

Figure 4-5 Months during light iceberg years when icebergs were recorded in PERD (2004) database ≥ 1 in 5 years

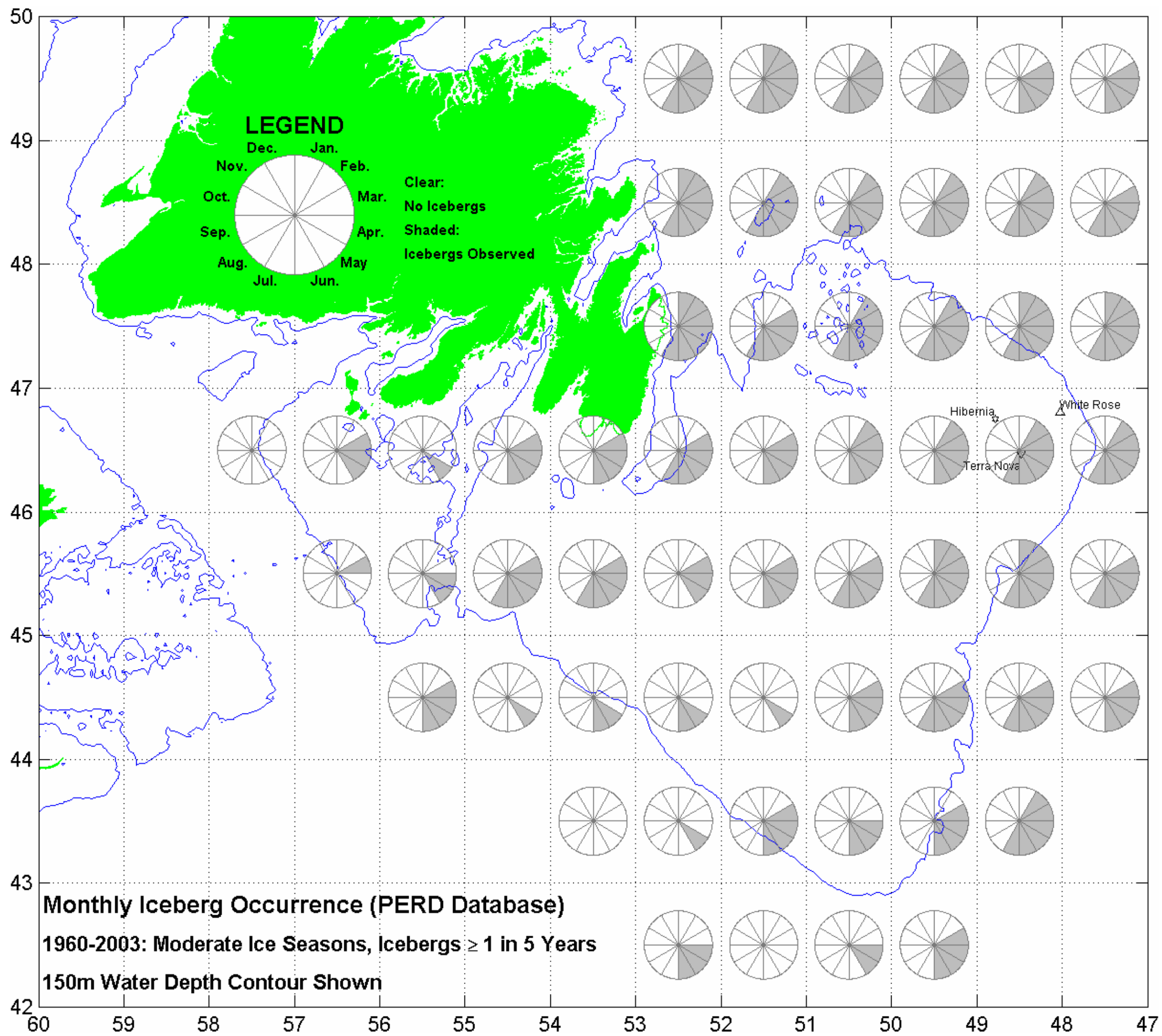

Figure 4-6 Months during moderate iceberg years when icebergs were recorded in PERD (2004) database ≥ 1 in 5 years

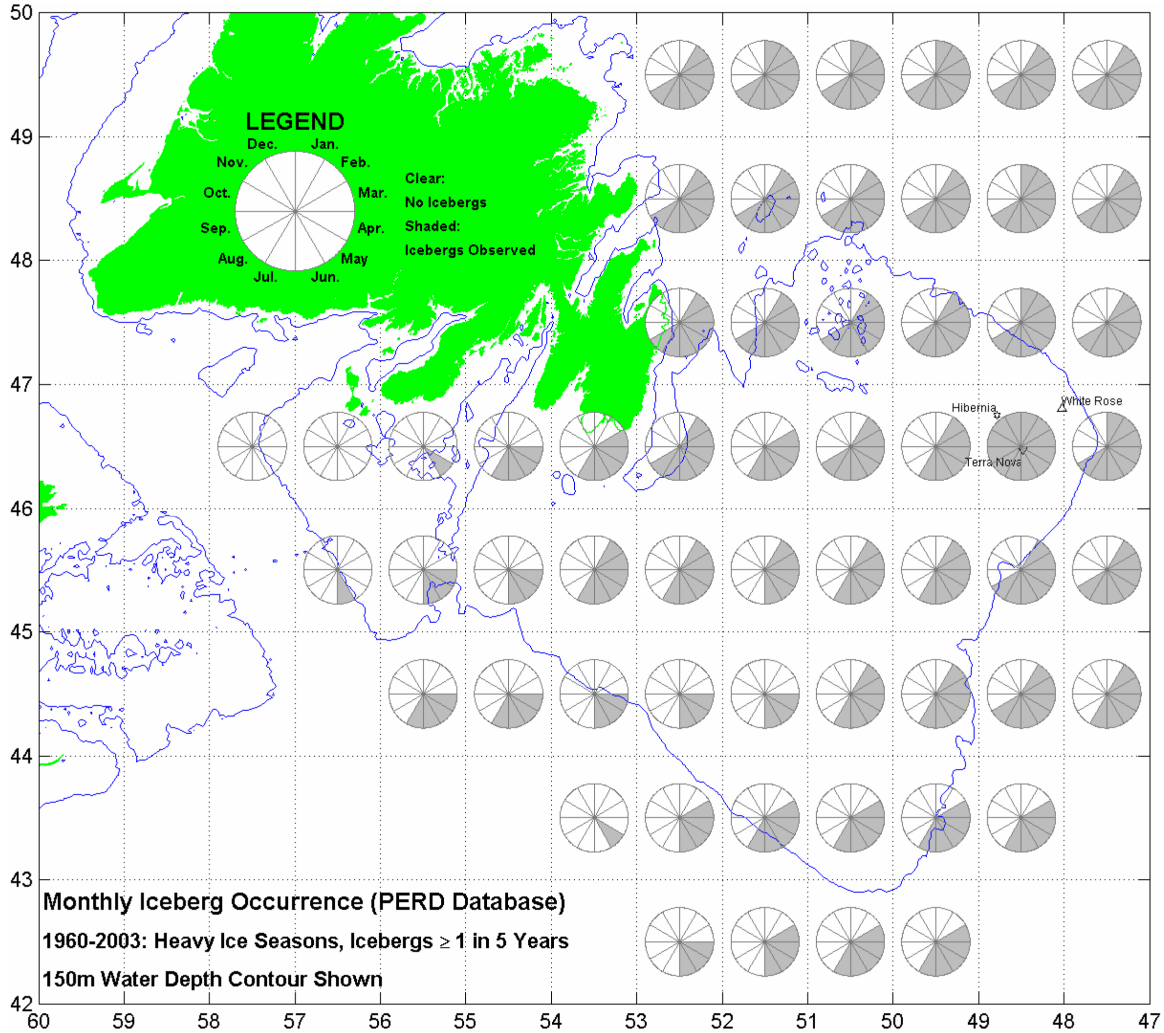

Figure 4-7 Months during heavy iceberg years when icebergs were recorded in PERD (2004) database ≥ 1 in 5 years

4.2 Pack Ice

The analysis of pack ice occurrence was conducted, using the method described in Section 3.2, for two separate ice-free definitions. The first definition considered whether any ice was observed in a degree-square over the entire 36 year duration of the data set. This represents the most conservative approach as it captures the maximum extent of all pack ice observations. The results for the study region are shown in Figure 4-8. Table 4-3 also provides the ice-free seasons for the four representative areas, shown in Figure 1-1, each presently containing exploration and/or production licenses, within the study region. Based on the entire dataset, the ice-free seasons at Jeanne D'Arc and Port-au-Port extend from June to December. Laurentian has an ice-free season from April to January. At South Whale, ice has only ever been observed during the month of March. This case, which considered any ice occurrence in the entire dataset as grounds for not being ice-free, produces a result that is overly conservative.

A more appropriate pack ice occurrence rate of no more than once every five years, on average, can still provide an adequate level of conservatism without being penalized by a rare pack ice incursion. The one in five year are shown in Figure 4-9, for the entire study region, and Table 4-3, for the four representative areas. Based on this criteria, both South Whale and Laurentian can be considered ice-free the entire year, four out of every five years. Jeanne D'Arc will only encounter ice during the month of March. Port-au-Port, however, will only be ice-free from May to December, as pack ice conditions in the Gulf of St. Lawrence are, generally, more severe than else where in the study region.

Table 4-3 Pack Ice free season for select areas in study region as defined by pack ice occurrence rate

Region	**Pack Ice Free Season**	
	Pack Ice Occurring at least once in entire dataset	**Pack Ice Occurring less than once in 5 years**
Jeanne d'Arc (46° - 47° N, 48° - 49° W)	June – December	April - February
South Whale (44° - 45° N, 52° - 53° W)	April – February	Year round
Laurentian (45° - 46° N, 55° - 56° W)	April - January	Year round
Port-au-Port (48° - 49° N, 59° - 60° W)	June - December	May - December

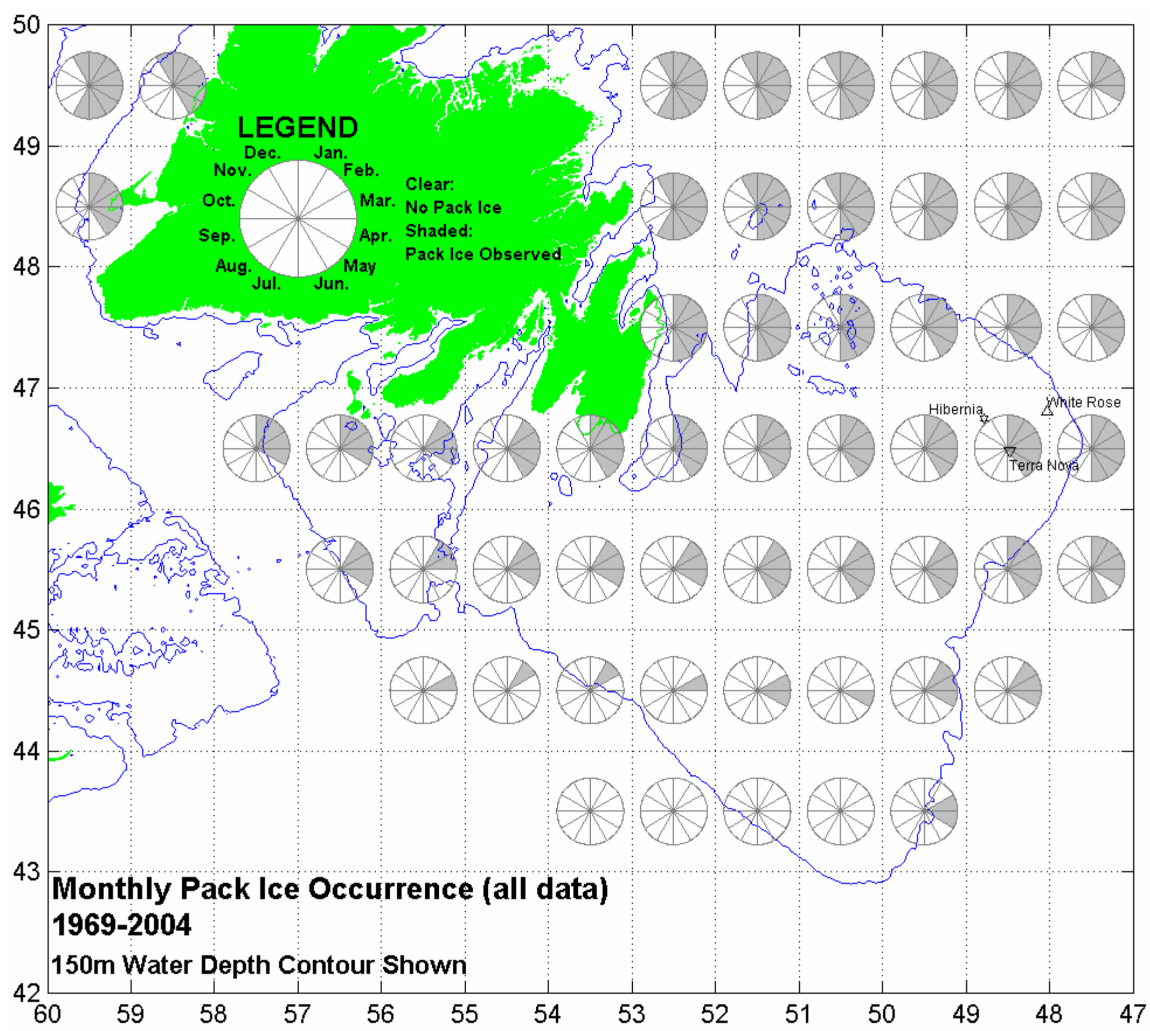

Figure 4-8 Monthly pack ice occurrence based on at least one observation in all years

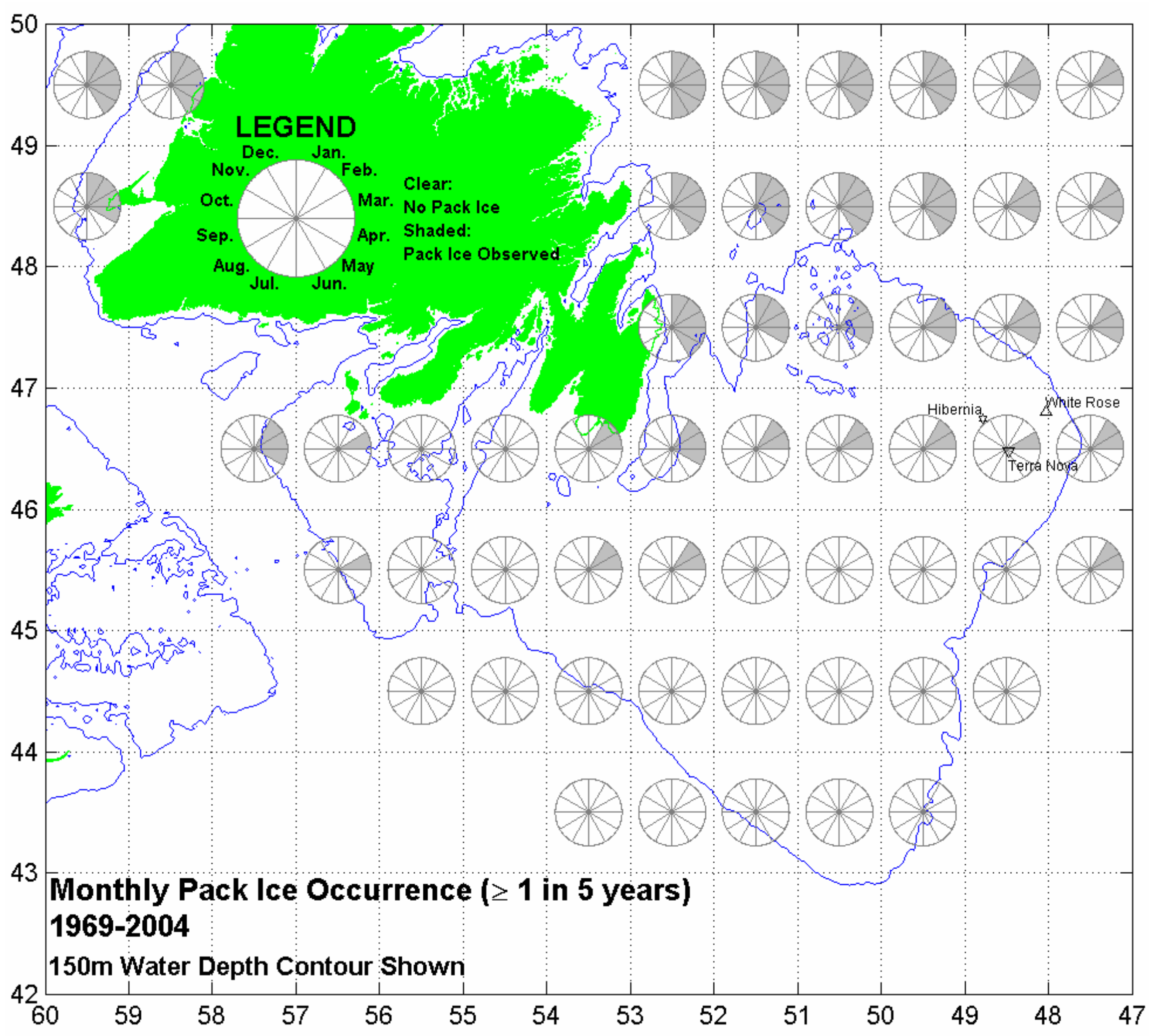

Figure 4-9 Monthly pack ice occurrence exceeding 1 in 5 years, on average

5 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The ice-free season was determined for the areas of interest indicated in Figure 1-1, based on the occurrence of ice in each month with a frequency of less than once in five years. The ice-free season was determined as the months that are free of both icebergs and pack ice. On the degree squares designated as Jeanne d'Arc, South Whale and Laurentian, the presence of icebergs dominates, while on the west coast on the Port-au-Port degree square the presence of pack ice dominates. Table 5-1 gives the ice-free season for each area, accounting for both icebergs and pack ice. Since pack ice data was not analyzed with respect to iceberg season severity, the ice-free seasons given in Table 5-1 do not account for variations according to the severity of the iceberg season. These results are discussed in Section 4.1.

These estimates of the duration of the ice-free season are intended to be conservative. A variety of strategies (long-range detection and forecasting, evasive maneuvers, etc.) would serve to mitigate risk and extend the effective ice-free season.

Table 5-1 Ice-free season based on long-term average conditions

Region	Ice-Free Season
Jeanne d'Arc (46°-47° N, 48°-49° W)	August - January
South Whale (44°-45° N, 52°-53° W)	July – March
Laurentian (45°-46° N, 55°-56° W)	July - March
Port-au-Port (48°-49° N, 59°-60° W)	May - December

5.2 Recommendations

Improvements in long-term forecasting of iceberg season severity would be useful for planning ice-sensitive operations. While statistically-based approaches have been developed, the increasing availability of satellite imagery to determine ice concentrations upstream (further north) allows other approaches to be developed which incorporate these additional data. This would better enable the CNOPB to authorize commencement of ice-sensitive operations during a given year based on the expected severity of the ice season (light, moderate or heavy).

While the current analysis gives a good indication of the typical ice-free season, as offshore operations expand into new areas (i.e. Labrador, Orphan Basin) additional environmental data will be required for effective risk assessment. This will require ongoing, long term, comprehensive data collection programs. With respect to ice, and in particular icebergs, this would be accomplished by more frequent surveys to provide support for future exploration and possible production activities. This may be accomplished by a combination of aerial and satellite surveys.

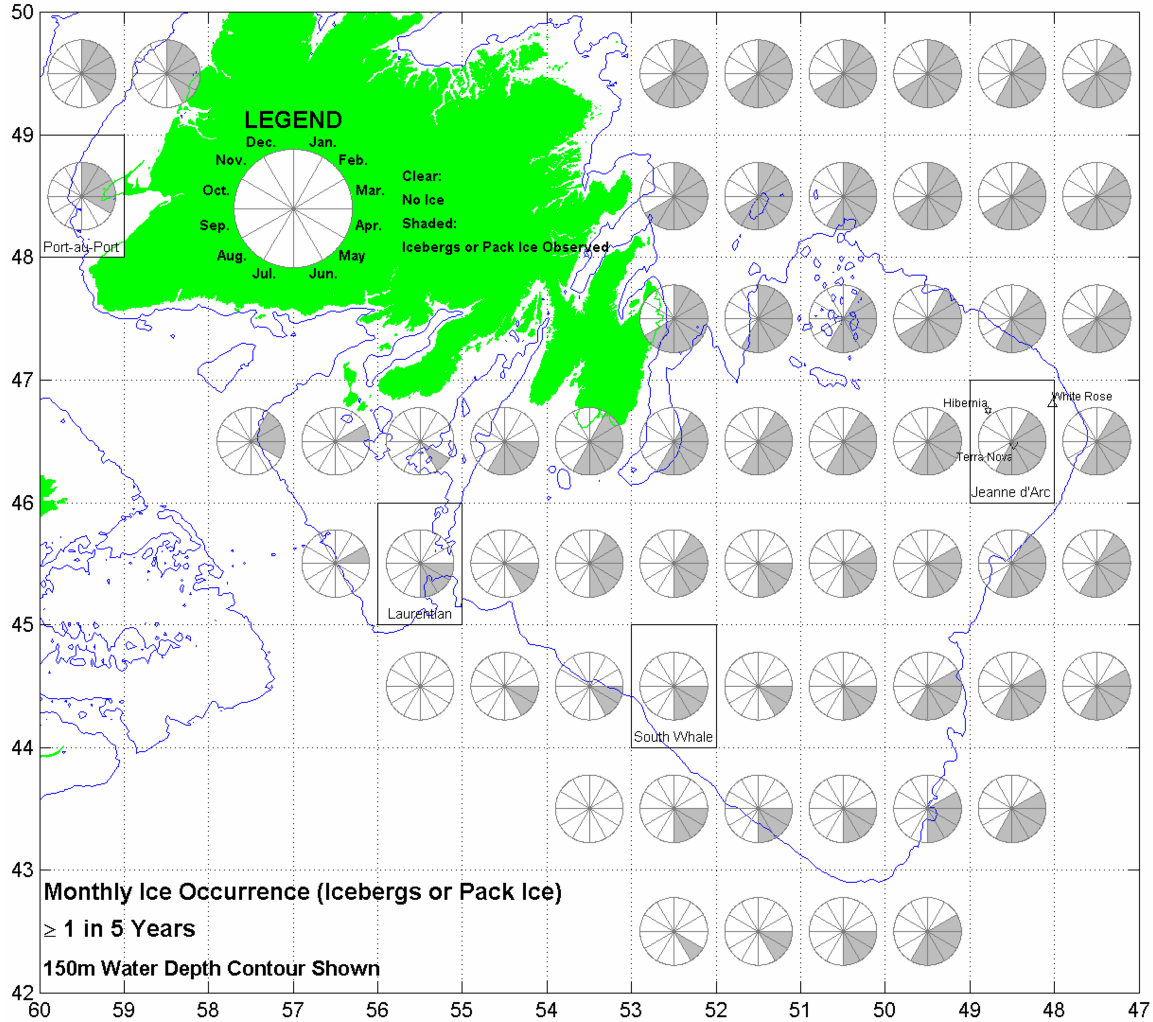

Figure 5-1 Typical ice-free season (no shading) based on ice occurrence once in 5 years

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APPENDIX A: ICEBERG OCCURRENCE USING IIP AND CIS DATA

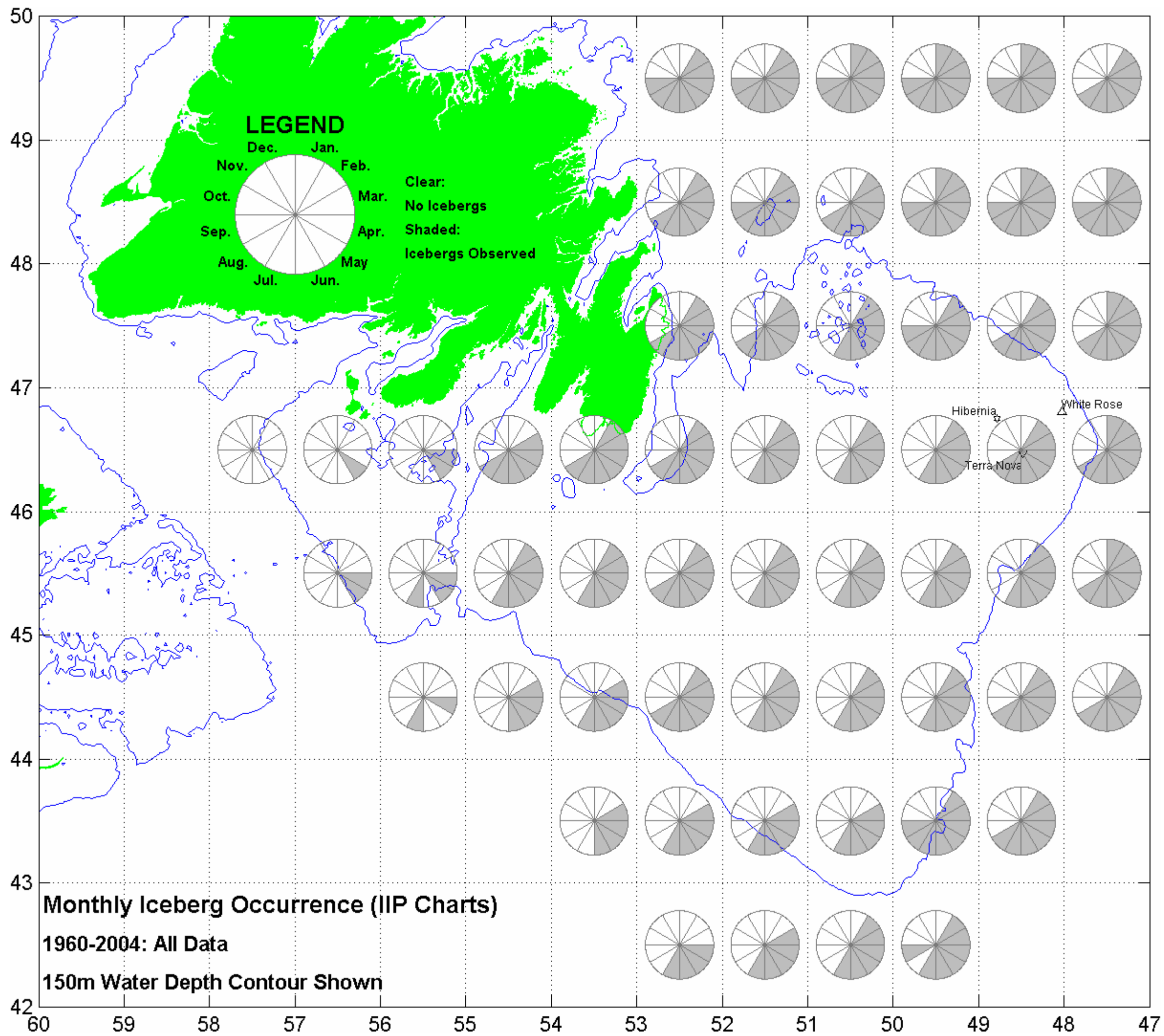

Figure A.1 Months when any icebergs were recorded in IIP charts

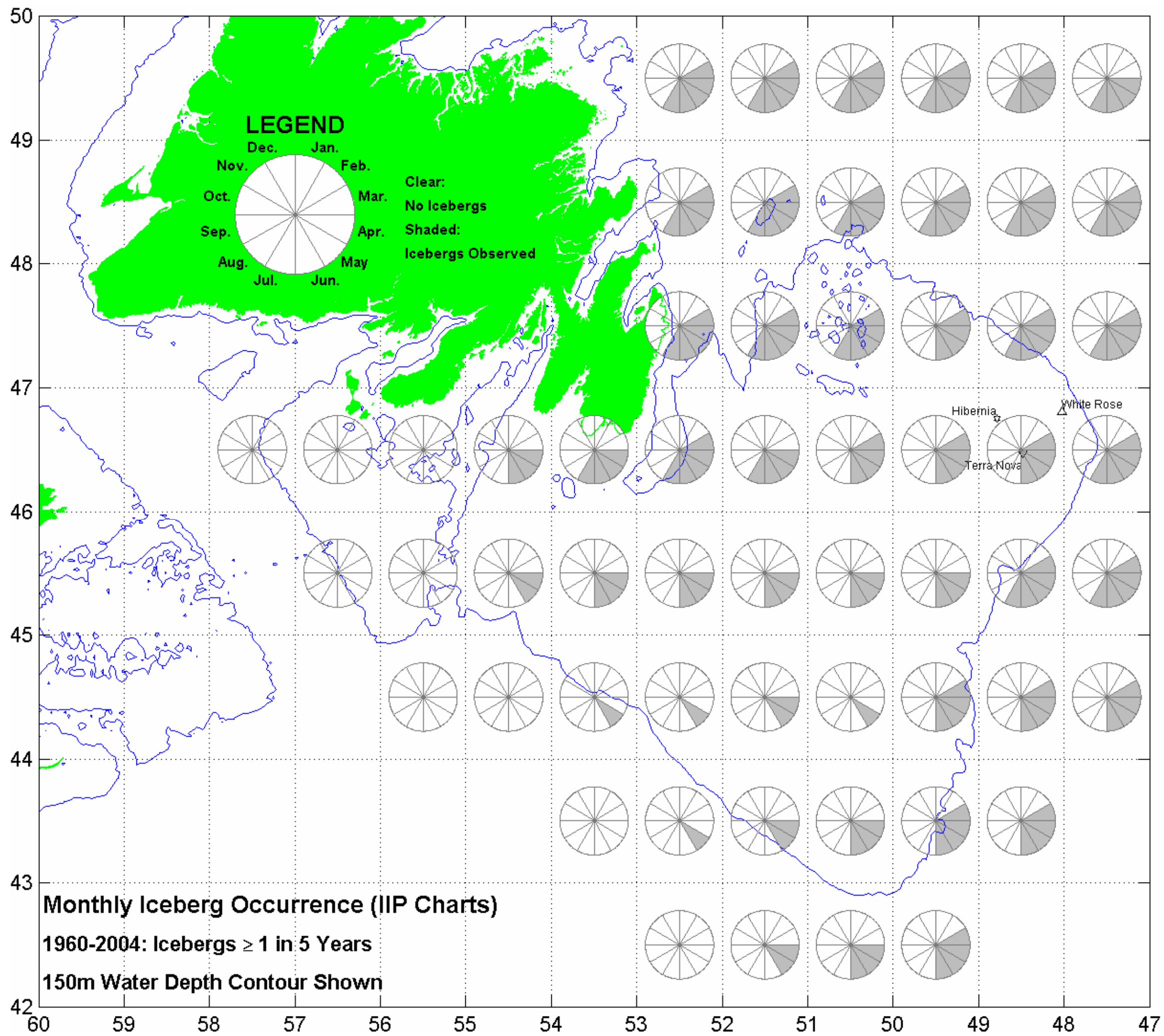

Figure A.2 Months when icebergs were recorded in IIP charts at least 1 in 5 years

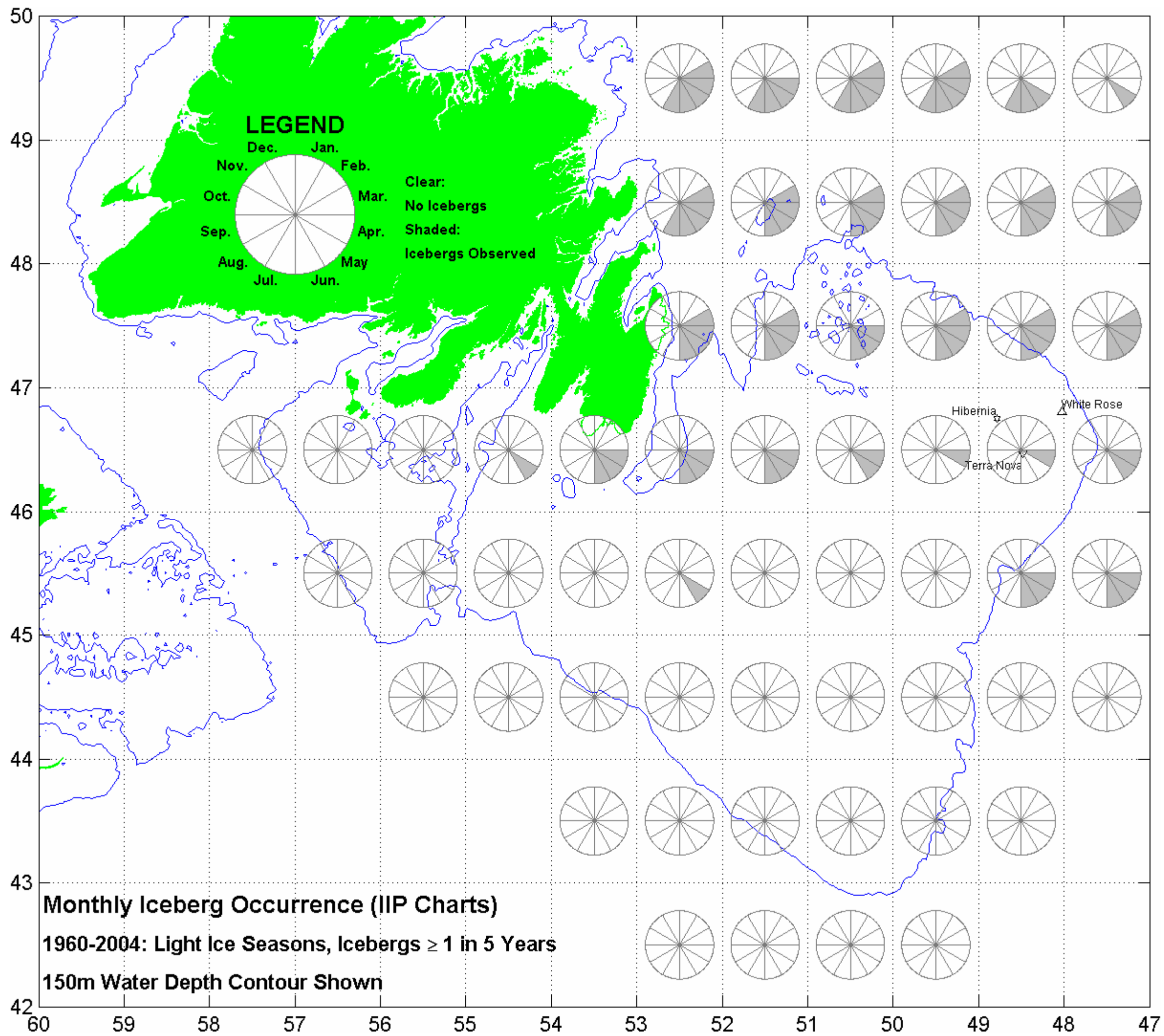

Figure A.3 Months during light iceberg years when icebergs were recorded in IIP charts at least 1 in 5 years

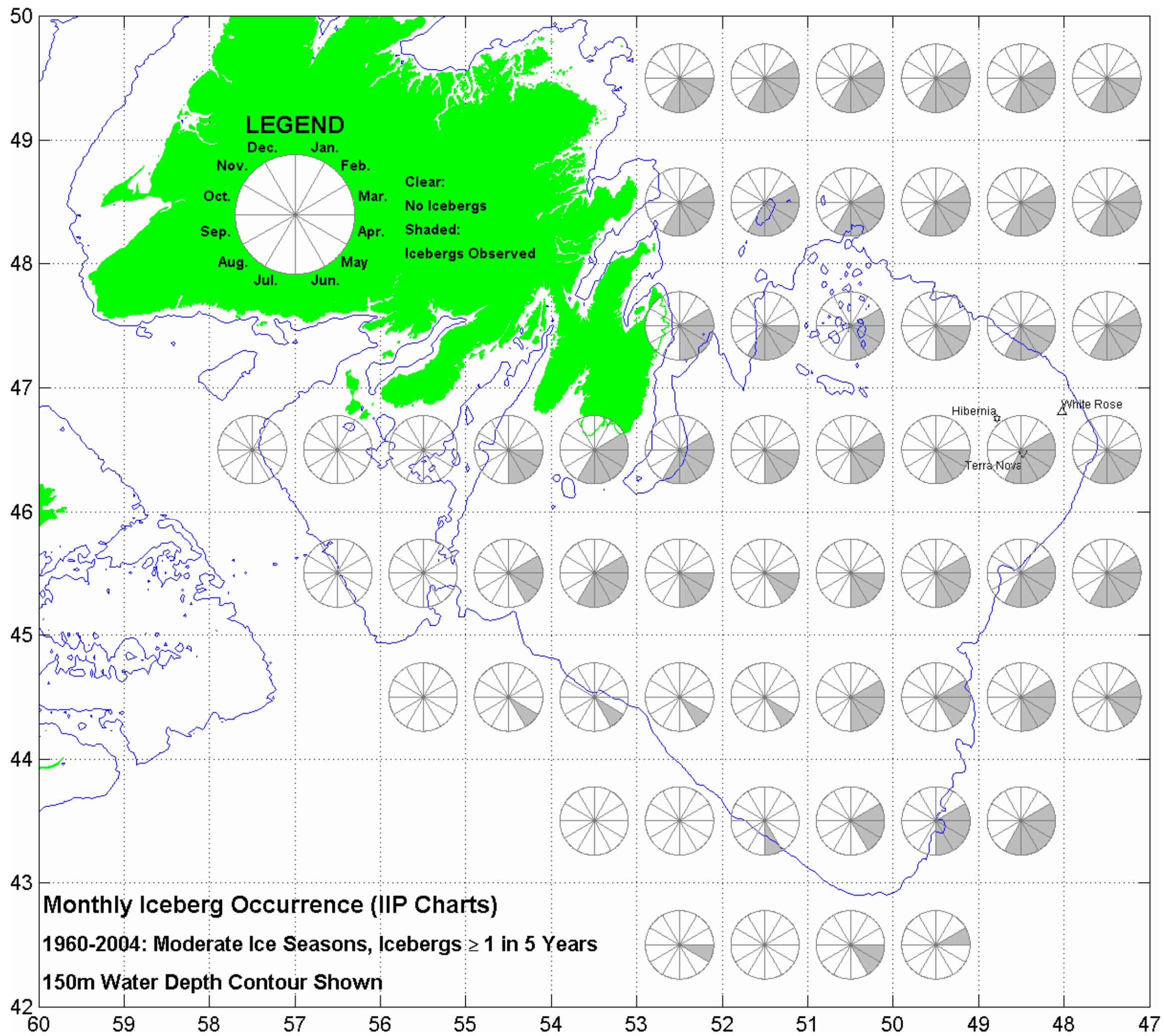

Figure A.4 Months during moderate iceberg years when icebergs were recorded in IIP charts at least 1 in 5 years

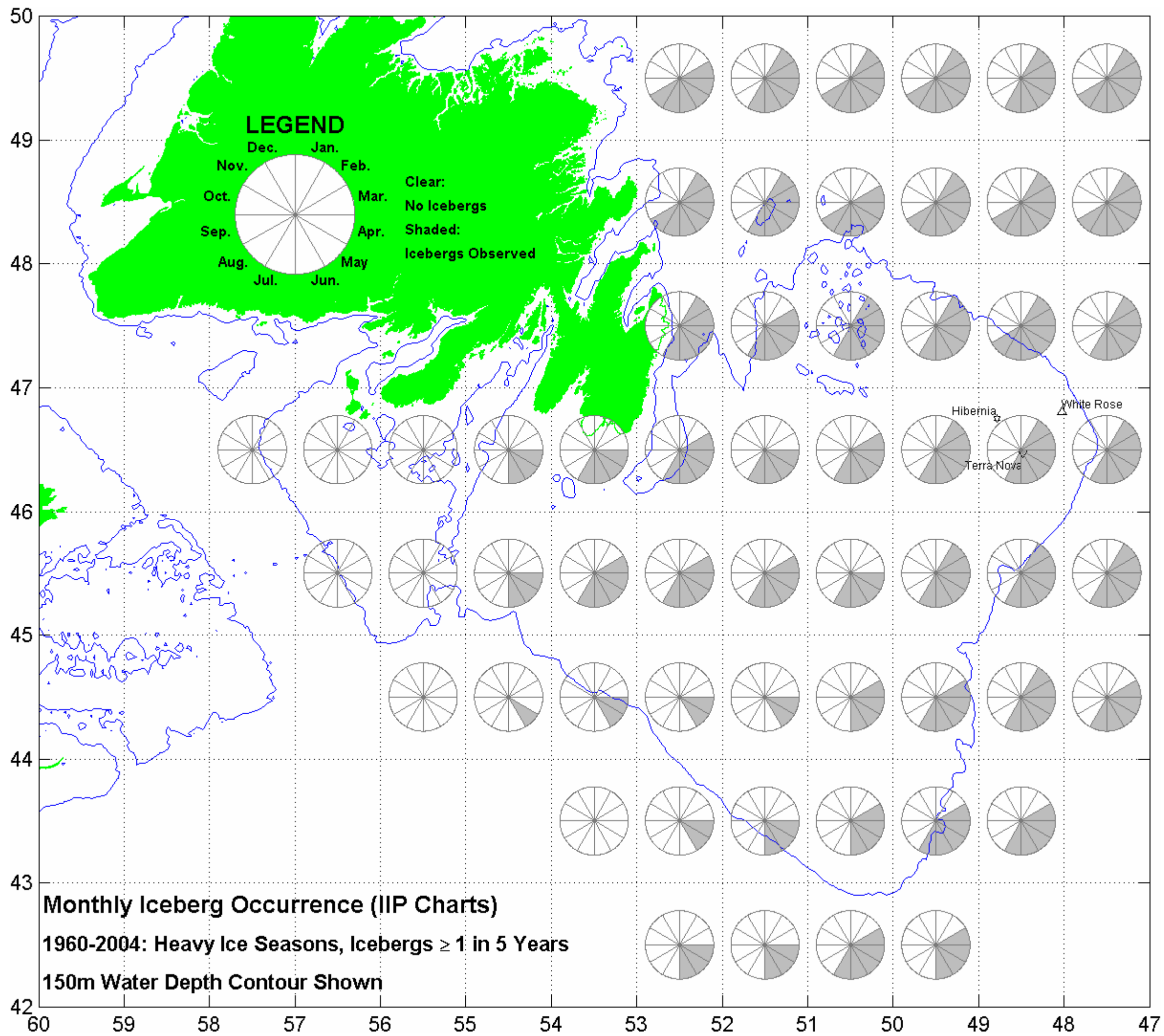

Figure A.5 Months during heavy iceberg years when icebergs were recorded in IIP charts at least 1 in 5 years

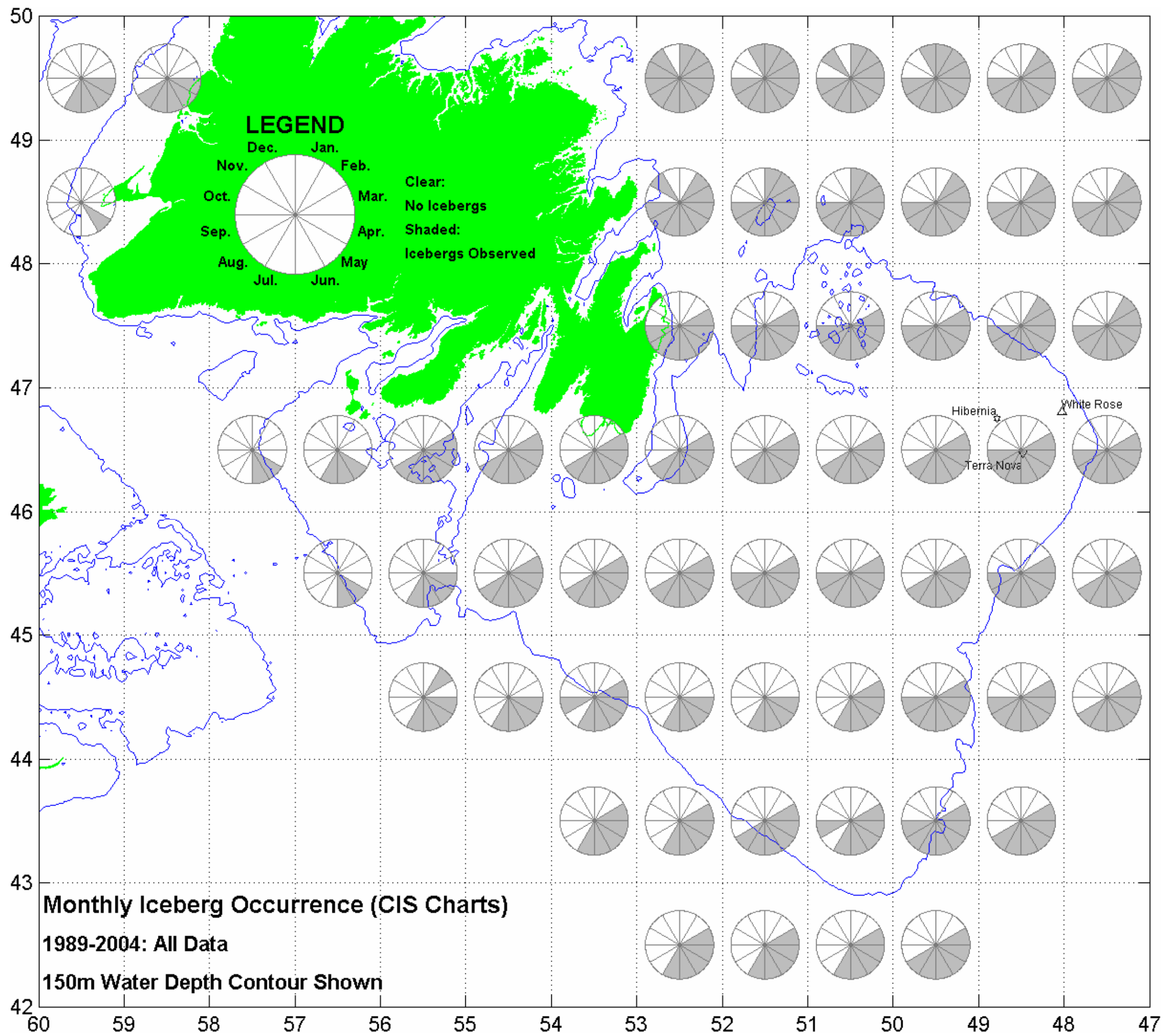

Figure A.6 Months when any icebergs were recorded in CIS charts

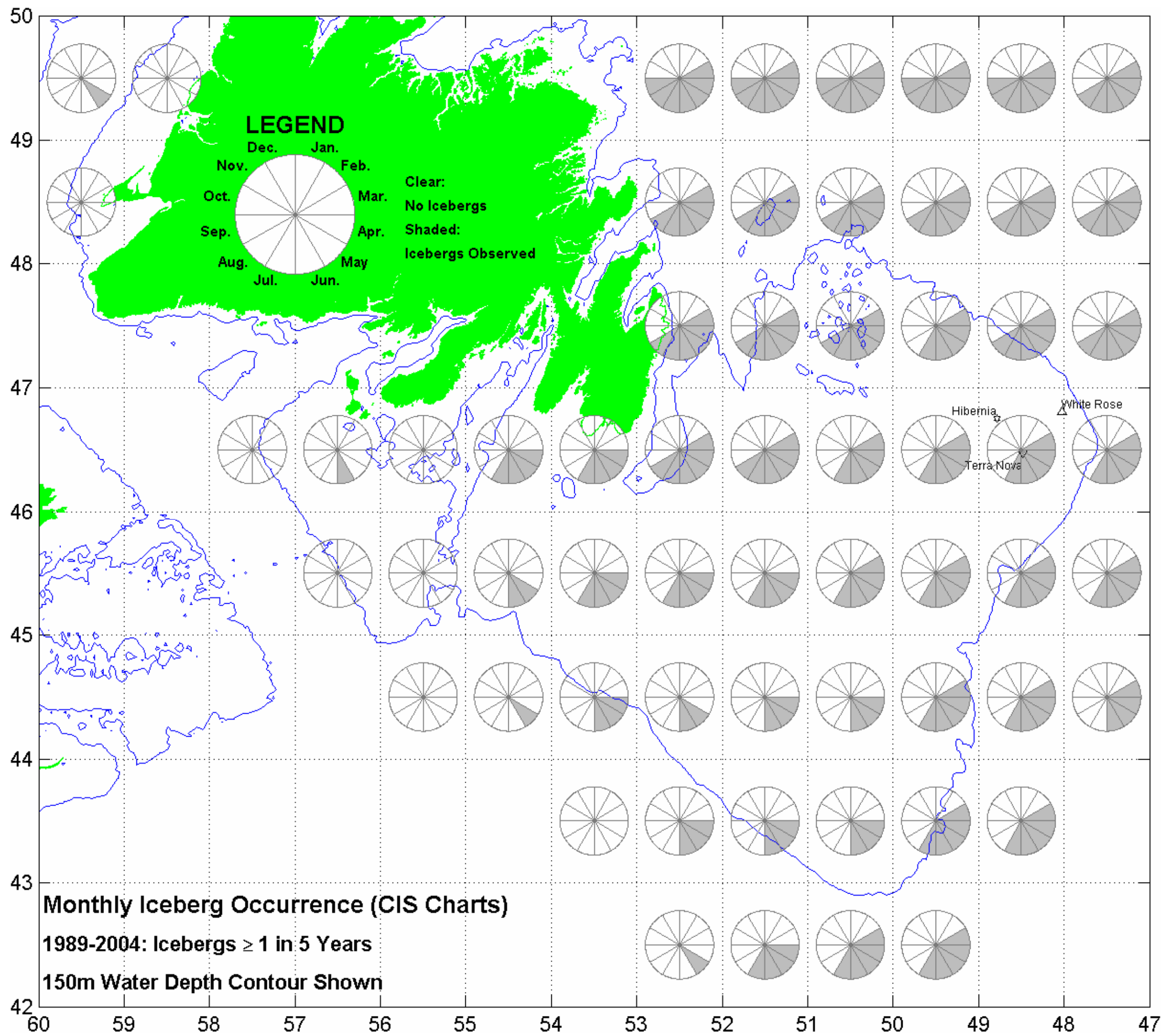

Figure A.7 Months when icebergs were recorded in CIS charts at least 1 in 5 years

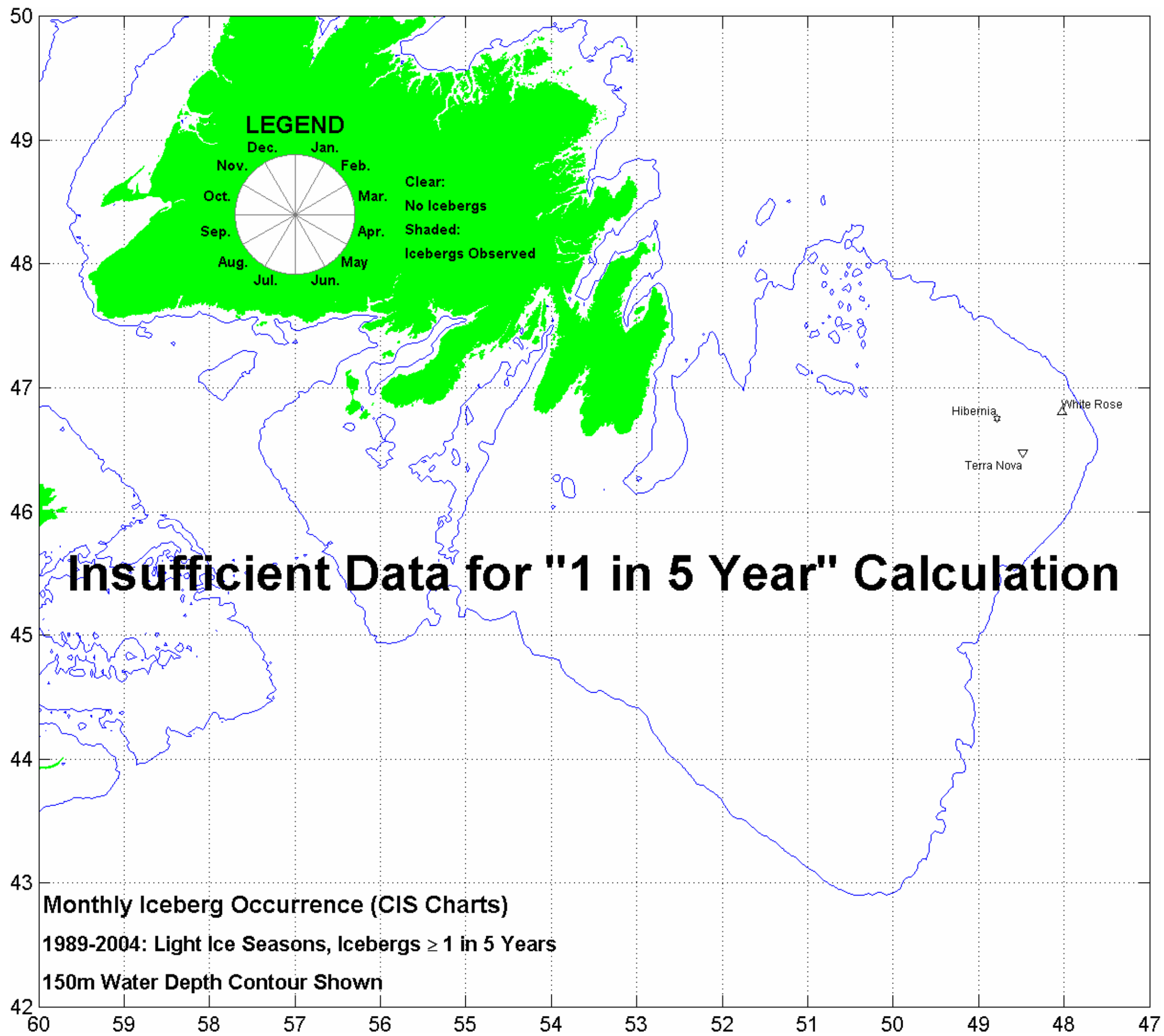

Figure A.8 Months during light iceberg years when icebergs were recorded in CIS charts at least 1 in 5 years

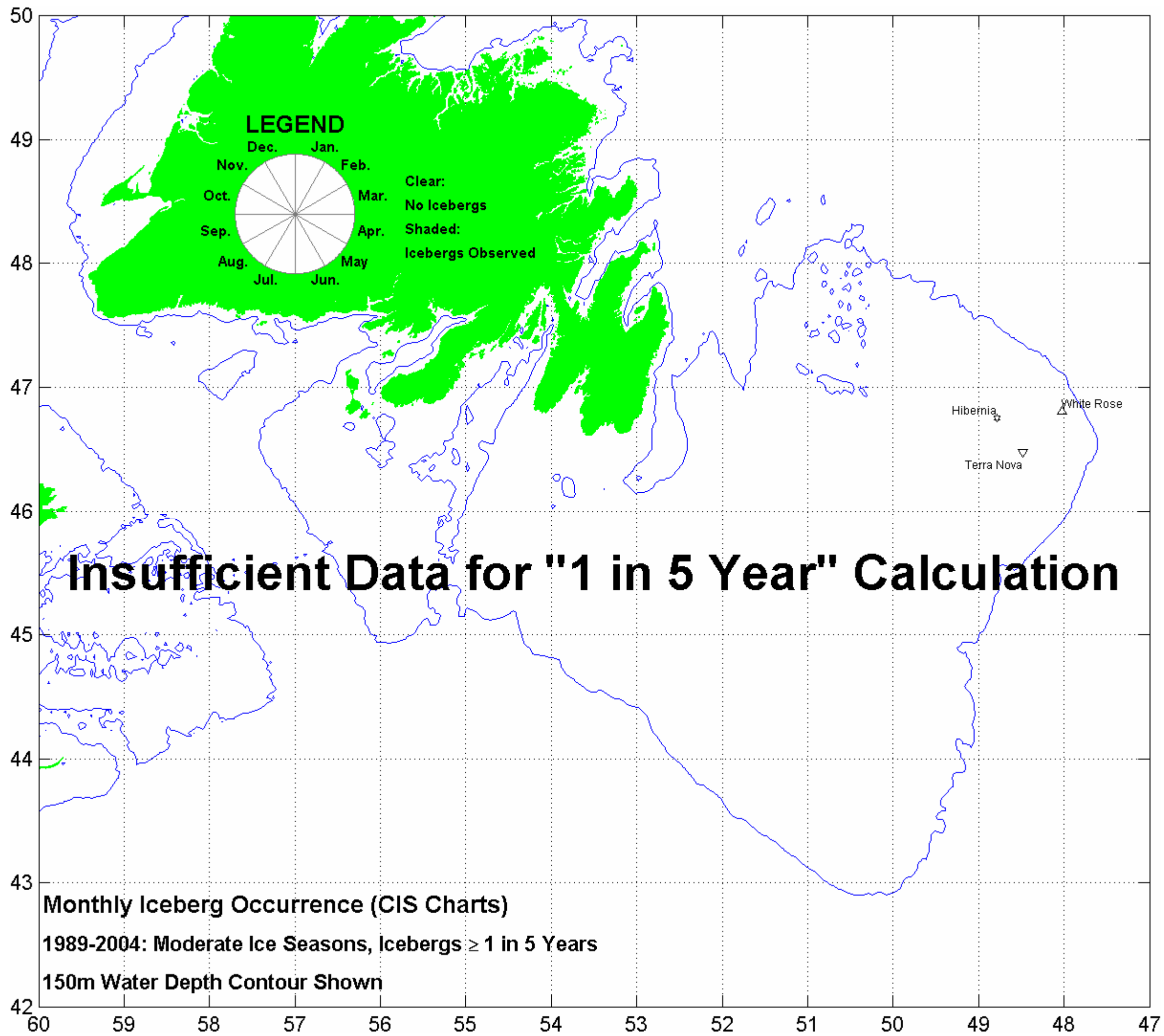

Figure A.9 Months during moderate iceberg years when icebergs were recorded in CIS charts at least 1 in 5 years

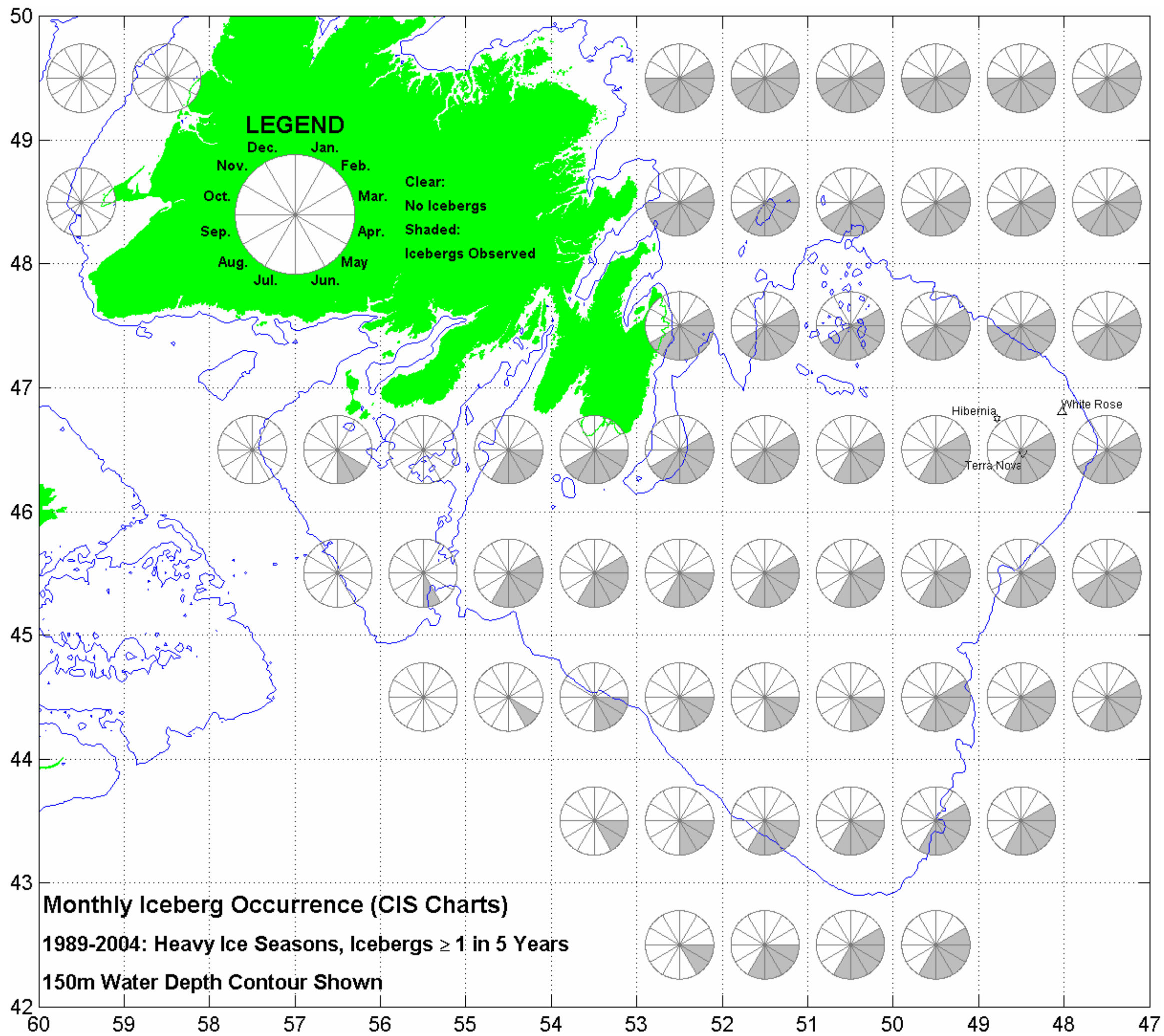

Figure A.10 Months during heavy iceberg years when icebergs were recorded in CIS charts at least 1 in 5 years