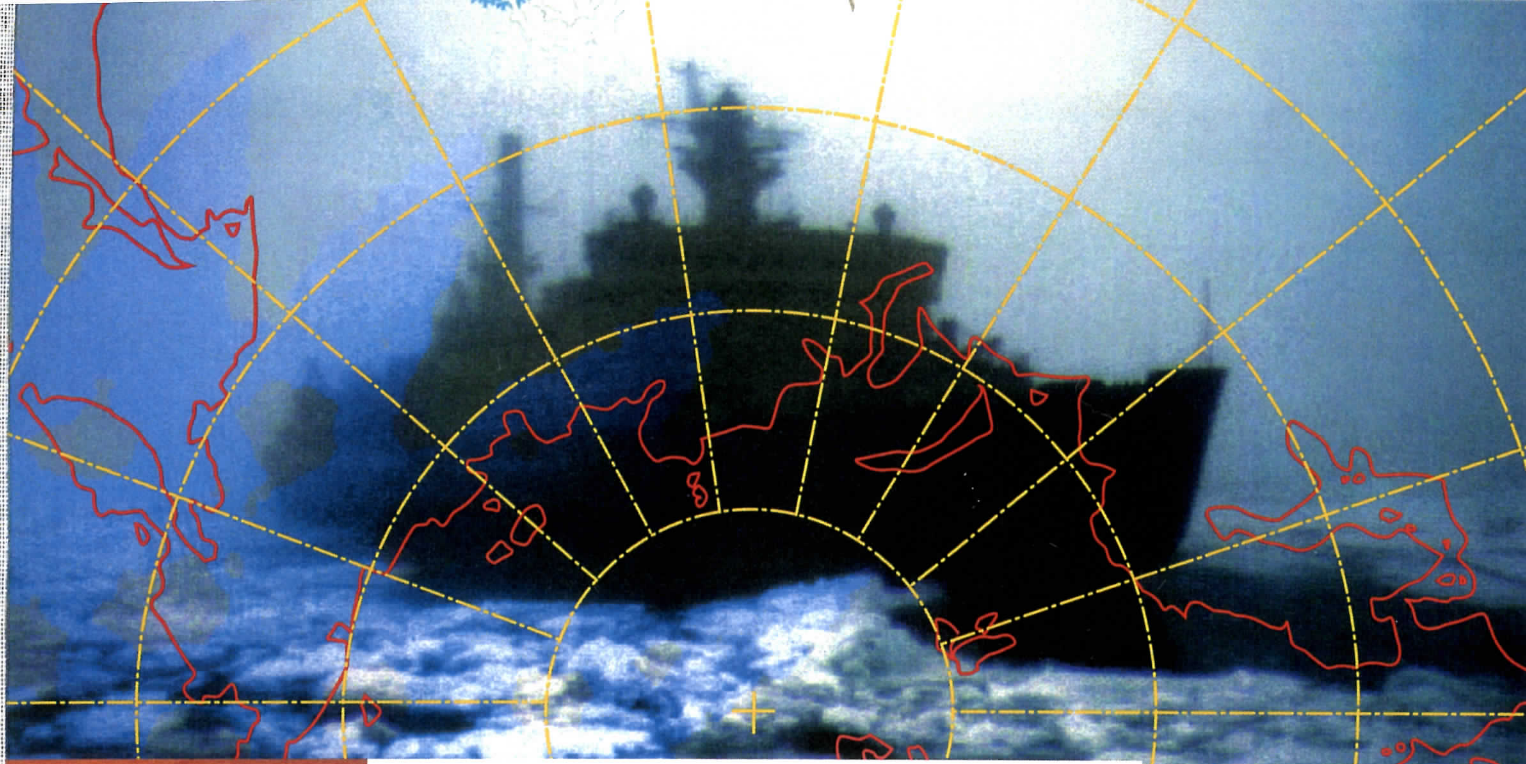
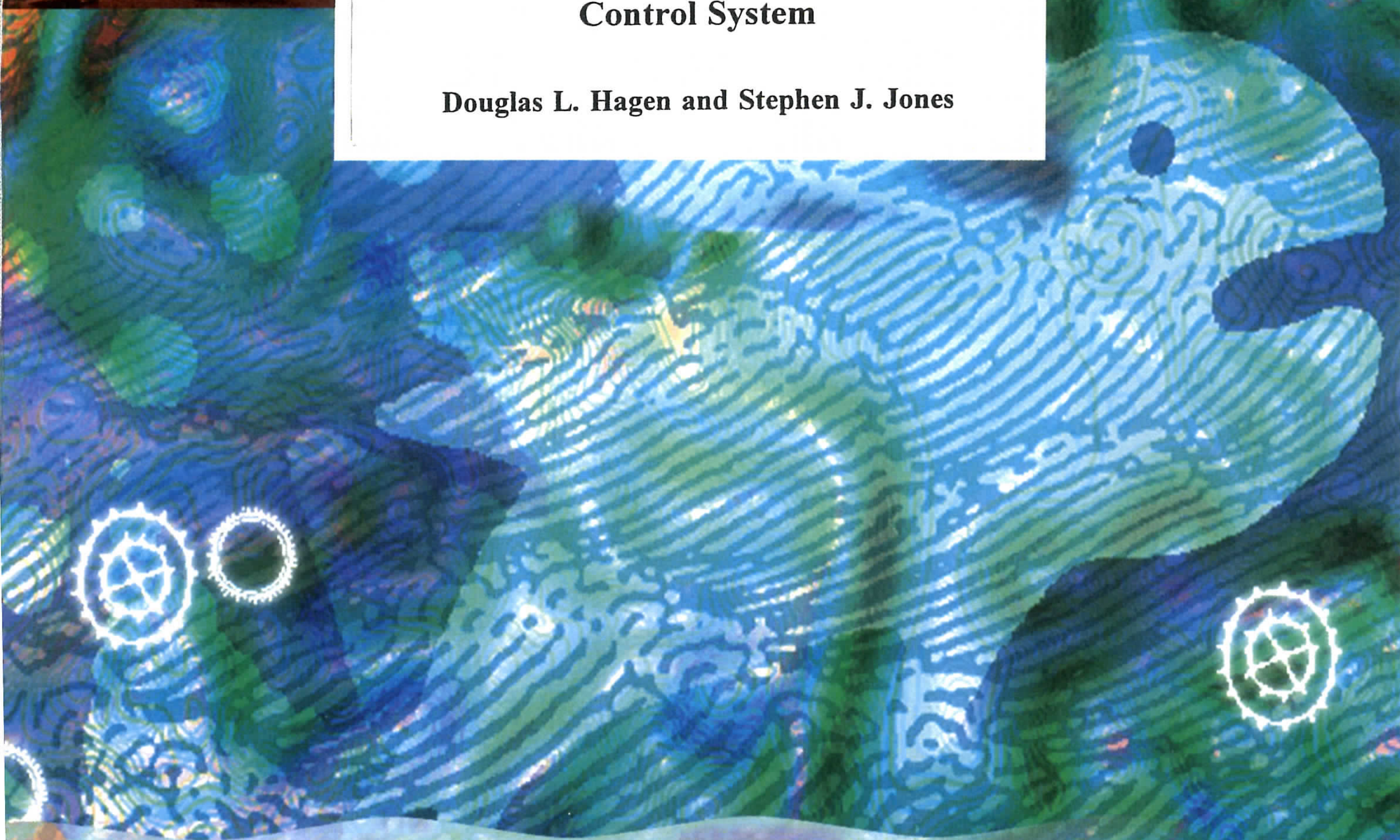


INSROP WORKING PAPER
NO. 32 - 1996, I.2.2

Evaluation of the Northern Sea Route Using the Ice Regime Shipping Control System

Douglas L. Hagen and Stephen J. Jones



INSROP International Northern Sea Route Programme

Central Marine Research & Design Institute, Russia

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International Northern Sea Route Programme (INSROP)

Central Marine Research & Design Institute, Russia

The Fridtjof Nansen Institute, Norway

Ship & Ocean Foundation, Japan

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FOREWORD - INSROP WORKING PAPER

INSROP is a five-year multidisciplinary and multilateral research programme, the main phase of which commenced in June 1993. The three principal cooperating partners are **Central Marine Research & Design Institute (CNIIMF)**, St. Petersburg, Russia; **Ship and Ocean Foundation (SOF)**, Tokyo, Japan; and **Fridtjof Nansen Institute (FNI)**, Lysaker, Norway. The INSROP Secretariat is shared between CNIIMF and FNI and is located at FNI.

INSROP is split into four main projects: 1) Natural Conditions and Ice Navigation; 2) Environmental Factors; 3) Trade and Commercial Shipping Aspects of the NSR; and 4) Political, Legal and Strategic Factors. The aim of INSROP is to build up a knowledge base adequate to provide a foundation for long-term planning and decision-making by state agencies as well as private companies etc., for purposes of promoting rational decisionmaking concerning the use of the Northern Sea Route for transit and regional development.

INSROP is a direct result of the normalization of the international situation and the Murmansk initiatives of the former Soviet Union in 1987, when the readiness of the USSR to open the NSR for international shipping was officially declared. The Murmansk Initiatives enabled the continuation, expansion and intensification of traditional collaboration between the states in the Arctic, including safety and efficiency of shipping. Russia, being the successor state to the USSR, supports the Murmansk Initiatives. The initiatives stimulated contact and cooperation between CNIIMF and FNI in 1988 and resulted in a pilot study of the NSR in 1991. In 1992 SOF entered INSROP as a third partner on an equal basis with CNIIMF and FNI.

The complete series of publications may be obtained from the Fridtjof Nansen Institute.

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Evaluation of the Northern Sea Route Using the Ice Regime Shipping Control System

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1
Introduction

1.1 Background

INSROP, the International Northern Sea Route Programme is a comprehensive multi-national, multi-disciplinary five-year research programme designed to investigate the possibilities for commercial navigation through the North-East Passage. The programme is based on a mutual agreement of cooperation between three principal partners: Ship and Ocean Foundation, Japan, Central Marine Research and Design Institute, Russia and the Fridtjof Nansen Institute, Norway. The Northern Sea Route is described in general terms as the ship route from northern Europe to the Bering Strait following the Arctic coastline. This is a shorter distance from Europe to Japan than if one went south through the Suez canal (approx. 6900 nmi. via the Northern Sea Route, 11,400 nmi. via the Suez Canal). There is however, the added element of sea ice when one considers the Northern Sea Route. By following the Arctic Ocean coastline, the Northern Sea Route will always encounter at least some areas of drifting sea ice. It becomes imperative then, to assess the feasibility of the Northern Sea Route as it is affected by ice. Some work has already been done in this area with regards to data collection of ice conditions, and trafficability of ice conditions by both icebreakers and ice strengthened cargo ships. An extensive database of ice observations by the Russians is also available. These data describing ice conditions are varied in detail and geographical coverage as well as representing different observing techniques.

To assess the feasibility of transiting the Northern Sea Route ice conditions, it thus becomes necessary to have a baseline on which to compare all available data. It is believed that such a baseline exists in the recently published Canadian Coast Guard document: **The Ice Regime Shipping Control System** (IRSCS). The IRSCS is the shipping control aspect of the Arctic Shipping Pollution Prevention Regulations (ASPPR). These regulations control shipping in Canadian waters north of 60 ° N. Lat. The IRSCS is a new element of the ASPPR where access to an area is governed by the amount and type of actual ice present in an area. The old system was based on a zone and date system whereby a given class of ship was allowed entry to a given area at the same time and for the same duration each year. The new IRSCS uses actual ice conditions to determine whether entry is advisable for a particular ice class vessel (a detailed description of how entry is determined using ice conditions under the IRSCS is contained in **Appendix A** of this report).

This report presents the results of an analysis of ice data using the IRSCS as the common denominator. Data were gathered and transferred to common basemaps of the Northern Sea Route to determine the feasibility of transiting it when operating under the IRSCS. It should be noted that in many cases data describing particular characteristics of the ice cover such as stage of decay, amount of ridging, and floe size were not directly available, and had to be estimated based on general descriptions of the region. The results of this analysis do however, indicate what ice class a vessel would need to transit the Northern Sea Route under the IRSCS, and what areas would likely require Icebreaker assistance.

1.2 Objectives

The principle objective of this project is:

- To assess the feasibility of utilizing the Northern Sea Route as a commercial trade route between Japan and Europe, as indicated by the Ice Regime Shipping Control System

This objective was reached by assessing several different data sets and published reports describing ice conditions along the route, and comparing them to the various classes and types of ice strengthened vessels to determine the minimum ice class a vessel would need to possess to make the transit safely. To determine what is *safe* the IRSCS was used as a baseline for comparison. Under the IRSCS each ice type is given a weighting relative to each type and class of ice strengthened vessel. When an ice type is deemed too severe for the construction standard specified for that type or class of vessel, that ice type is considered hazardous, and is given a negative weighting. One then takes the sum of the products of each ice type weighting, times the amount of ice that is present in tenths, to arrive at a decision numeral. If the decision numeral is zero or positive the vessel can proceed, but if the decision numeral is negative the vessel must stop. In this way it is possible to determine the minimum ice class of vessel that is required to transit the entire route in zero or positive decision numerals.

1.3 Report Organization

This report is divided into five sections, the first of which is this introduction. Section two describes the method of approach and the datasets that were used. Section three describes the analysis process, and discusses the results. Section four provides conclusions, while section five provides references.

This report is supported by two appendices. Appendix A describes the Ice Regime Shipping Control System in detail, Appendix B presents the Russian ice observation data map sets of decision numerals.

2

Method of Approach

The Northern Sea Route as considered in this report spans the vast area from the Bering Sea to Norway along the northern, arctic, coast of Russia. To cover this area on a map scale that allowed for analysis a three map set was developed. These three maps covering the Northern Sea Route (NSR) are presented as **Figures 2.1, 2.2,** and **2.3.** On these three maps the Russian Ice Observation data were plotted as a single dot. The colour of the dot represented the minimum ship class that could transit that grid square with a zero or positive decision numeral as determined using the IRSCS. To then determine what the minimum ship class would be for the entire route a set of overlays were developed that represented the normal shipping route through the area. It was then a process of recording what ship class (or type) of vessel would have had zero or positive decision numerals along the entire route.

The process described above provided an *unmodified* or baseline data set for the route. It was then necessary however, to modify the ice data to reflect other parameters of concern to the IRSCS; specifically: whether or not the ice is decayed, how much of the ice cover is in brash floe sizes, and how much of the ice has greater than three tenths ridging when the total concentration in greater than six tenths. These parameters are known as modifiers within the IRSCS, and allow one to increase the ice multiplier in the case of decayed ice and brash floe sizes in recognition of the lower risk of structural damage they pose to a vessel, and decrease the ice multiplier in the case of ridging as ridged ice poses a larger risk to a ship's structure. Thus although the Russian data provided information on concentration, partial concentration, and ice type, it did not provide all the information needed to accurately apply the IRSCS. For this reason other data sources were consulted which did contain this type of information. These other data sources are described below.

2.1 Datasets

2.1.1 Russian Ice Data

The principle data source on ice conditions in the Northern Sea Route was the Russian Ice Observations. These were obtained from the US National Ice Centre and area data which AARI (Arctic Antarctic Research Institute in St. Petersburg - Russia) digitized from the Russian Integrated Ice Charts. The Russian Integrated Ice Charts charts, produced in Russia, are based on side-looking airborne radar (SLAR), visual, and satellite data. This data is believed to be the most accurate for the region, and was used to determine minimum ship class for the entire route in each period for each year. This dataset did not, however, contain information on state of decay, amount of brash ice present, or amount in tenths of ridging. These data were obtained from other sources (described in the following four sections) and applied to the Russian data where applicable.

2.1.2 Norwegian Voyage Observations

Norvald Kjerstad, an employee of the Norwegian Marine Training Institute, collected two detailed data sets on ice conditions during the summer in the Northern Sea Route. In 1991 a voyage was documented which went from Murmansk to Yokohama, and in 1994 a voyage from Murmansk to the North Pole via the Kara Sea was documented. These two data sets contained all the information required to determine where modifiers to the decision numerals should be applied. They do however, represent only a single time slot in a single year thus they were used in conjunction with other data from additional years.

2.1.3 Nuclear Icebreaker Rossia Voyage Data

In late July-early August of 1987 the nuclear powered Russian Icebreaker Rossia conducted a voyage from Murmansk through the Kara Sea to Severnaya Zemlya then to the North Pole and back again. Onboard this vessel was an employee of Norland Science who was specifically tasked to collect detailed ice information. Although this provides only a single time frame in one particular year, it provided very detailed data that was easily used to determine where to apply the ice modifiers. Unfortunately this trip provided information on the western and central sections of the NSR, but nothing to the east.

2.1.4 Helsinki University - Description of Ice Conditions

A document from the Helsinki University of Technology - Arctic Offshore Research Centre produced by Kaj Riska and Olli Salmela titled Description of Ice Conditions along the Northeast Passage was also used. This document did not include actual observations of ice conditions, however it did provide an excellent overview. It was based on a literature review, NOAA satellite images and on the Russian Ice Atlas (Arctic Ocean Atlas 1980). On a monthly basis it provided information on temperature regime, total ice coverage, maximum level ice thickness, average ridge sail height, an index of pressure, and coverage in tenths of multi-year ice. This data also provided a check against the primary data set of Russian Ice observations.

2.1.5 U.S. Navy/NOAA Ice Charts

The National Ice Centre in Washington D.C. produces ice charts covering the Northern Sea Route (and all other ice-covered waters in the Northern Hemisphere) once a week all year round. These charts were used to assess the overall picture of the region at any given time when assessing other more detailed data. For example, when the Russian data showed a lot of multi-year ice along the Siberian coast east of Wrangel Island, the Navy/NOAA charts were used to determine if this was a local condition, or if the Polar Pack had pushed right down to the coast. These charts did not provide any information beyond what the Russian Ice Observation data did in regards to detail, however, they were a good second opinion on ice concentration and type, and also provided a broader perspective of ice conditions.

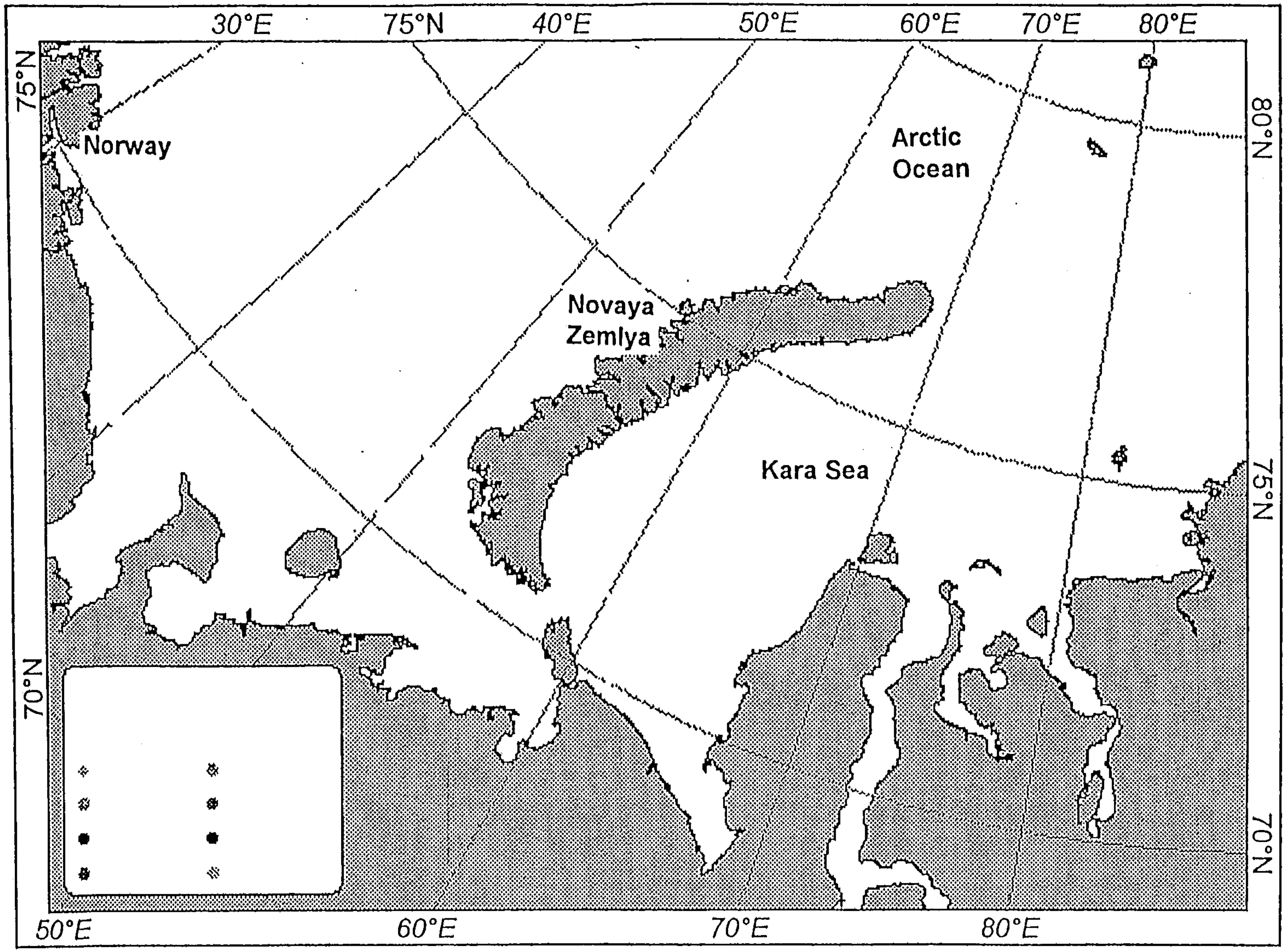

Figure 2.1
Western Section of Northern Sea Route

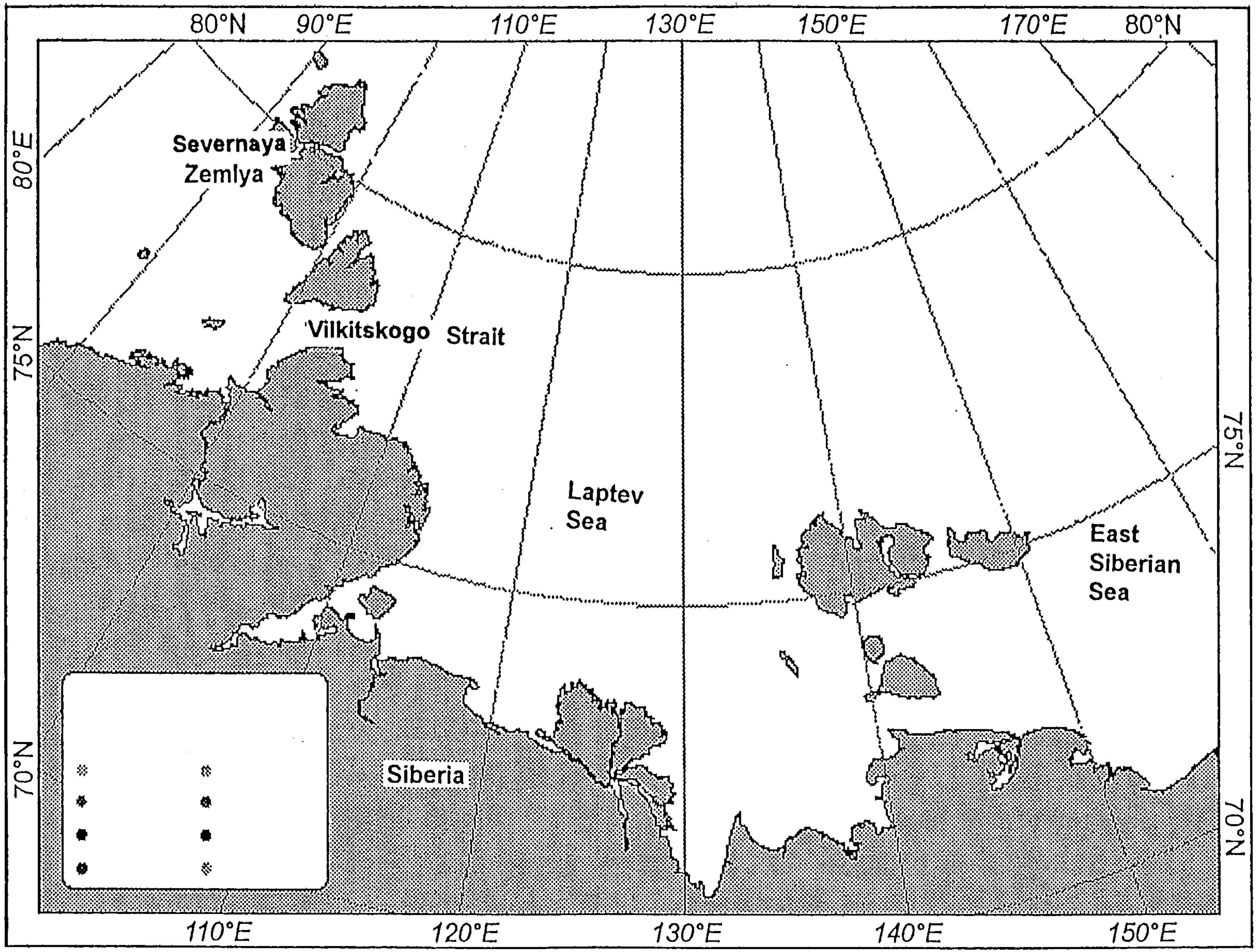

Figure 2.2
Central Section of Northern Sea Route

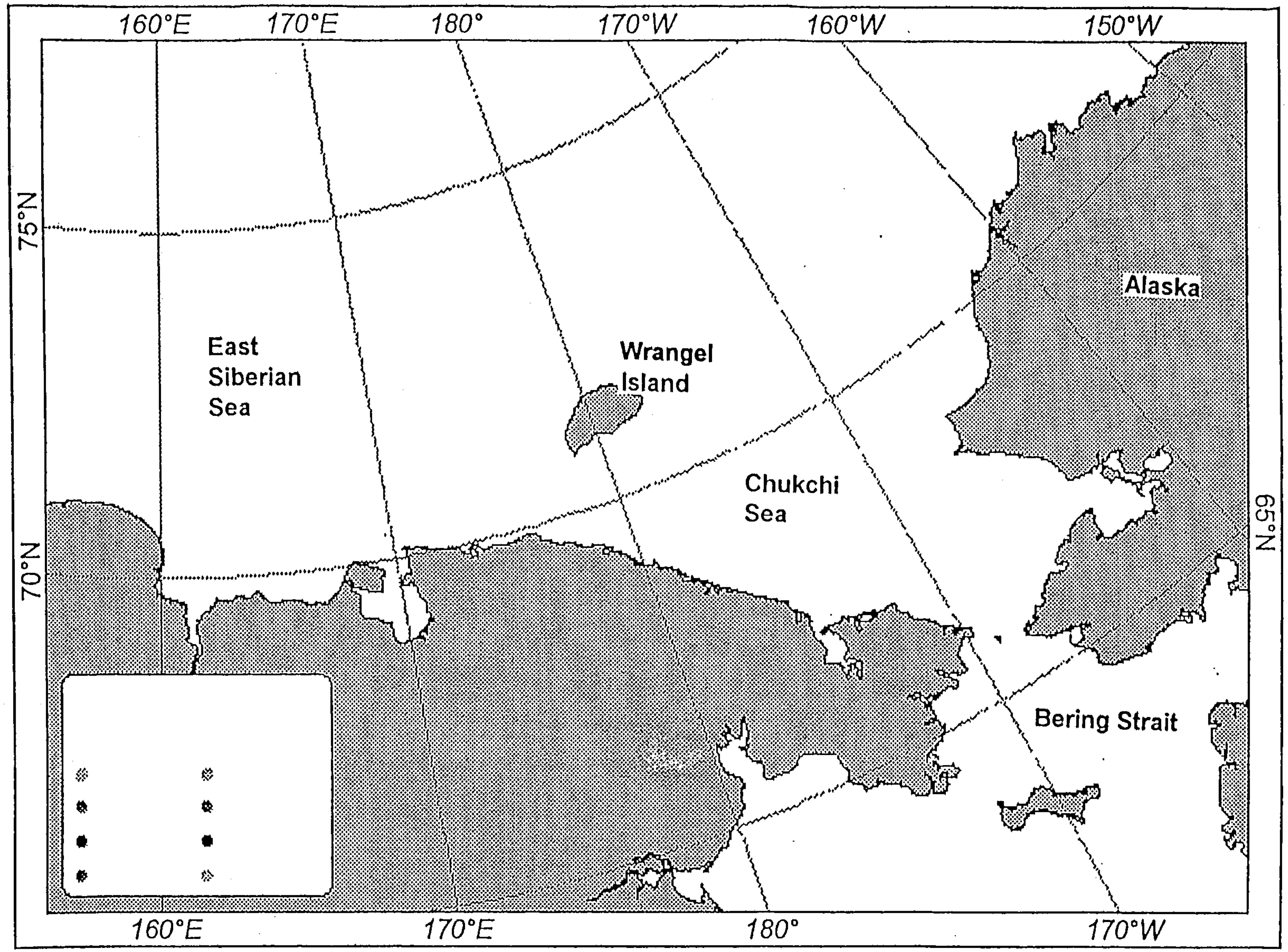

Figure 2.3
Eastern Section of Northern Sea Route

3

Results of Analysis

The Russian ice observations formed the basis of the analysis, with validation data and photographs being used to estimate particular *auxiliary* ice cover parameters not available in the Russian data. The *auxiliary* ice cover parameters of importance to the IRSCS are:

- concentration of ridging on the ice cover
- whether the ice is decayed (has thaw holes) or not, and
- how much of the ice cover is composed of brash floe sizes (<2.0m in diam.).

The Russian ice data for the project were obtained (by CANATEC Consultants) from the US National Ice Centre and are data which AARI (in St. Petersburg) digitized from the Russian Integrated Ice Charts. Examples of these ice charts are not available, however, the charts are based on SLAR (side-looking airborne radar), visual, and satellite data, and are believed to be the best data available for the area. Nineteen years of data are available from 1972 to 1990; this project used data from 1987, 88, 89, and 90 as this is where other identified data sets overlapped and the Russian data was very complete. The original data are in SIGRID format, on an approximately 10 day interval throughout the year, and on a grid of 1/4° latitude by 1/2° longitude south of 76 °N and 1/4 ° latitude by 1 ° longitude north of 76 °N over the region of interest here (grid cells are about 15nmi. square). The Russian Ice data provides information on concentration and partial concentration, as well as ice type.

A program was written to run through the Russian ice data that applied the ice multipliers for each ship category and ice type to the data. The program identified the minimum ship class (or Type) of vessel that would have had a decision numeral under the IRSCS of zero or greater. These computations were done for four time slots as follows:

- late January - representing mid winter conditions as would be encountered by a vessel on year-round operations
- mid May - representing peak ice thickness conditions
- mid July - representing early season summer operations, and
- early September - representing maximum open water conditions and maximum ice decay

The results of the analysis of these data were plotted on a three map set covering the entire northern sea route. An example of the map product is presented in **Figure 3.1.** The complete map set is contained in **APPENDIX B** of this report. On this map each coloured dot represents the results of the IRSCS comparison for that grid point. Overlays were then developed which represented the likely route (or routes) a vessel might take while transiting the Northern Sea Route. In this way it was possible to determine the minimum class of vessel that could transit a portion or all of the route during each of the four time slots.

3.1 Russian Ice Data

Ice information from the Russian integrated ice maps covered the entire Northern Sea Route on a roughly 10 day interval. From this data the four time slots were selected, and decision numerals were calculated for each type and class of vessel. The minimum ship class of vessel that had a zero or positive decision numeral was then plotted as a coloured dot on the three map set described earlier (complete map set contained in APPENDIX B).

The maps were generated from data for the date indicated on the map, when these data were available. If data for the specific date were not available, the January and September maps use data from the ice chart for 10 days later and if these data are not available, they use the data from the chart for 10 days earlier. The May and July maps use preferentially data from 10 days earlier and if these data are not available, they use the data from 10 days later. In this way, when data for the required date is not available, the maps indicate more difficult ice situations than we would expect on the indicated dates, in each case. In 1989 there was no data for the eastern area for the 4 and 14 of January, so maps from the 24 of January were used. In 1988 there were data for the 4 and 14 of January, but they were not available for the area of interest; so again maps of the 24 of January were used. On some occasions data were not available hence the white areas on some of the maps in Appendix B.

An overlay was developed which represented the normal shipping route. A small scale map showing the typical ship route(s) on the Northern Sea Route that was used as the overlay is presented in **Figure 3.2.** The resulting table of minimum ship class allowed under the IRSCS is presented here as **Table 3.1.** It must be remembered that this table represents minimum ship class using unmodified data i.e. decay, brash, and ridging are not considered.

From this table we see that the minimum ship class is predominantly the Class vessels. The breakdown is as follows:

CAC 2/1 required 5 times
CAC 3 required 8 times
CAC 4 required 2 times, and
Type E required 1 time

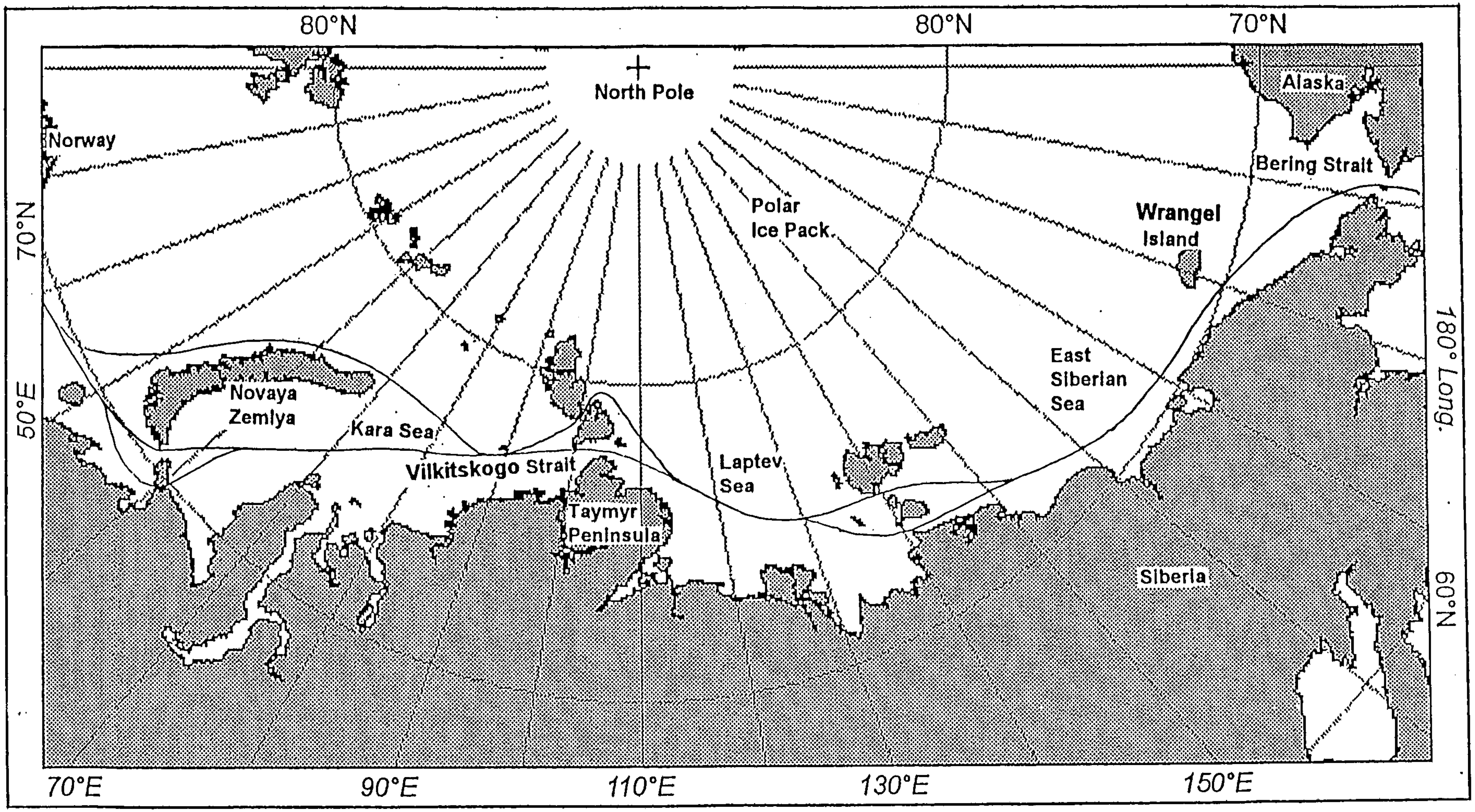

Figure 3.2
Typical Ship Route(s) Across The Northern Sea Route

Table 3.1

Minimum Ship Class to Transit The Northern Sea Route
As Indicated By
The Ice Regime Shipping Control System
(Using Unmodified Russian Ice Observation Data)

Date	West Section Min. Ship Class	Central Section Min. Ship Class	East Section Min. Ship Class
14 Jan 1987	Type A	Type A	CAC 2/1
14 May 1987	CAC 4	CAC 4	CAC 3 [3]
13 July 1987	CAC 4	CAC 3 [3]	CAC 3
11 Sept 1987	Type E	Type E [1]	CAC 2/1
24 Jan 1988	Type A	CAC 4	CAC 2/1
14 May 1988	CAC 4	CAC 4 [3]	CAC 3
13 July 1988	CAC 4	CAC 4	CAC 2/1
11 Sept 1988	Type E	CAC 3	CAC 2/1
24 Jan 1989	Type A	CAC 3	CAC 3
14 May 1989	CAC 4	CAC 3	CAC 4
13 July 1989	CAC 4	CAC 4	CAC 4 [1]
11 Sept 1989	CAC 4 [2]	CAC 4	Type E
14 Jan 1990	Type A	CAC 3	Type A
14 May 1990	CAC 4	CAC 3	CAC 4
13 July 1990	CAC 4	CAC 3	CAC 4
11 Sept 1990	Type E [1]	Type E	Type E

[1] - Selective routing required
[2] - Western edge of region only; remainder Type E
[3] - Some missing data

A summary of the minimum ship class broken down by the three map sections - west, central, and east is presented in **Table 3.2.** In this table we see that the majority of class vessel requirements occur in the eastern section. Referring to the maps in Appendix B it is apparent that intrusions of multi-year ice down to the coast most often occur here, and this is the cause of most of the high ice class requirements. The western section, in the Kara Sea area has typically the lowest ice class requirement due to the predominantly first-year ice cover in this area.

Table 3.2

Summary of Minimum Ice Class Vessel Required

Western Section	Central Section	Eastern Section
CAC 4 required 9 times	CAC 3 required 7 times	CAC 2 required 5 times
Type A required 4 times	CAC 4 required 6 times	CAC 3 required 4 times
Type E required 3 times	Type A required 1 time	CAC 4 required 6 times
	Type E required 2 times	Type A required 1 time
		Type E required 2 times

From the unmodified Russian ice observation data it appears that a transit of the Northern Sea Route in zero or positive decision numerals would usually require a CAC vessel, however these results do not consider decay, or brash, which will typically increase access by lower ice class vessels.

3.2 Modifications to Baseline Data

As described earlier, the baseline data provided by the Russian Ice Observation data does not include information on decay, brash or ridging. These elements are critical to the IRSCS as they can either increase or decrease decision numerals for a vessel.

Decayed ice is defined in the IRSCS as sea ice with thaw holes in it. In these cases the ice multiplier for all vessels is increased by one, giving higher decision numerals. This is a logical provision as decayed ice is much weaker, thus presenting less of a risk of damage to any ship's hull. Brash ice is defined as any age or type of ice found in floe sizes less than 2 metres in diameter. Damage to vessels is generally a function of ice strength, mass and speed. The provision for brash ice recognizes that ice pieces of such a small size do not have the mass to impart the load to a hull required to cause damage, thus brash ice has the same weighting as open water. This provision is particularly important to the lower ice class vessels (Type ships) as it can change multi-year ice from an ice multiplier of -4, to +2. Of equal significance, but less relevant here, is the impact on a vessel under icebreaker escort. Icebreakers always create a certain amount of brash generating a track of positive decision numerals for low ice class vessels. Ridging, on the other hand, recognizes that ridged ice has a much greater mass than level ice, and thus creates a greater risk of structural damage. Within the IRSCS ice that has greater than three tenths of its surface covered in ridges has its ice multiplier increased by one. However, this provision only applies when the overall concentration is greater than six tenths. This recognizes that in low ice concentrations vessels will typically avoid the ice, thus ridged or not is irrelevant.

In order to apply the detailed information from the other data sources listed earlier to the preliminary results generated from the Russian ice observation data, the following sections describe the auxiliary data available for each of the east, central and west sections separately. This is followed by a comparison of ship access before and after modifying the data with brash, decay and ridging.

3.2.1 Ice Modifiers - Western Section

The principle data sources available for modifying the data on the western section were:

- Rossia voyage data
- Helsinki University Report, and
- the Norwegian Murmansk-Yokohama voyage data

DECAYED ICE

This section (western) is composed largely of first-year ice that melts out each summer. As such, there is a period when the ice is present, yet decayed under the IRSCS definition. During the Rossia voyage, observations indicated that in early August the first year ice in the Kara Sea averaged 19% covered in thaw holes. This indicates decayed ice and would increase the ice multiplier for first-year ice in the August-September time slot by one. The ice multiplier change resulted in the following changes to minimum ship criteria in September data:

Western Section

Date	Previous min. Ship Category	Increase due decay
11 Sep 87	Type E	Type E
11 Sep 88	Type E	Type E
11 Sep 89	CAC 4	Type A
11 Sep 90	Type E	Type E

BRASH ICE

From photos taken in the Kara Sea by the Rossia voyage, and those presented in the Norwegian voyage record, the ice cover appears to generally contain two tenths of brash ice. This brash ice is present in the July to October time frame and affects the minimum ship criteria by increasing the decision numeral. The changes in minimum ship criteria as a result of brash concentrations are presented below:

Western Section

Date	Previous min. Ship Category	Increase due Brash
13 Jul 87	CAC 4	Type A
11 Sep 87	Type E	nil
13 Jul 88	CAC 4	Type A
11 Sep 88	Type E	nil
13 Jul 89	CAC 4	nil
11 Sep 89	Type A	nil
13 Jul 90	CAC 4	nil
11 Sep 90	Type E	nil

RIDGED ICE

The Kara and Pechora seas are notable from the other Russian seas in their relatively small amounts of fast ice. This results in the majority of the Kara sea remaining mobile all winter, and experiencing ice pressure within the ice cover and along fast ice edges during any significant wind event. This results in significant amounts of ridging during the winter months when first-year ice is predominant. Estimates of areal coverage of ridging (from [3] and [5]) on the first-year ice range as high as 50%. Ridging decreases the ice multiplier for all ice types. Ridging is a factor in the consolidated months of January and May. The resulting change in minimum ship class is shown on the following page:

Western Seotion

Date	Previous min. Ship Category	Decrease due Ridging
14 Jan 87	Type A	nil
14 May 87	CAC 4	nil
24 Jan 88	Type A	nil
14 May 88	CAC 4	nil
24 Jan 89	Type A	nil
14 May 89	CAC 4	nil
14 Jan 90	Type A	nil
14 May 90	CAC 4	nil

3.2.2 Ioe Modifiers - Central Seotion

The principle data sources available for modifying the data on the central section were:

- Norwegian voyage data
- Helsinki University Report, and
- The Rossia voyage data

DECAYED ICE

The central section of the Northern Sea Route (NSR) has a considerably more complex ice environment than the Western Section. Vilkitskogo Strait, which separates Severnaya Zemlya Island from the Taymyr Peninsula (Siberia), is subject to incursions of old ice from the Arctic Ocean. This is also the most northerly point of the NSR, thus melt is slower, and the sea ice reaches greater thicknesses than in the Western sector in most years

On the Rossia voyage in early September, the ice was reported as 4-5/10 second-year, and 4-5/10 first year, with 39% melt ponds and 8% thaw holes. This indicates that melt is not that far along and only some of the ice is decayed. Second-year ice is thicker, and generally melts out after first-year ice. Therefore it will be assumed that two tenths of the first-year ice is decayed, and the rest of the ice cover is not decayed in the Vilkitskogo Strait area.

The Russian observation data shows 8/10 second-year and 2/10 thick first-year in Vilkitskogo Strait. Thus two tenths of decayed first-year ice is compatible with this data set as well.

The Norwegian voyage photographs of the area to the east of Vilkitskogo Strait in the Laptev Sea show more brash ice, and more decayed first-year ice. The vessel also reached open water soon after Vilkitskogo Strait, indicating rapid ice melt in the area. All first-year ice is estimated to be decayed in September east of the Taymyr Peninsula in the Laptev Sea.

To summarize, two tenths of first-year ice will have their ice multiplier increased by one for decay in Vilkitskogo Strait, and the ice multipliers for all first-year ice east of Vilkitskogo Strait will be increased by one for decay in the month of September. The resulting minimum ship class changes are presented below:

Central Seotion

Date	Original Min. Ship Class	Min. Ship Class After Modification for Decay
11 September 1987	Type E	Type E
11 September 1988	CAC 3	CAC 3
11 September 1989	CAC 4	CAC 4
11 September 1990	Type E	Type E

BRASH ICE

From the Norwegian voyage data there appears to be a an average of 4 tenths of brash ice in September in the area east of the Taymyr Peninsula, where it is predominantly first-year ice.

The Helsinki report describes this area as usually receiving an offshore wind in the winter. This would lead to more dynamic ice formation conditions, and cause the ice to have a greater tendency to disintegrate into brash during melt, which supports the observation of higher concentrations of brash in this area shown in the Norwegian voyage data.

The resultant increase in minimum ship class for the central region as a result of the four tenths of brash in September in the Laptev Sea are presented below:

Note: *These modifications are cumulative i.e. in this table the ice multiplier for first-year ice is increased for decay, then four tenths are increased for brash, then the decision numeral calculations are performed.*

Central Section

Date	Original Min. Ship Class	Min. Ship Class After Modification for Brash
11 September 1987	Type E	Type E
11 September 1988	CAC 3	CAC 4
11 September 1989	CAC 4	Type A
11 September 1990	Type E	Type E

RIDGED ICE

This sector (central) has vast areas of fast ice in the winter, as well as typically offshore winds. This results in less ridging than the western sector. No decrease in ice multipliers for ridging will be applied for this area.

3.2.3 Ice Modifiers - Eastern Section

The principle data sources available for modifying the data on the Eastern section were:

- Helsinki University Report, and
- Norwegian voyage data

This area is the most similar to conditions in Canadian waters. There has been a great deal of study on the properties of old and first-year ice in the Arctic Ocean ice pack when it pushes down into the Beaufort Sea and against the Alaskan Coast. The general clockwise rotation of ice in the Arctic Ocean causes ice to drift from east to west along the Alaskan coast, thus these conditions eventually find their way to the eastern portions of the Russian Arctic coastline. As is seen in Canada, when the polar pack encroaches on the Alaskan Coast such that no open lead exists, ice conditions beyond the capability of the Icebreaker *Polar Sea* (75,000 shaft horsepower) have been documented [10]. Ridging in areas containing more than six tenths concentration is common. An illustration of the Polar pack coming down to the Russian shore can be seen in the ice chart of 10 November 1987 presented in **Figure 3.3**. Also presented in this figure is an ice chart from 7 November 1989. The 1989 chart shows the polar pack approximately 300 nautical miles further north at longitude 170^{0} E. than in 1987.

In the absence of the polar pack however, the East Siberian Sea (west of Wrangel Island) melts out relatively early. The vast area of fast ice in the Laptev Sea allows for considerable in-situ melt in the spring as well.

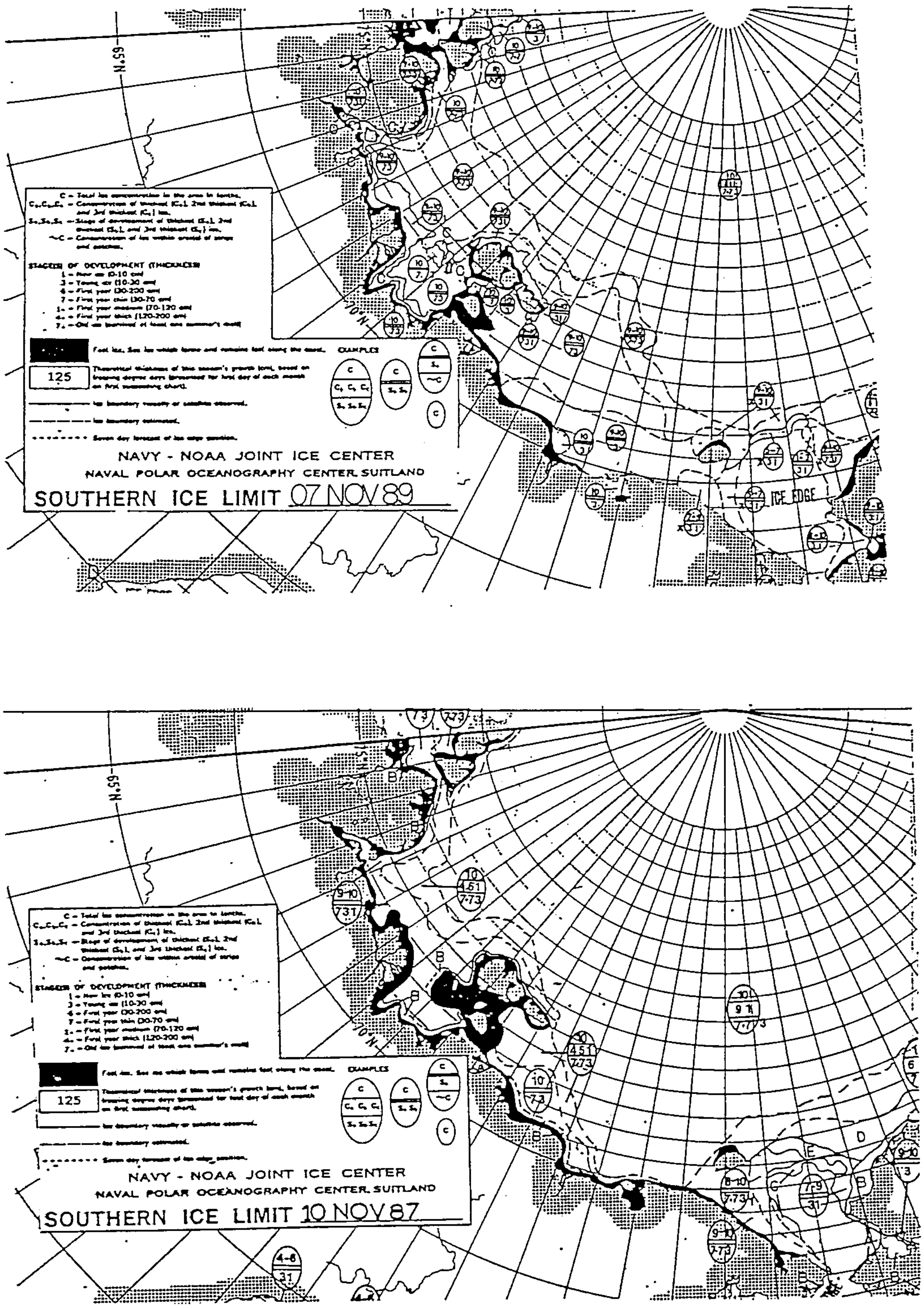

Figure 3.3
U.S. Navy/NOAA Ice Charts Showing the Polar Pack Pressing Down Against the Russian Coastline (1987), 300 nmi. Offshore (1989)

DECAYED ICE

By mid July in the eastern sector, most of the first-year ice is melted out, with extensive areas of open water becoming common [9]. Most old ice when present however, is from the polar pack and does not become significantly decayed.

During September 1991 when the Norwegian voyage data was collected, this entire sector was open water. For the July and September time slots, all first-year ice multipliers will be increased by one for decay, old ice will not.

Eastern Section

Date	Original Min. Ship Class	Min. Ship Class After Modification for Decay
13 Jul 87	CAC 3	CAC 3
11 Sep 87	CAC 2/1	CAC 2/1
13 Jul 88	CAC 2/1	CAC 2/1
11 Sep 88	CAC 2/1	CAC 2/1
13 Jul 89	CAC 4	Type A
11 Sep 89	Type E	Type E
13 Jul 90	CAC 4	Type A
11 Sep 90	Type E	Type E

BRASH ICE

Similar to the Kara Sea, the eastern portion of the NSR is quite dynamic thus the occurrence of brash is quite common. Experience in the Canadian Beaufort with the Polar pack and coastal waters indicate that there is generally 2/10s of brash in the summer ice cover. Two tenths of the ice cover will be modified for brash in the July and September time slots. No modification will be made to winter data as brash is usually in the form or ridging and rubble when temperatures are below freezing.

The resultant increase in minimum ship class for the eastern region as a result of the two tenths of brash in July and September are presented below:

Note: These modifications are cumulative i.e. in this table the ice multiplier for first-year ice is increased for decay, then two tenths are increased for brash, then the decision numeral calculations are performed.

Eastern Section

Date	Original Min. Ship Class	Min. Ship Class After Modification for Brash
13 Jul 87	CAC 3	CAC 3
11 Sep 87	CAC 2/1	CAC 2/1
13 Jul 88	CAC 2/1	CAC 2/1
11 Sep 88	CAC 2/1	CAC 2/1
13 Jul 89	Type A	Type B
11 Sep 89	Type E	Type E
13 Jul 90	Type A	Type B
11 Sep 90	Type E	Type E

RIDGED ICE

Within the polar pack, and along the coastlines, ridging is extensive and virtually always present. Therefore ice multipliers will be reduced by one for ridging and will be applied to all ice, at all times of the year, when concentrations are above six tenths[1].

---

[1]The IRSCS as it now stands (see Appendix A) states that ridging modifiers may only be applied when concentrations are over six tenths. This recognises the ability of a vessel to avoid all ice at low concentrations, thus making the amount of ridging irrelevant.

Eastern Section

Date	Original Min. Ship Class	Min. Ship Class After Modification for Ridging
14 Jan 1987	CAC 2/1	CAC 2/1
14 May 1987	CAC 3	CAC 2/1
13 Jul 87	CAC 3	CAC 2/1
11 Sep 87	CAC 2/1	CAC 2/1
24 Jan 1988	CAC 2/1	CAC 2/1
14 May 1988	CAC 3	CAC 2/1
13 Jul 88	CAC 2/1	CAC 2/1
11 Sep 88	CAC 2/1	CAC 2/1
24 Jan 1989	CAC 3	CAC 3
14 May 1989	CAC 4	CAC 4
13 Jul 89	Type B	Type A
11 Sep 89	Type E	Type E
14 Jan 1990	Type A	Type A
14 May 1990	CAC 4	CAC 4
13 Jul 90	Type B	Type A
11 Sep 90	Type E	Type E

3.3 Summary of Modifications

The results of all modifications to all sectors are contained in the table presented as **Table 3.2** below.

Table 3.2

Minimum Ship Class to Transit The Northern Sea Route
As Indicated By
The Ice Regime Shipping Control System
(All modifications included)

Date	**West Section Min. Ship Class**	**Central Section Min. Ship Class**	**East Section Min. Ship Class**
14 Jan 1987	Type A	Type A	CAC 2/1
14 May 1987	CAC 4	CAC 4	CAC 2/1
13 July 1987	Type A [1]	CAC 3 [3]	CAC 2/1
11 Sept 1987	Type E	Type E	CAC 2/1
24 Jan 1988	Type A	CAC 4	CAC 2/1
14 May 1988	CAC 4	CAC 4	CAC 2/1
13 July 1988	Type A [1]	CAC 4	CAC 2/1
11 Sept 1988	Type E	CAC 4	CAC 2/1
24 Jan 1989	Type A	CAC 3	CAC 3
14 May 1989	CAC 4	CAC 3	CAC 4
13 July 1989	CAC 4	CAC 4	Type A [1]
11 Sept 1989	Type A [2]	Type A	Type E
14 Jan 1990	Type A	CAC 3	Type A
14 May 1990	CAC 4	CAC 3	CAC 4
13 July 1990	CAC 4	CAC 3	Type A
11 Sept 1990	Type E [1]	Type E	Type E

[1] - Selective routing required
[2] - Western edge of region only; remainder Type E
[3] - Some missing data

4

Conclusions

CONCLUSION #1

From the integration and analysis of the five datasets, the minimum ship class that would be allowed passage through the Northern Sea Route under the IRSCS has been determined. Although the Russian Ice Data is composed of actual observations, the ice modifiers (decay, brash, ridging) are based on interpretation of verbal descriptions, analysis of photographs, analysis of historical ice information, and assumptions based on experiences in Canadian waters. The resulting minimum ice class of vessel that would be required by the proposed Canadian Arctic Shipping Pollution Prevention Regulations' Ice Regime Shipping Control System to transit the Northern Sea Route during the sixteen time slots investigated are shown in the box to the right.

CAC 2/1 - required 8 times
CAC 3 - 5 times
CAC 4 - 1 time
Type A - 1 time and
Type E - 1 time

CONCLUSION #2

Analysis of the various data sources available for this project clearly identified the eastern portion of the Northern Sea Route, particularly just west of Wrangel Island, as the potentially most difficult area. In this area in 1987 and 1988 a CAC 2/1 vessel would have been required all year. Not surprisingly this is the class of icebreaker the Russians use for escort operations (Arktika class, nuclear powered, average 75,000 hp.). During periods when the Polar pack does not push down to the coast, an open water route exists here; such as in 1989 and 1990.

Second in severity is the central area, particularly the area between the Taymyr Peninsula and Severnaya Zemlya (Vilkitskogo Strait). The northerly location of this strait (78° N Lat.) causes it to have greater ice thickness, and melt out later. In addition, the Polar Pack often encroaches on Severnaya Zemlya and varying amounts of Multi-year ice subsequently drift into the strait. Another unique characteristic of this area is its tendency to produce second-year ice. Cool summers invariably result in significant amounts of second-year ice particularly just east of Vilkitskogo Strait. This combination of thick first-year ice, second-year ice, and often multi-year ice caused this area to require a CAC 3 vessel 6 times.

The western portions of this region, particularly the Kara Sea, are first-year ice regimes, thus at no time was a vessel of greater ice class than CAC 4 required. It should be noted that the CAC 4 requirement is a structural indicator, not a trafficability indicator. All evidence suggests that pressure events in the Kara Sea in the first-year ice are common and often severe [11]. Most Russian activity in this area in the winter is conducted by CAC 3 and CAC 2/1 icebreakers escorting CAC 4 cargo ships.

CONCLUSION #3

The need for icebreaker escort to conduct regular transits of the Northern Sea Route by a low ice class cargo ship is clearly apparent in the data analysed in this project. On two occasions, once with a Type E vessel and once with a Type A vessel, transits of the NSR could have been completed by low ice class vessels without the need for an icebreaker escort. On one other occasion a CAC 4 vessel could have made the trip thus a total of only three voyages could have been made without an icebreaker escort in the 16 time slots investigated. It should be noted however, that on many of the occasions during the summer months the ice was mobile and in concentrations of 9/10 or less suggesting there was no pressure, thus escort operations would likely have been quite effective.

CONCLUSION #4

The Ice Regime Shipping Control System appears to be a reasonable method of controlling shipping in the Russian Arctic. The requirements for icebreaker escort (CAC 2/1) appear to be in line with what the Russians do operationally. The occasional opportunity for unescorted low ice class vessels to make the transit under the regulations recognize the natural spatial and temporal variability of sea ice. The requirement for CAC 2/1 vessels when operating in the Polar Pack appear to be in line with Russia's present icebreaker fleet, and corresponds with Canadian experiences in the Polar Pack when it impinged on the Beaufort Sea offshore drilling activity in the 1980's, and experiences along the Alaskan coast [10].

* * *

5

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***

APPENDIX A : Ice Regime Shipping Control System

List of Abbreviations

AC	Arctic Class
AES	Atmospheric Environment Service
ASPPR	Arctic Shipping Pollution Prevention Regulations
AWPPA	Arctic Waters Pollution Prevention Act
CAC	Canadian Arctic Class
CCG	Canadian Coast Guard
CSA	Canada Shipping Act
ECAREG	Eastern Canada Traffic System
IM	Ice Multiplier
IN	Ice Numeral
NORDREG	Arctic Canada Traffic System
PPO	Pollution Prevention Officer

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1.0 ARCTIC SHIPPING POLLUTION PREVENTION REGULATIONS

1.1 Background

In the *Arctic Waters Pollution Prevention Act* (AWPPA) of 1970, the Government of Canada enforces its' responsibility for ensuring that navigation in Arctic waters is controlled so as to preserve and protect the sensitive northern ecosystem. The *Arctic Shipping Pollution Prevention Regulations* (ASPPR) were established in 1972 as a direct result of this Act. The regulations apply to all Arctic-going vessels carrying more than 453m^3 of oil. Among other requirements, they also address: ship construction, Arctic Pollution Prevention certificates, Ice Navigators, and restrictions on the deposit of garbage and oil.

The ASPPR control some aspects of safe navigation through what is commonly known as the Zone/Date system. In this system the Arctic waters are divided into sixteen Shipping Safety Control Zones, with a schedule of earliest and latest entry dates for each zone corresponding to specific categories of vessels (see Appendix A). Zone 1 has the most severe ice conditions, Zone 16 the least severe.

1.2 Ice Regime Shipping Control System

In 1989, following an extensive review process, the Canadian Coast Guard proposed the following revisions to the ASPPR:

1) A new Arctic vessel classification system, with improved structural design and construction requirements.

2) A new directive on navigation safety.

3) A new system for Shipping Safety Control, commonly known as the Ice Regime System.

Initial versions of all of these are included in TP-9981 (Reference 1). Following extensive consultation with government, industry, and other organizations a revised set of proposals for the last two areas have been developed. These are included in Appendix B.

The Ice Regime system will be introduced through these proposals as a means of allowing season extensions when conditions allow; replacing in this regard the existing Section 6(3) of the Arctic Shipping Pollution Prevention Regulations. The Ice Regime System will control ship safety on the basis of actual ice conditions within a given area.

The existing Zone/Date system will be retained for a transitional period, and will continue to govern access during the "traditional" seasons. Operators are encouraged to use the Ice Regime System throughout the season to gain familiarity with it, and to take benefit from the useful guidance it can provide for route selection and hazard avoidance.

Once operators have gained more familiarity with the system, and a number of improvements to the infrastructure have been made, the Coast Guard intends to implement a control system based entirely on the Ice Regime concept. These 'Guidelines' will then be updated, and may become a section of the manual "Ice Navigation in Canadian Waters", TP-5064 (reference 2).

ASPPR Type ships can use the Ice Regime system directly. For higher class vessels, there is no direct equivalency between the existing Arctic Classes (AC) and the new Canadian Arctic Class (CAC) categories. Owners will build new vessels to meet CAC standards and, in the case of existing AC ships, they may apply to the Canadian Coast Guard for CAC equivalency on a case by case basis.

2.0 USING THE ICE REGIME SYSTEM

2.1 Important Concepts

The Ice Regime System controls ship safety on the basis of actual ice conditions within a given area, or ice regime.

> **An ice regime is a relatively even distribution of any mix of ice types, including open water.**

More guidance on the definition of an Ice Regime is given in Section 2.2.

A regime may contain some ice which is beyond the structural capabilities of the ship, and some which is not. The decision to enter a given Ice Regime will be based on the quantity of dangerous ice present, and the **ability of the vessel to avoid the dangerous ice.** The Ice Regime system provides mariners with a tool which can be used to help make this decision. The tool is a simple arithmetic calculation which uses **Ice Multipliers** to determine an **Ice Numeral.** If the value of the **Ice Numeral** is less than zero, then entry into the ice regime is unlikely to be safe; a value of zero or greater indicates that entry may be considered.

Here is how the calculation works:

Every ice type (including open water) has a numerical value which is dependent on the ice category of the vessel. This number is called an **Ice Multiplier (IM).** The value of the Ice Multiplier reflects the level of danger or operational constraint that the particular ice type poses to the particular category of vessel.

For any ice regime, an **Ice Numeral (IN)** is calculated by taking the sum of the products of the concentrations of the ice types present (in tenths) and their ice multipliers. This is not as complicated as it may sound:

$$IN = (C_a \times IM_a) + (C_b \times IM_b) + \ldots$$

where:
- IN - Ice Numeral
- C_a - concentration in tenths of ice type "a"
- IM_a - Ice Multiplier for ice type "a" (from Table)

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 Numeral is therefore unique to the particular ice regime and the ship operating within its boundaries. Appendix C presents an example of a typical Ice Numeral calculation.

Ice multipliers may be adjusted to reflect decay and/or ridging in the ice. The reason is that, a given ice type will be weaker when it is decayed, and stronger when it is ridged because it's thicker.

Important Ice Regime Concepts

- ♦ An **Ice Regime** is any area composed of a relatively even distribution of any mix of ice types, including open water.
- ♦ Each ice type has an **Ice Multiplier** whose value depends on how dangerous the ice is for a given ship category.
- ♦ **Ice Multipliers** may be increased (for decay) or decreased (for ridging).
- ♦ **Ice Numerals** are calculated based on the concentrations of different ice types within an ice regime, and the corresponding ice multipliers.
- ♦ **Ice Numerals** must be zero or positive for a ship to enter an ice regime.

In many ice regimes to which entry is permitted, mariners must be aware that the vessel's operating speed should cautiously be selected to minimize the risk of damage in the event of accidental impact with dangerous ice.

2.2 Defining Ice Regimes

Ice information may come from a variety of sources, including:

- visual observations
- AES ice charts
- reports from shore stations and from other ships in the area
- helicopter reconnaissance
- direct satellite and airborne radar imagery

The AES ice chart contains information on ice types, concentrations and their distribution which can be used to define Ice Regimes and calculate their severity directly. Other information may require more interpretation by an experienced Ice Navigator.

There is no set maximum or minimum size for an ice regime.

The Ice Navigators (who may or may not also be the Master / Officer of the Watch) must use the best available information to develop a picture of the ice conditions which is relevant to their needs.

When planning voyages, a Master may have to rely on relatively broad information, such as that from the current AES ice charts. As the ship enters an area, it should be possible to use direct visual observations to define the conditions in the immediate vicinity. Within a large overall ice field, several distinct smaller regimes may be obvious; some of which will be safe for the ship while others are not.

A safe regime may consist of a relatively narrow lead through dangerous ice, provided that conditions are likely to remain stable during the transit. The Master must not define regimes more locally than is warranted by the ice conditions and the maneuvering characteristics of the vessel. If inbound, the Master will also carefully consider how conditions may change before the outbound journey. The mariner's judgment is crucial throughout.

2.3 Planning Routes

In general, a Master should plan routes to avoid ice as much as possible, and use the available regime information to select the easiest routes. If one or more Ice Numerals along an intended route are negative, the mariner should consider an alternate route.

An experienced Master may recognize that some broadly drawn regimes with negative numbers are likely to include more local areas through which transits can be made safely. Another factor to consider is that conditions may evolve favourably during the passage to the area, particularly during the early season. On the other hand, when conditions are deteriorating more caution is needed before entering regimes marginally within the vessel's capabilities.

Routing guidance from NORDREG (see Section 3) will take these factors into account. When reporting voyage plans to NORDREG (see Section 2.7), Masters should provide the rationale for routings which appear likely to encounter negative Ice Numerals.

2.4 Considering Icebreaker Escort

Icebreaker escorts are another factor which may be considered in planning routes and defining local ice regimes, on a case by case basis. Under some circumstances an Icebreaker escort can be effective in easing the ice conditions along the route (for example, breaking large pieces of dangerous ice or assisting vessels to maneuvering around them). However, if: the Icebreaker's broken track is too narrow, the ice is under pressure, or in various other circumstances the effectiveness of an Icebreaker can be severely limited. The Ice Regime as modified by the Icebreaker should be the basis for the decision on whether to proceed.

The Masters of both the icebreaker and the escorted ship must work closely together. The Icebreaker will decide whether it is safe to break a track, but the Master of the escorted ship must continue to evaluate the conditions in order to determine whether it is safe to follow, and at what speed. Good communication is essential throughout the escorted transit.

- ✦ The Canadian Coast Guard publication entitled, Ice Navigation In Canadian Waters (Reference 2), is an excellent source of information that contains useful knowledge on escort operations.

2.5 Training and Experience

Vessels will only be allowed to use the Ice Regime system if they have on board an Ice Navigator with the training and experience needed to understand and apply it. During the transition period, CCG will be working with the shipping industry to develop formal certification processes for Ice Navigators (who may not necessarily be the Master of the ship). In the interim, personnel will be assessed on a case-by-case basis, using the March 1993 recommendations of the ASPPR Sub-Committee on Training and Certification (reference 3) as a guide.

Even experienced Ice Navigators must recognize that the Arctic is a complex and potentially dangerous environment, and that every ship has its own individual performance characteristics. Objectivity, humility, and due caution are essential to safe navigation in Arctic waters.

2.6 Responsibilities and Authority

It is the responsibility of Masters to ensure the safety of their vessel. This includes avoiding areas with ice regimes beyond the ship's capabilities, and operating at speeds which prevent unsafe collisions with lower concentrations of dangerous ice. Section 10 of the of the ASPPR (attached at Appendix B) clearly defines this responsibility. Operating within the Ice Regime System provides a useful framework for operational decisions, but does not in itself guarantee safety.

The authority of the Canadian Coast Guard under the Arctic Waters Pollution Prevention Act is discussed in Section 3. The Canadian Coast Guard will exercise control authority only if a pollution prevention officer has sound reason to believe that a vessel's operations are hazarding the environment or the safety of life.

2.7 Documentation and Reporting

Whenever the Ice Regime System is used to permit operations outside of the Zone/Date system, specific routing messages and 'after-action reports' are to be submitted to the Ice Operations Officer at NORDREG (see Section 3 for a full description of NORDREG and its general reporting procedures). This reporting system will be used during the transitional implementation phase and reviewed or modified as considered necessary before full implementation of the Ice Regime System.

The contents of the Ice Regime routing messages are as follows:

ICE REGIME ROUTING MESSAGE CONTENTS
♦ The ship's name and ice strengthening category.
♦ Name(s) of qualified Ice Navigator(s) on board.
♦ Intended route through NORDREG controlled waters.
♦ Description of Ice Regimes and associated Ice Numerals along the intended route; sources of ice regime information.
♦ Other pertinent information.

Most of this is self-explanatory, and the message can in general be very brief. However, if the vessel's route will include areas with apparent negative numerals, it will be desirable to include additional pertinent information explaining the voyage plan.

Routing messages should be updated if the plan or the ice conditions change significantly. In any event, the ship should provide an update prior to entering any area for which it has previously reported a negative numeral.

The after-action report is to be submitted within 30 days of leaving controlled waters.

The information contained in the after action report is to include:

AFTER ACTION REPORT CONTENTS
♦ The ship's name and ice strengthening category.
♦ Description of the actual route, including ice regimes encountered and the ice numerals for each.
♦ Details of ice information used for planning.
♦ Any other important information.

Again, the report can generally be quite brief. However, in cases where the voyage has involved difficulties or unexpected occurrences, it will be valuable for the future development of the system and for the overall safety of Arctic navigation for the Master to provide any feedback which he considers significant. This information will be kept confidential by CCG, except in cases where it relates to a noticeable incident under the AWPPA or the *Canada Shipping Act* (CSA).

Periods under Icebreaker escort should be reported, and should describe:

- the duration of the escort;
- the surrounding ice regime, and the characteristics of the track;
- speeds and separations used, with an indication of variability.

3.0 AUTHORITIES

The updated regulations do not contain any new provisions related to control authority. As has been the case since 1972 with the ASPPR Zone/Date Shipping Safety Control System, the CCG will control ship safety, now with the aid of the Ice Regime System. The CCG authority is administered at three principal levels:

- Arctic Canada Traffic System
- Ice Operations Office
- Pollution Prevention Officers

3.1 Arctic Canada Traffic System

For ships of 300 GRT or more operating in Arctic waters, the CCG administers and operates the Arctic Canada Traffic System NORDREG CANADA. The primary objectives of NORDREG are: 1) to enhance the safe and expeditious movement of maritime transportation in Arctic waters; 2) to safeguard the Arctic environment; and 3) to contribute to Canadian ability to administer in its Arctic waters and territories.

Among other activities, NORDREG issues clearances to ships entering Arctic waters, distributes ice information and ice routings for individual ships, and coordinates requests for icebreaker assistance. In these areas NORDREG operates in a similar manner to ECAREG CANADA, and has similar general reporting requirements, as contained in the Annual Edition of Notices to Mariners, TP 390 (reference 4). The specific requirements associated with using the Ice Regime System have been detailed at Section 2.7.

At this time NORDREG is a voluntary system; however, all vessels are strongly encouraged to participate. In providing its services, the CCG have made it clear there is no intention on their part to attempt to navigate or maneuver ships from a shore station, or to over-ride the authority of the Masters or their responsibility for the safe navigation of the ship.

ARCTIC CANADA TRAFFIC SYSTEM

NORDREG CANADA - HIGHLIGHTS

- Compliance with NORDREG CANADA is voluntary.
- The Ice Operations Office will provide support for vessels which comply with NORDREG CANADA requirements.
- Ice routings issued by NORDREG CANADA are advisory in nature. NORDREG CANADA will not attempt to navigate or maneuver ships from a shore station, to over-ride the authority of Masters, or to take over their responsibility for the safe navigation of their ship.

3.2 Ice Operations Office

During the Arctic operating season, a NORDREG office based in Iqaluit is staffed by a CCG Ice Operations Officer. The Ice Operations Officer is a CCG Officer who is also a Pollution Prevention Officer (PPO) with specific powers under the AWPPA (see Section 3.3, Pollution Prevention Officers).

The Ice Operations Officer will not become involved in operational decision making as a result of the ice regime shipping control system. The ship's Master will make operational decisions according to the Ice Regime System and communicate these decisions to the Ice Operations Officer.

These communications do not constitute requests for permission to proceed. Rather, they are made for the information of the Ice Operations Officer. On the basis of this information and other requirements of the NORDREG CANADA system, a NORDREG clearance may be issued for the vessel to proceed along the projected route and through the anticipated ice conditions. This clearance represents an acknowledgment by CCG that the planned route appears appropriate - it does not relieve Master's of their responsibility to navigate with due caution and with continuous careful attention to the local ice conditions.

3.3 Pollution Prevention Officers

Pollution Prevention Officers (PPO's) are authorized by law to exercise specific powers described in the AWPPA of 1972. The Ice Regime System does not affect this law. Under Section 15(4), a PPO has the authority to direct a ship clear of any area at any time. This clause reads in part:

15(4) A Pollution Prevention Officer may:

> (b) order any ship that is in or near a shipping safety control zone to proceed outside the zone in such a manner as the officer may direct, to remain outside the zone or to anchor in a place selected by the officer, if
>
> > (iii) the officer is satisfied, by reasons of weather, visibility, ice or sea conditions, the condition of the ship or its equipment or the nature or condition of its cargo, that such an order is justified in the interests of safety.

As a PPO, the NORDREG Ice Operations Officer will take into account ice regime information provided by ships Masters and from other sources in monitoring marine traffic. This will be used to help ensure that no vessels are operating at risk of structural damage which could lead to pollution. However, unless the Ice Operations Officer has a valid and justifiable reason to doubt the safety of a given vessel, the powers of control over it will not be invoked.

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[6] **Vessel Traffic Services,** Centre Manual, Arctic Canada Traffic System (NORDREG), Element T-2, June 1994. TP 1526

[7] **WMO Sea-Ice Nomenclature,** World Meteorological Organization 1985 Reference Publication. WMO/OMM/BMO No. 259.

Appendix A

ASPPR Shipping Safety Control

Zones and Dates of Entry

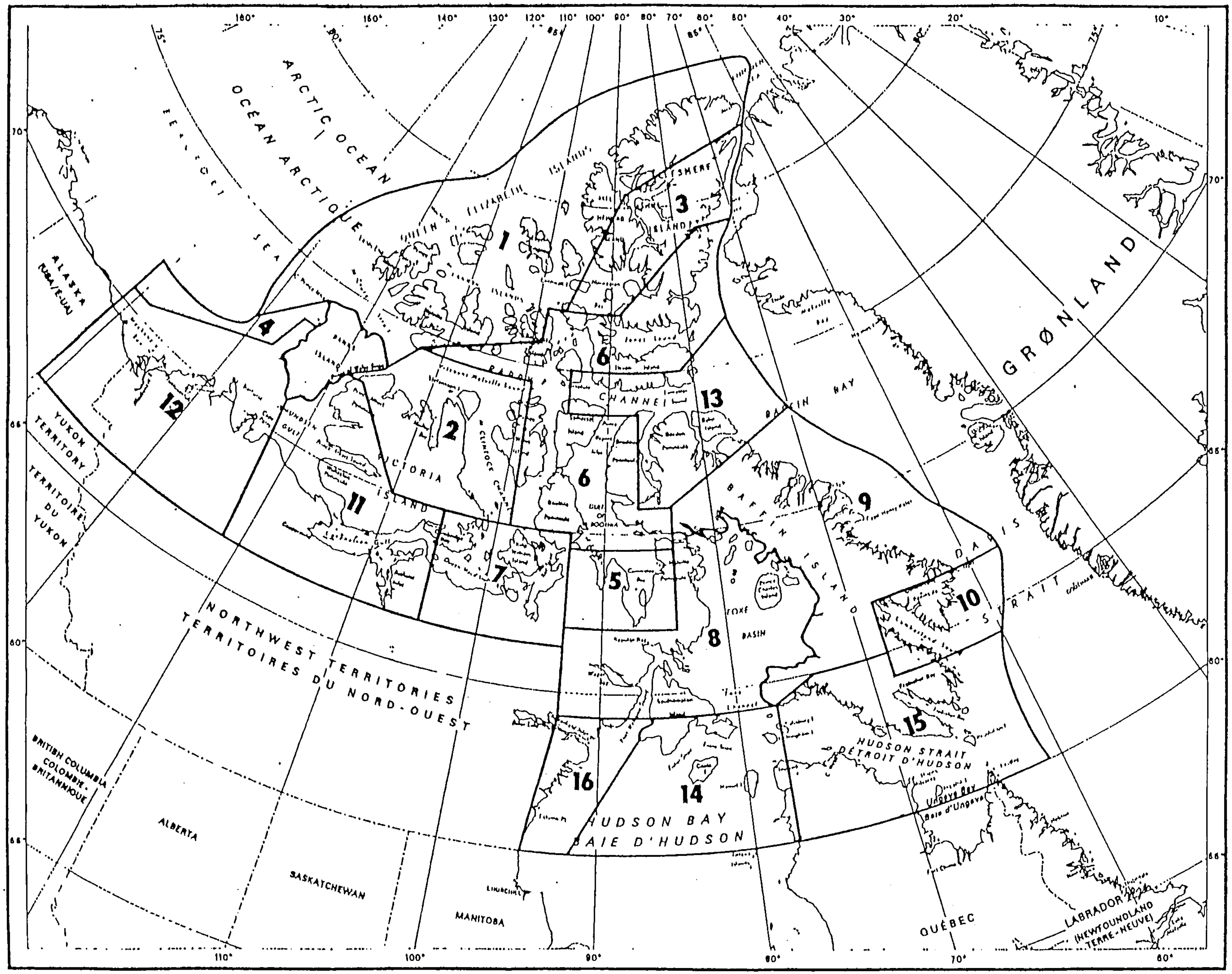


Figure 1-1 ASPPR Shipping Safety Control Zones

Source: Sailing Directions, Arctic Canada, Volume 1

Item	Col. I Category	Col. II Zone 1	Col. III Zone 2	Col. IV Zone 3	Col. V Zone 4	Col. VI Zone 5	Col. VII Zone 6	Col. VIII Zone 7	Col. IX Zone 8	Col. X Zone 9	Col. XI Zone 10	Col. XII Zone 11	Col. XIII Zone 12	Col. XIV Zone 13	Col. XV Zone 14	Col. XVI Zone 15	Col. XVII 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 Oct. 15	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
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[a] 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	No	No	No	No	No	No	Aug. 10	Aug. 20	Aug. 20	Aug. 10	July 15	July 1	Aug. 15	July 20	July 20	July 1

Appendix B

Proposed

Ice Regime Shipping Safety Control System

NAVIGATION SAFETY

10. Every ship in Arctic waters shall at all times proceed in a safe speed so that she can take proper action to avoid unsafe collision with ice and, if necessary, be stopped within a distance appropriate to the prevailing conditions. In determining a safe speed the following factors shall be among those taken into account:

    (a) By all ships:
    - (i) the category of the ship,
    - (ii) weather, visibility, ice or sea conditions,
    - (iii) the power, and manoeuvring capability of the ship with special reference to the stopping distance and the turning ability in the prevailing conditions and
    - (iv) the elapsed time since the on board ice information was collected.

    (b) Additionally, by ships fitted with electronic ice detection equipment:
    - (i) the characteristics, efficiency and limitations of that equipment,
    - (ii) any constraints imposed by the range scales of that equipment,
    - (iii) the effect of weather, ice or sea conditions on that equipment.

    (c) Additionally by ships fitted with electronic and other means of receiving ice date from external sources:
    - (i) the elapsed time since the data was obtained at source.
    - (ii) the quality of the data in terms of its resolution and the differentiation between ice types.

Proposed Text for Parts of Section 6 of the
Arctic Shipping Pollution Prevention Regulations

6. (1) No ship, carrying oil in a quantity in excess of 453 m^3, shall navigate in any zone unless,

(a) it meets the standards of construction prescribed for any category of ship in Schedule V or Schedule VI; and

(b) in the case of an Arctic Class ship, it meets the standards of construction prescribed for that ship in Schedule VII.

(2) Subject to subsections (3) to (9), and except in accordance with an order of a pollution prevention officer pursuant to subparagraph 15(4)(c)(ii) of the Act, no ship of a category set out in column I of an item of Schedule VIII and carrying oil in a quantity in excess of 453 m3 shall navigate in any zone set out in the heading of any column of that item:

(a) where the words "No Entry" are shown in that column of that item; and

(b) where a period of time is shown in that column of that item, except during that period of time.

unless

(c) the decision numeral determined in accordance with Schedule X for the ship is zero or greater, and

(i) in determining whether to proceed, the following factors shall be among those taken into account by the Master of the ship:

(A) the manoeuvring characteristics of the ship and escort, if any,

(B) the operating characteristics and condition of any equipment on board designed for the purpose of detecting ice hazards

(C) the probability of change in the ice conditions during the intended transit, and

(D) weather conditions;

(ii) the master shall send a message to the Coast Guard containing:

(A) the ships particulars and escort if any,

(B) a description of the proposed route

(C) a description of the ice regime or regimes on the proposed route with the decision numerals,

(D) a statement that paragraph 6.(2)(c)(i) has been complied with, and

(E) a statement verifying the presence of an 'Ice Navigator' on board the ship who meets the qualifications stated in the ASPPR regulations.

(iii) the master obtains an acknowledgement from the Coast Guard before entry; and

(iv) the master shall send to the Coast Guard within 30 days after entry an after action reporting containing

(A) a copy of the ice information used, and

(B) a summary description of the transit.

SCHEDULE X

ICE REGIME SHIPPING CONTROL SYSTEM

Refer to Section 11 of the Main Regulations

INTERPRETATION

1. In this schedule, the **ice terminology** is that used in the World Meteorological Organisation Publication; WMO Sea-Ice Nomenclature, reference WMO/OMM/BMO-No. 259, as of March 1985.

"Open water" means (a) **an area which contains no ice**
(b) an area which contains any amount of brash ice.]

"Decayed ice" means [any ice] which
(i) is flooded over part of its surface with 30% thaw holes formed or
(ii) is rotten ice.

"Suitable escort" means a ship which
(a) is of a higher category than the ship being escorted and
(b) is not a Type B, C, D or E ship.

"Ice Numeral" means a number calculated in accordance with section 3.

"Decision Numeral" means a number calculated in accordance with section 4.

"Brash ice" means an accumulation of floating ice made up of fragments not more than 2 metres across, the wreckage of other forms of ice.

ICE TYPE WEIGHTING

2. (1) Ice types shall have weights relating to each category of ship as set out in Table 1.

2. (2) For the purposed of this section open water is an ice type.

2. (3) Where the total ice concentration in a regime is 6 tenths or greater and 30% of the area of an ice type [other than brash ice] is deformed by ridges, rubble or hummocking the weights for that ice type, given in Table 1, shall be decreased by 1.

2. (4) Where ice is decayed ice the weights for that ice type, in Table 1, may be increased by 1.

ICE NUMERAL

3. (1) The Ice Numeral for an ice regime in any Shipping Safety Control Zone or part of a Zone shall be the sum of the products of
   (a) the concentration in tenths of each ice type and
   (b) the ice type weight relating to the category of the ship in question.

DECISION NUMERAL

4. (1) Subject to subsection (2) the Decision Numeral is the Ice Numeral calculated in accordance with Section 3.

WMO DEFINITIONS

5. **Nilas Ice:** A thin elastic crust of ice, easily bending on waves, and swell, and under pressure, growing in a pattern of interlocking "fingers" (finger rafting). Has a matte surface and is up to 10 cm. in thickness

Young ice: Ice in the transition range between nilas and first-year ice, 10-30 cm. in thickness. May be subdivided into grey ice and grey-white ice.

Grey ice: Young ice 10-15 cm thick. Less elastic than nilas and breaks on swell. Usually rafts under pressure.

Grey-White Ice: Young ice 15-30 cm thick. Under pressure it is more likely to ridge than to raft.

First-Year Ice: Sea ice of not more than one winter's growth, developing from young ice; 30 cm - 2 m thick. May be subdivided into thin first-year ice/white ice, medium first-year ice and thick first-year ice.

Thin First-Year Ice/White Ice - First Stage: First year ice 30-30 cm thick.

Thin First-Year Ice/White Ice - Second Stage: First year ice 50-70 cm thick.

Medium First-Year Ice: First year ice 70-120 cm thick.

Thick First-Year Ice: First year ice over 120 cm thick.

Old ice: Sea ice which has survived at least one summer's melt. Topographic features generally are smoother than first-year ice. May be subdivided into second-year ice and multi-year ice.

Second-year Ice: Old ice which has survived only one summer's melt. Thicker and less dense than first-year ice, it stands higher out of the water. In contrast to multi-year ice, summer melting produces a regular pattern of numerous small puddles. Bare patches and puddles are usually greenish-blue.

Multi-year ice: Old ice which has survived at least two summer's melt. Hummocks are smoother than on second-year ice, and the ice is almost salt-free. Colour, where bare, is usually blue. Melt pattern consists of large interconnecting, irregular puddles, and a well-developed drainage system.

Appendix C

Typical Ice Numeral Calculation

Ice Numeral Calculation
Example 1

Region containing 7/10ths thick first year
1/10th old ice
2/10ths open water

Ice not decayed

Type B (7 x -2) + (1 x -4) + (2 x 2) = -14

Type A (7 x -1) + (1 x -4) + (2 x 2) = -7

Ice Numeral Calculation

Example 2

Region containing 7/10ths medium first year
1/10th old ice
2/10ths open water

First year ice decayed

Type B (7 x 0) + (1 x -4) + (2 x 2) = +7

Type A (7 x +2) + (1 x -4) + (2 x 2) = +14

Table Of Proposed Ice Multipliers
By Ship Category

SHIP CATEGORY ICE TYPE	TYPE E	TYPE D	TYPE C	TYPE B	TYPE A	CAC 4	CAC 3
Multi-Year (MY)	-4	-4	-4	-4	-4	-3	-1
Second Year (SY)	-4	-4	-4	-4	-3	-2	1
Thick First-Year (TFY)	-3	-3	-3	-2	-1	1	2
Medium First-Year (MFY)	-2	-2	-2	-1	1	2	2
Thin First-Year Second Stage (THFY2)	-1	-1	-1	1	2	2	2
Thin First-Year First Stage (THFY1)	-1	-1	1	1	2	2	2
Grey-White (GW)	-1	1	1	1	2	2	2
Grey Ice (G)	1	2	2	2	2	2	2
Open Water (OW)	2	2	2	2	2	2	2

Special Notes:

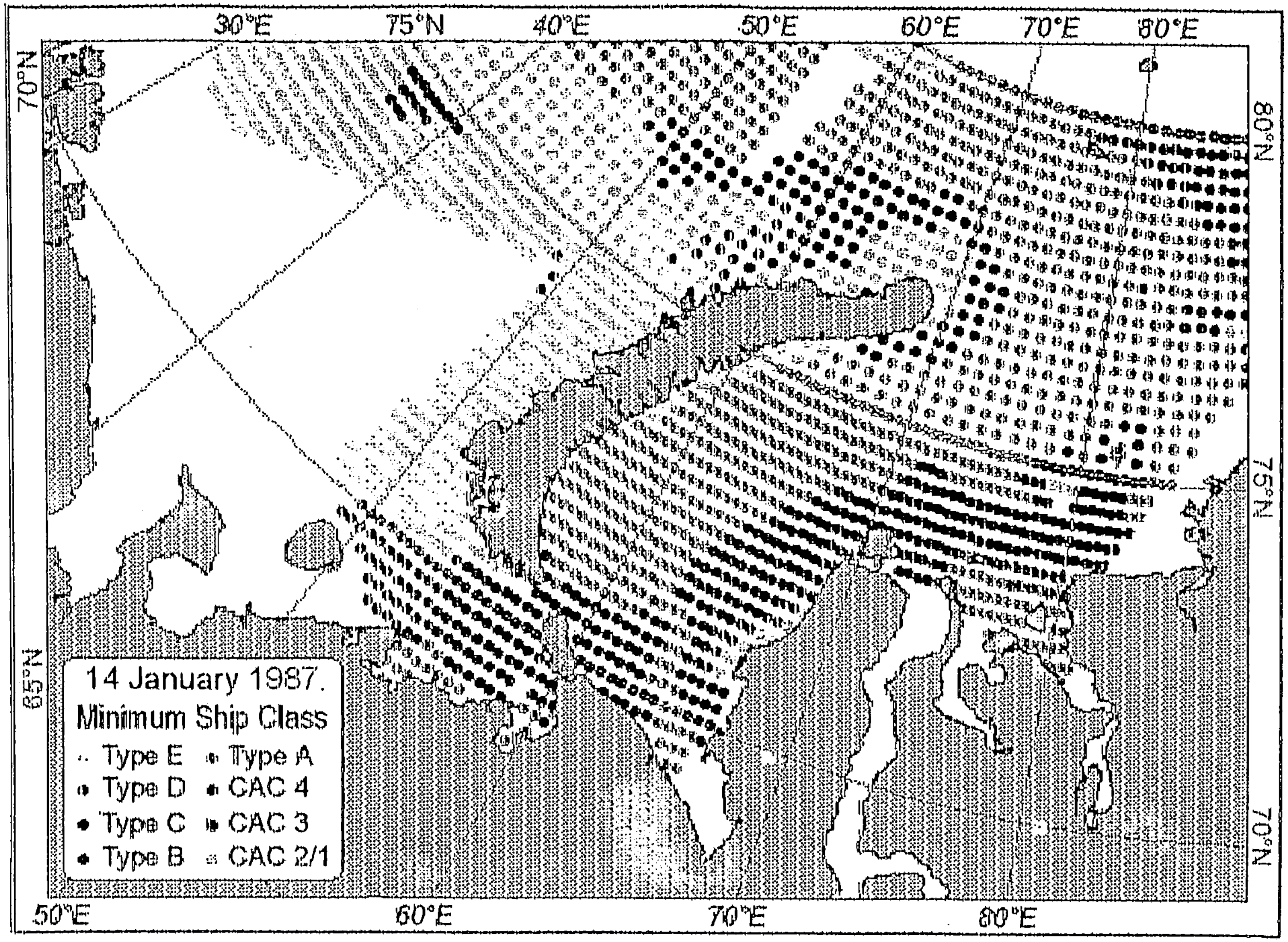
Decayed Ice: for MY, SY, THY, or MFY ice tpyes, add 1 to the multiplier.

Ridged Ice (must be > 3/10ths ridged and ≥ 6/10ths total concentration): subtract 1 from the ice multiplier.

APPENDIX B : Russian Ice Data Plotted as Minimum Ship Criteria
1987-1990
January, May, July and September

NOTE:-

A limited number of colour versions of this appendix is available on request to Dr. S.J. Jones.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Type D
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Type C
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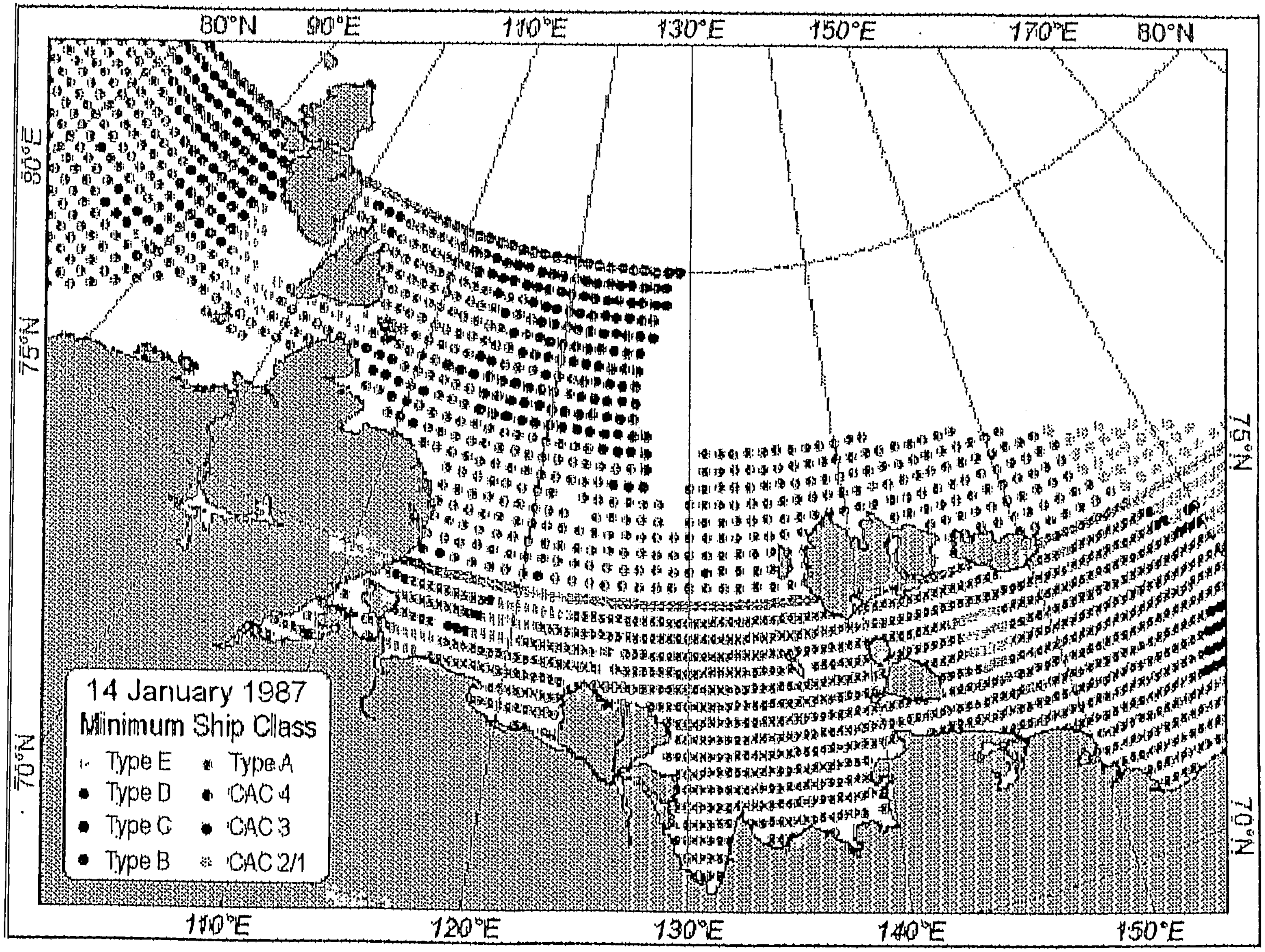
Type B
CAC 2/1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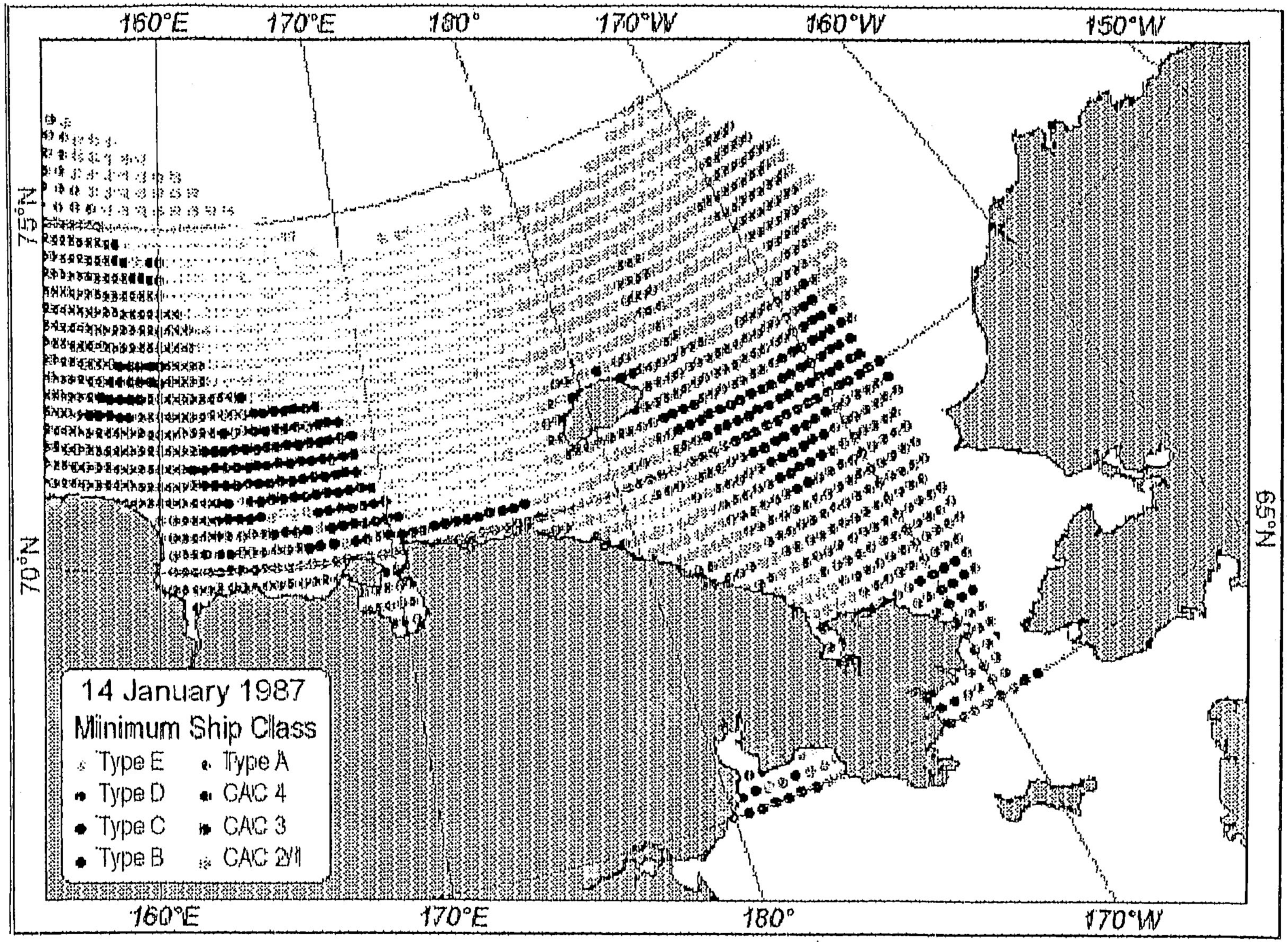
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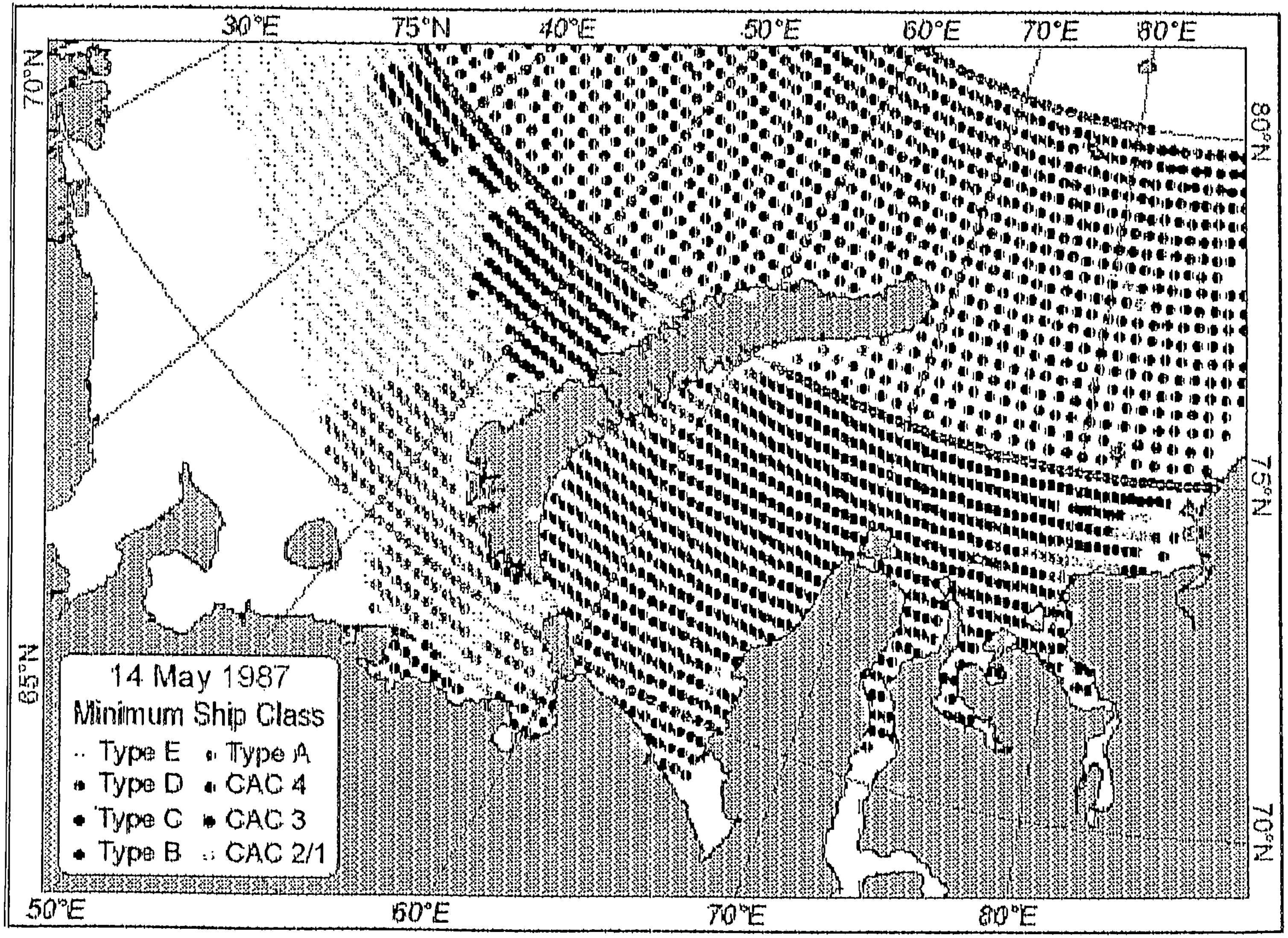
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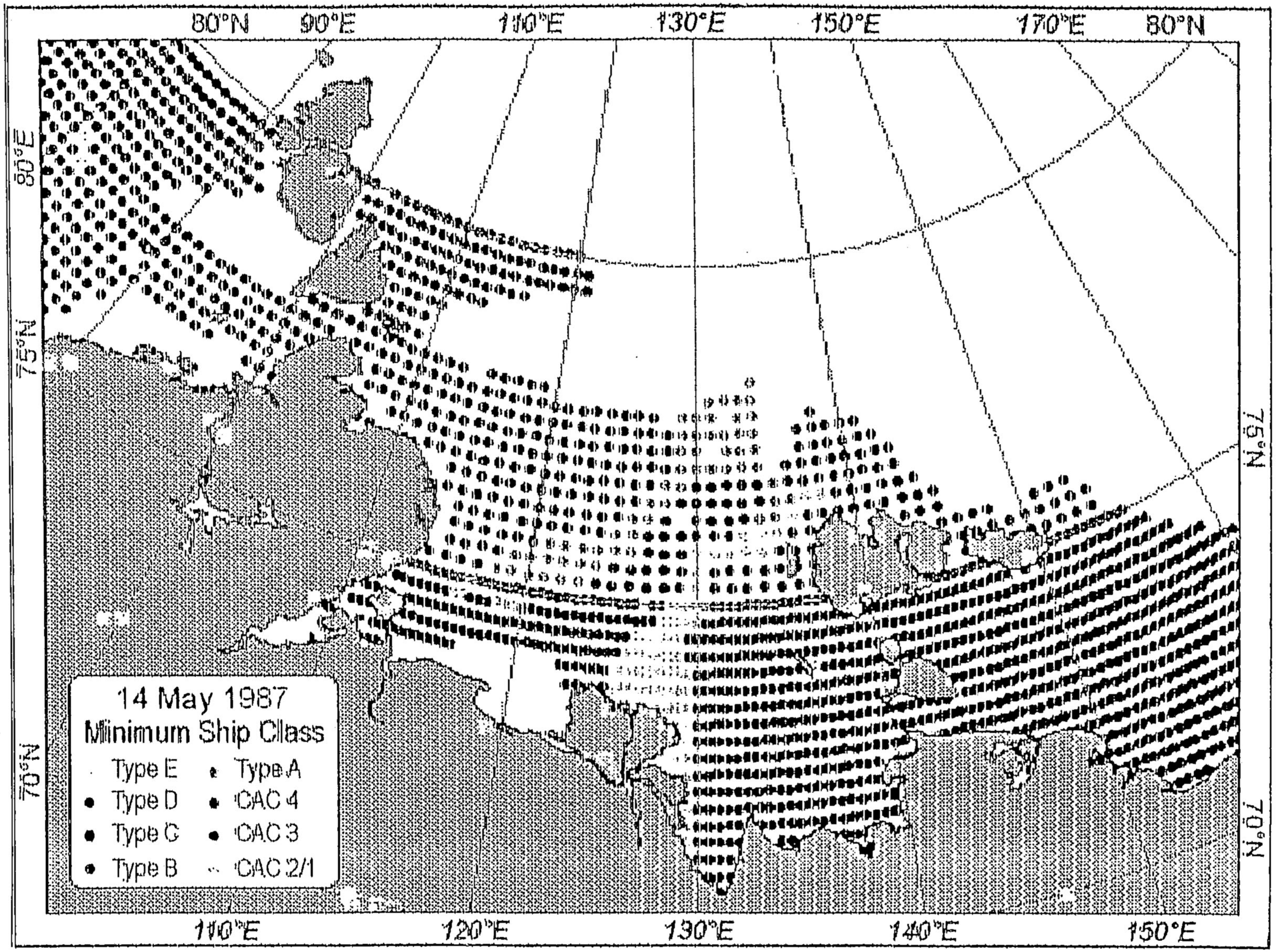
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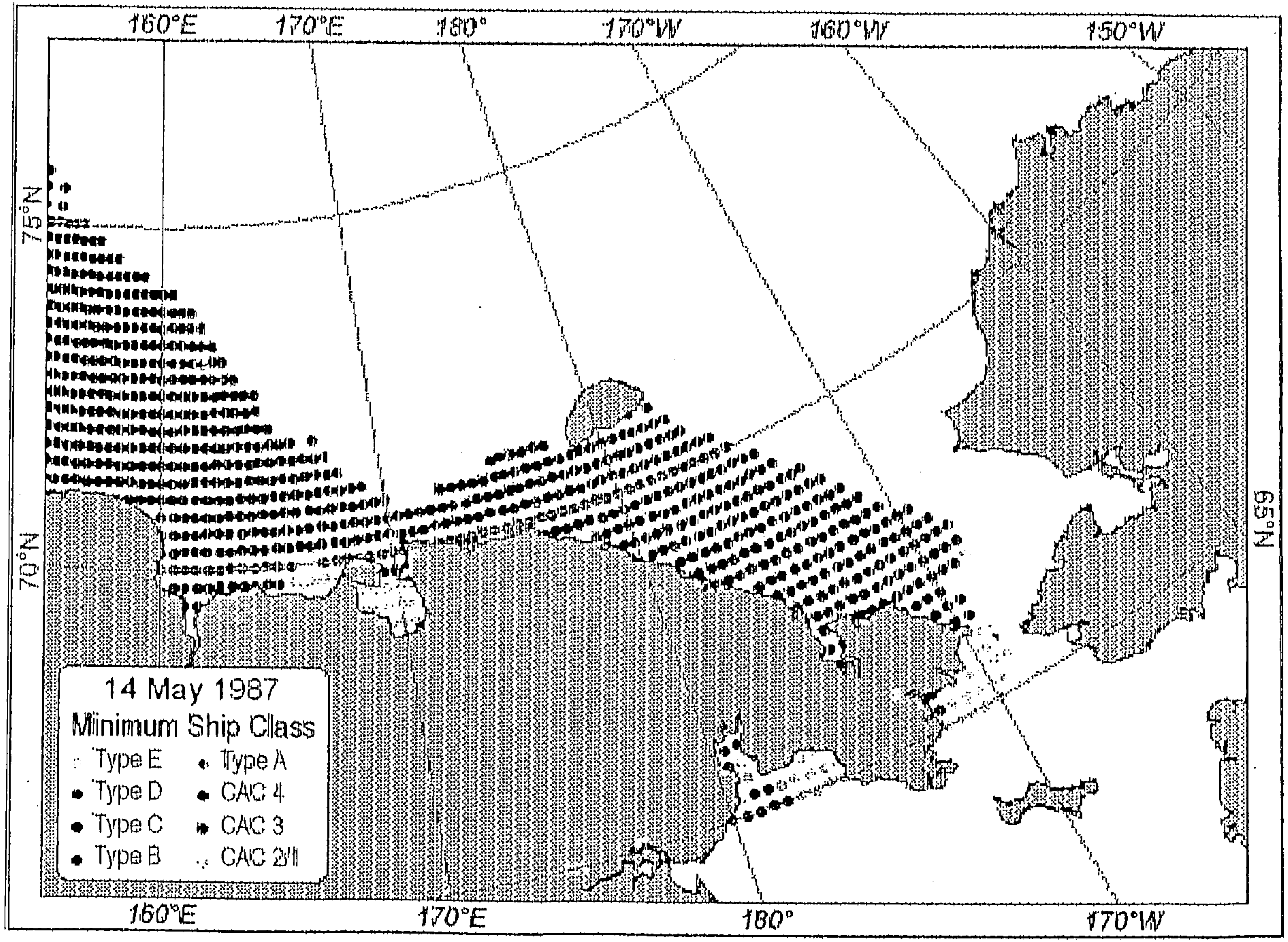

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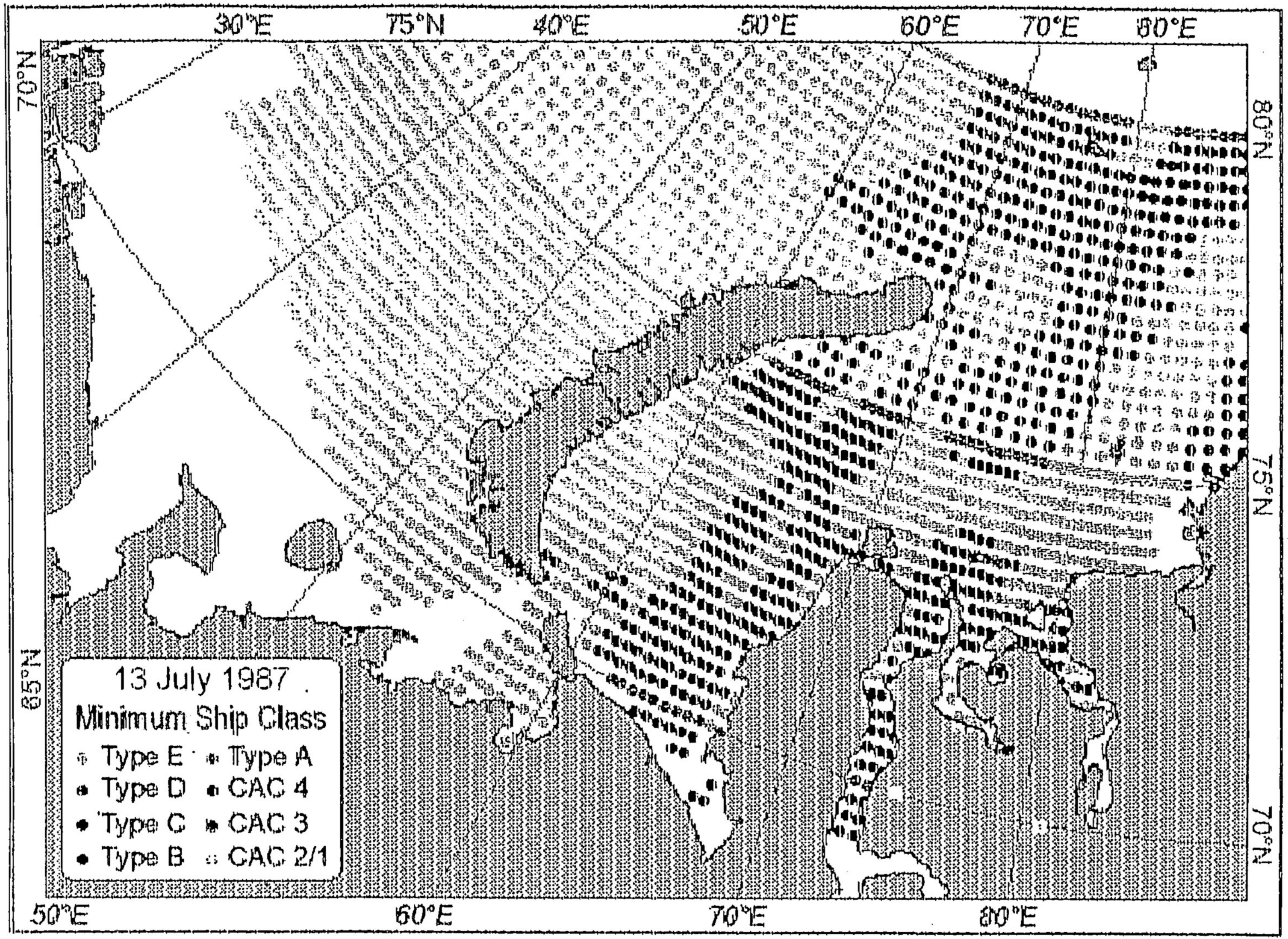
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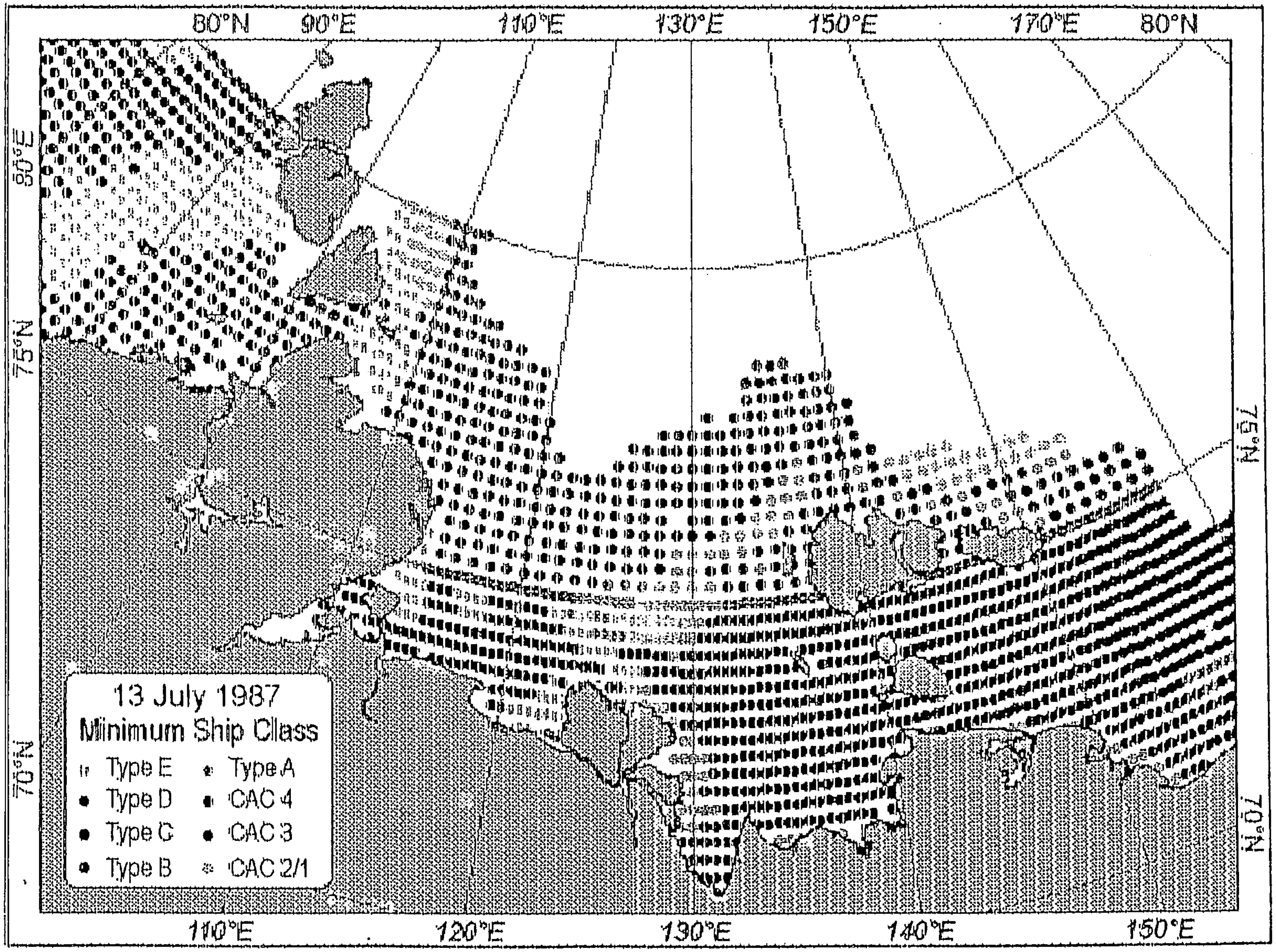
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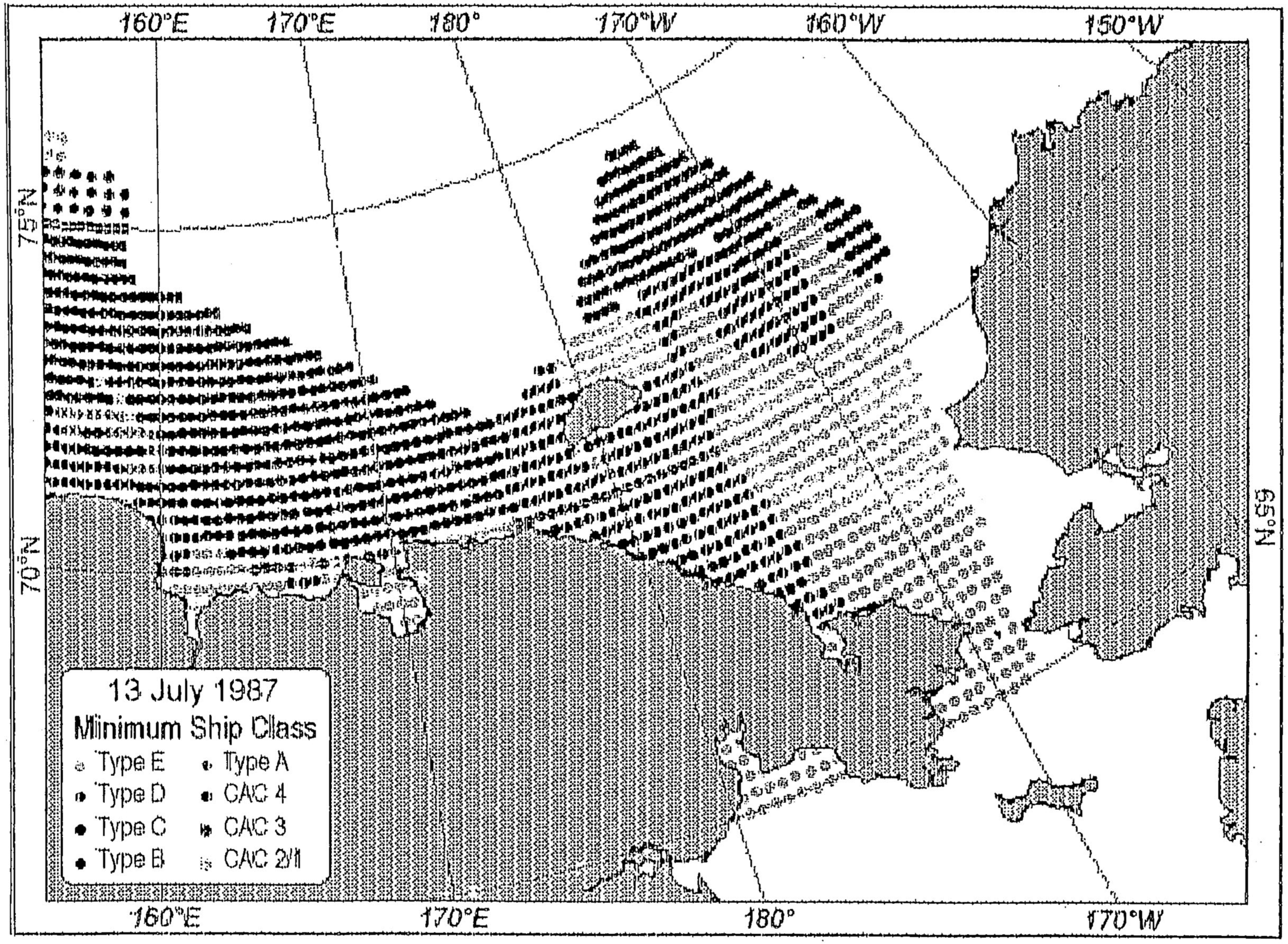
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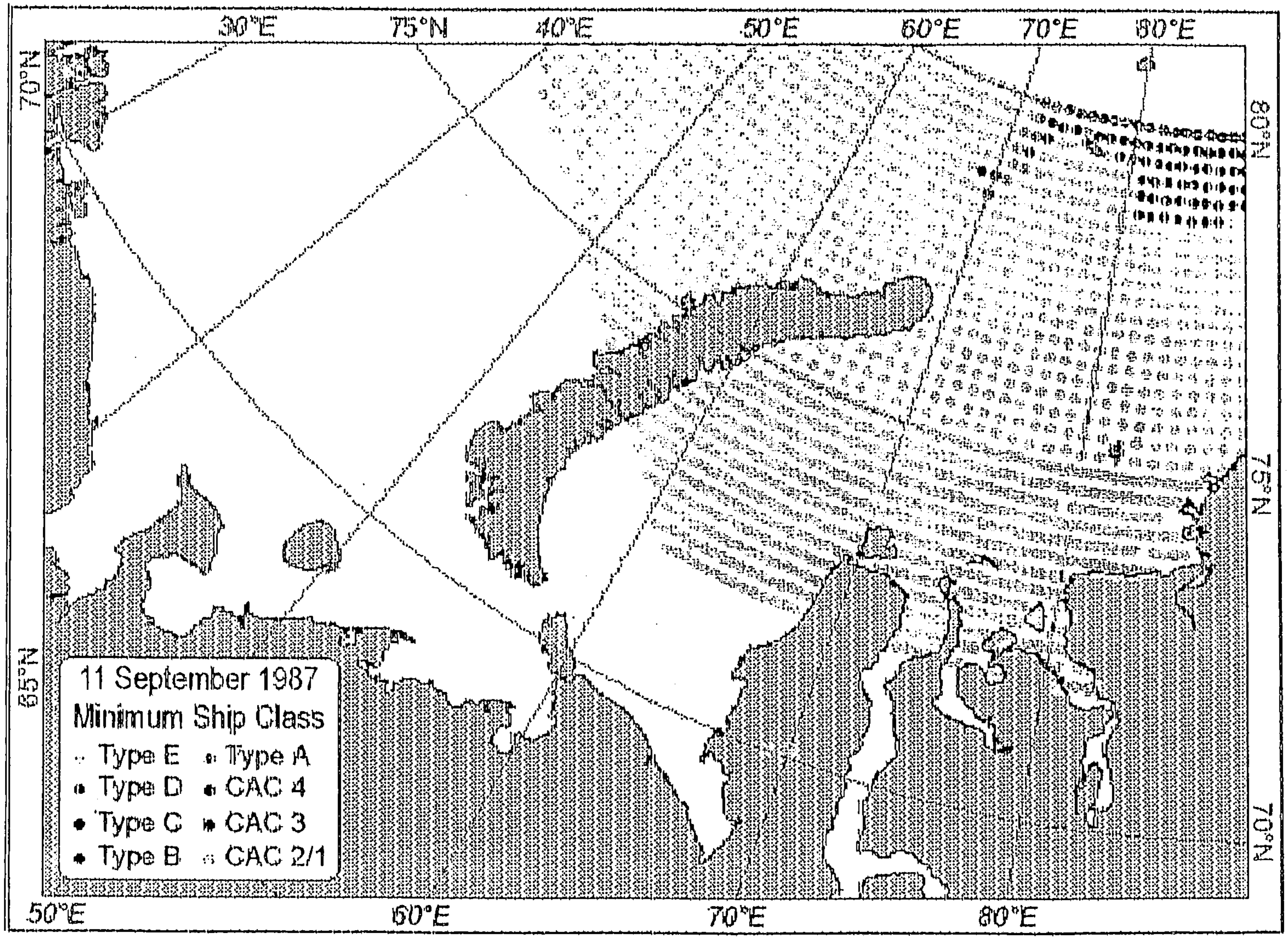
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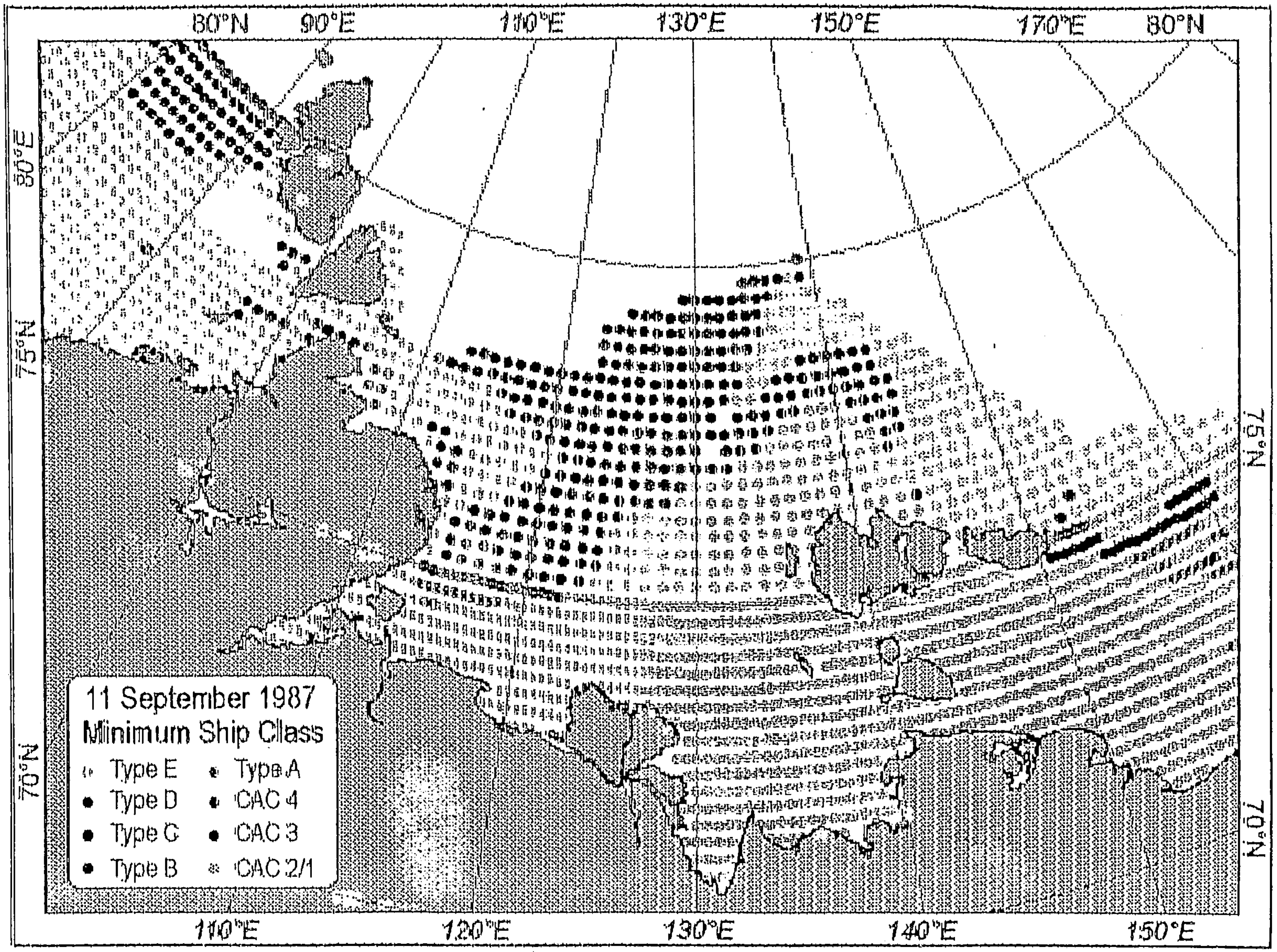
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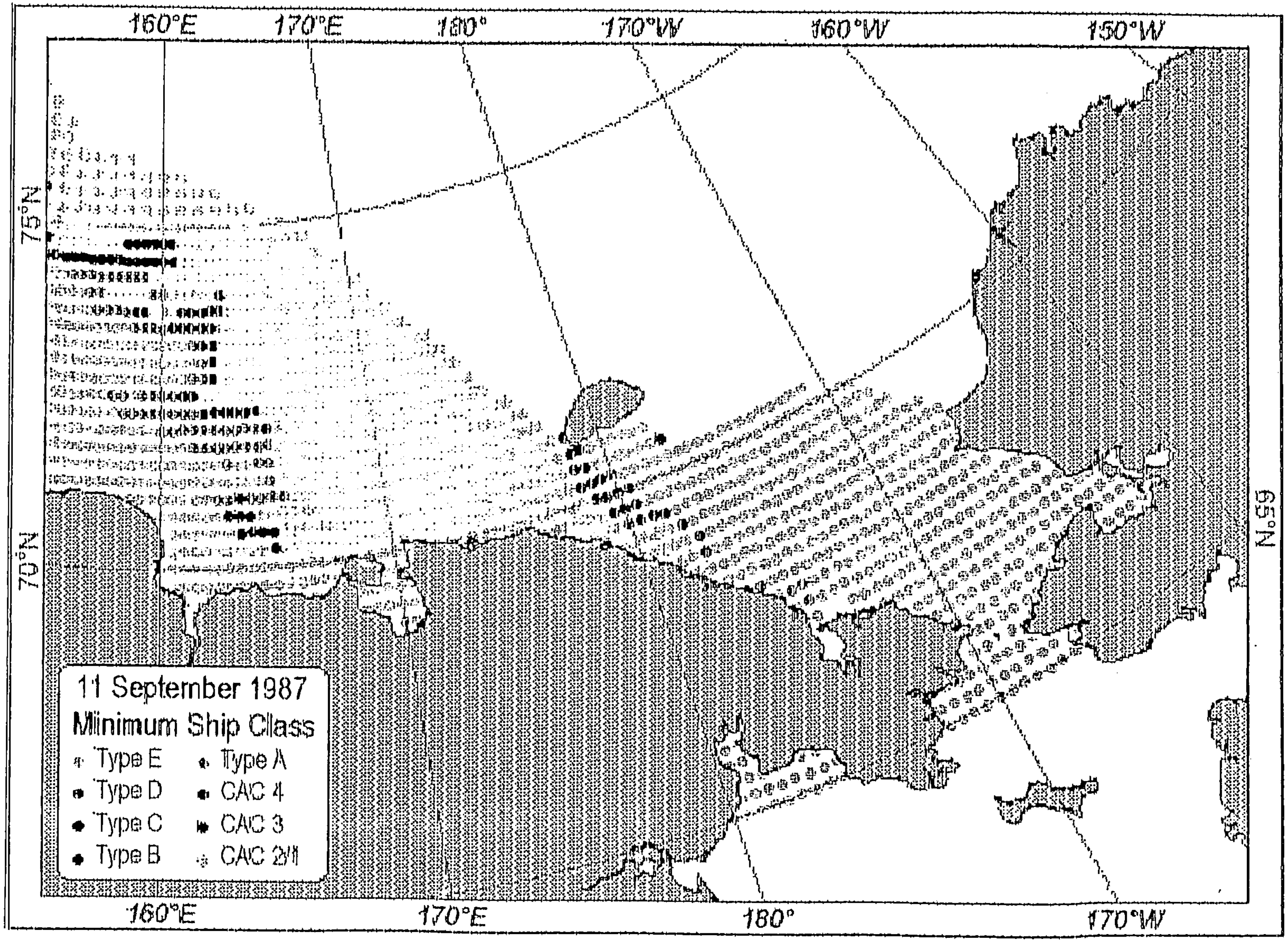
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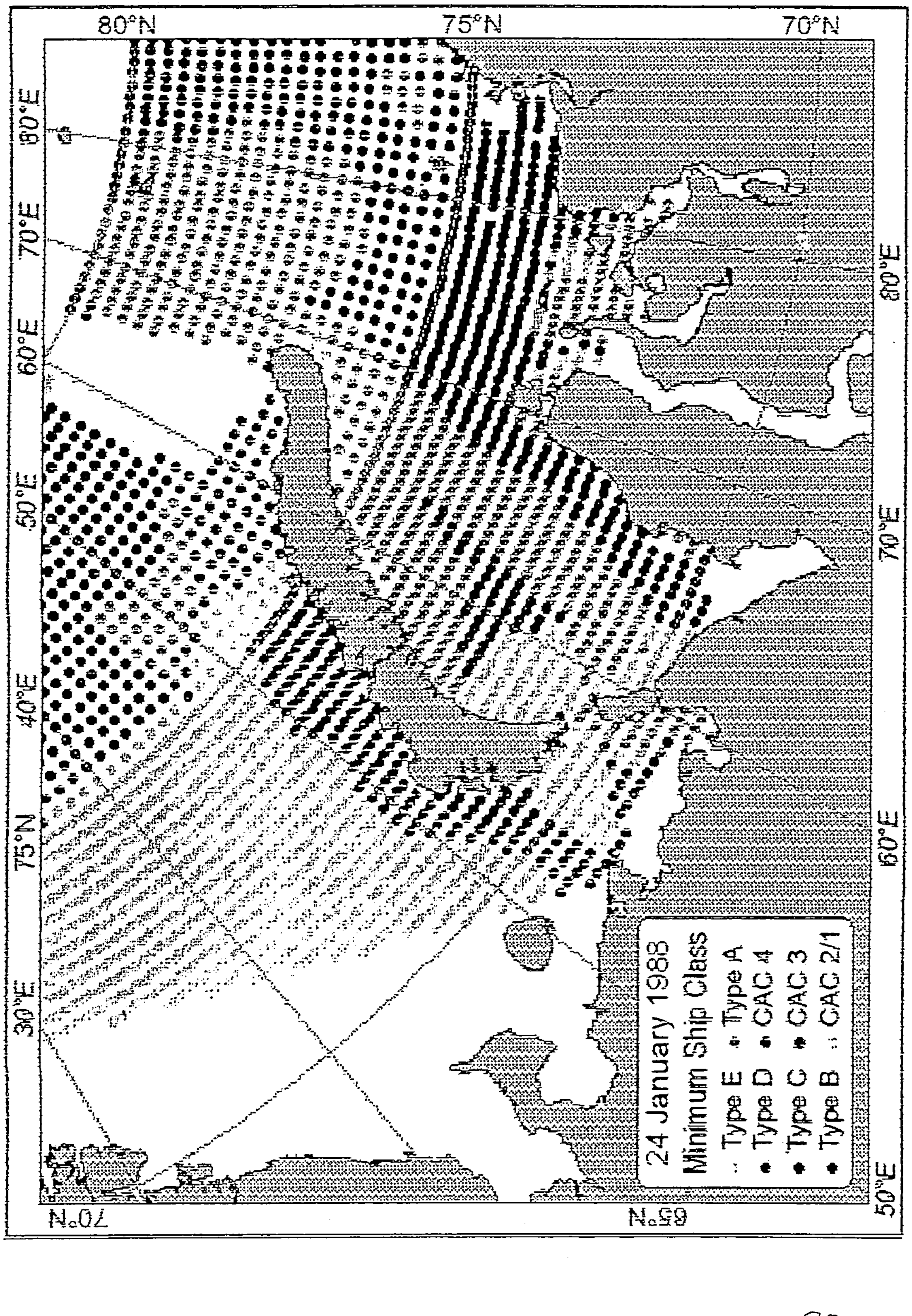
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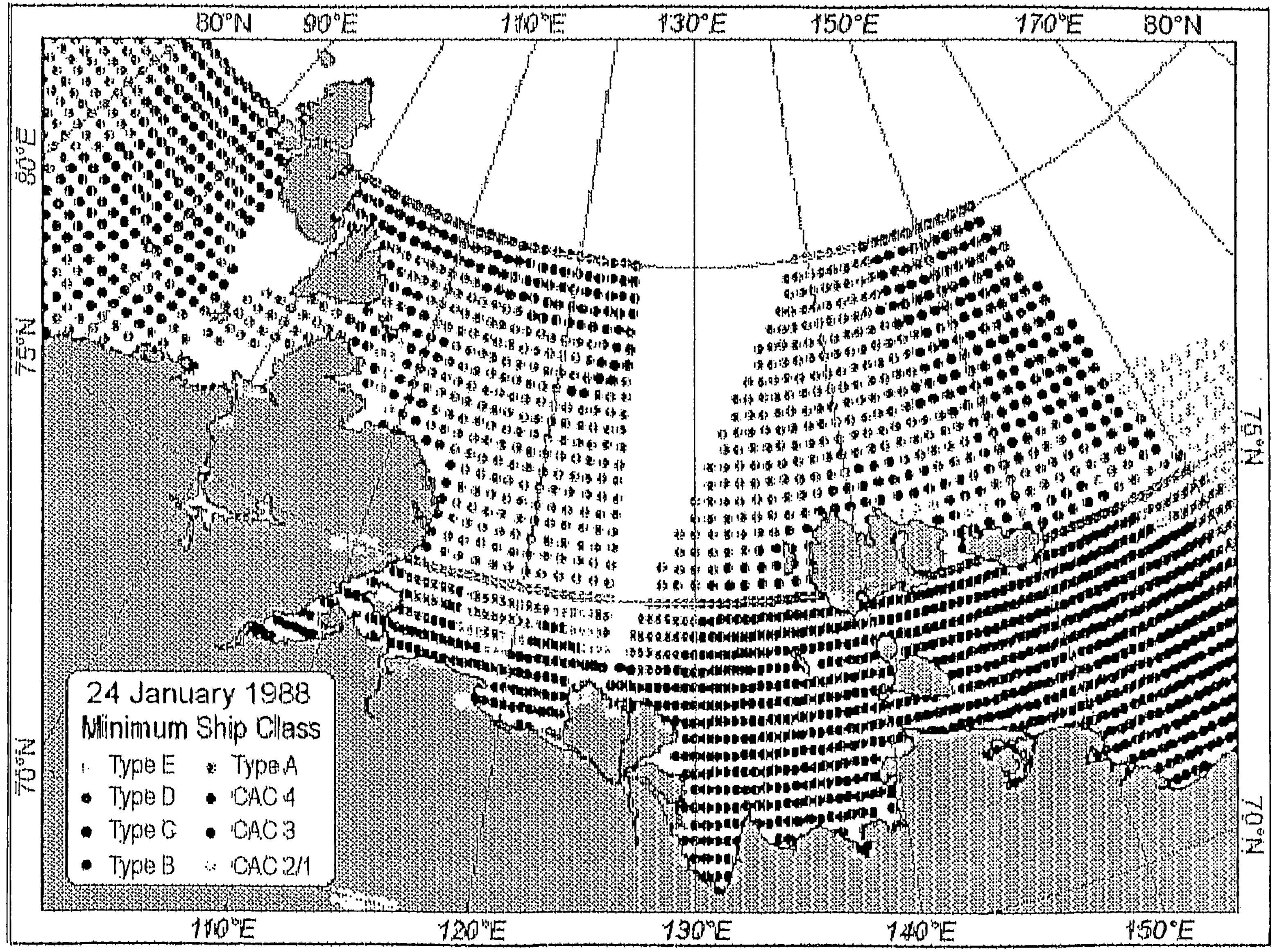
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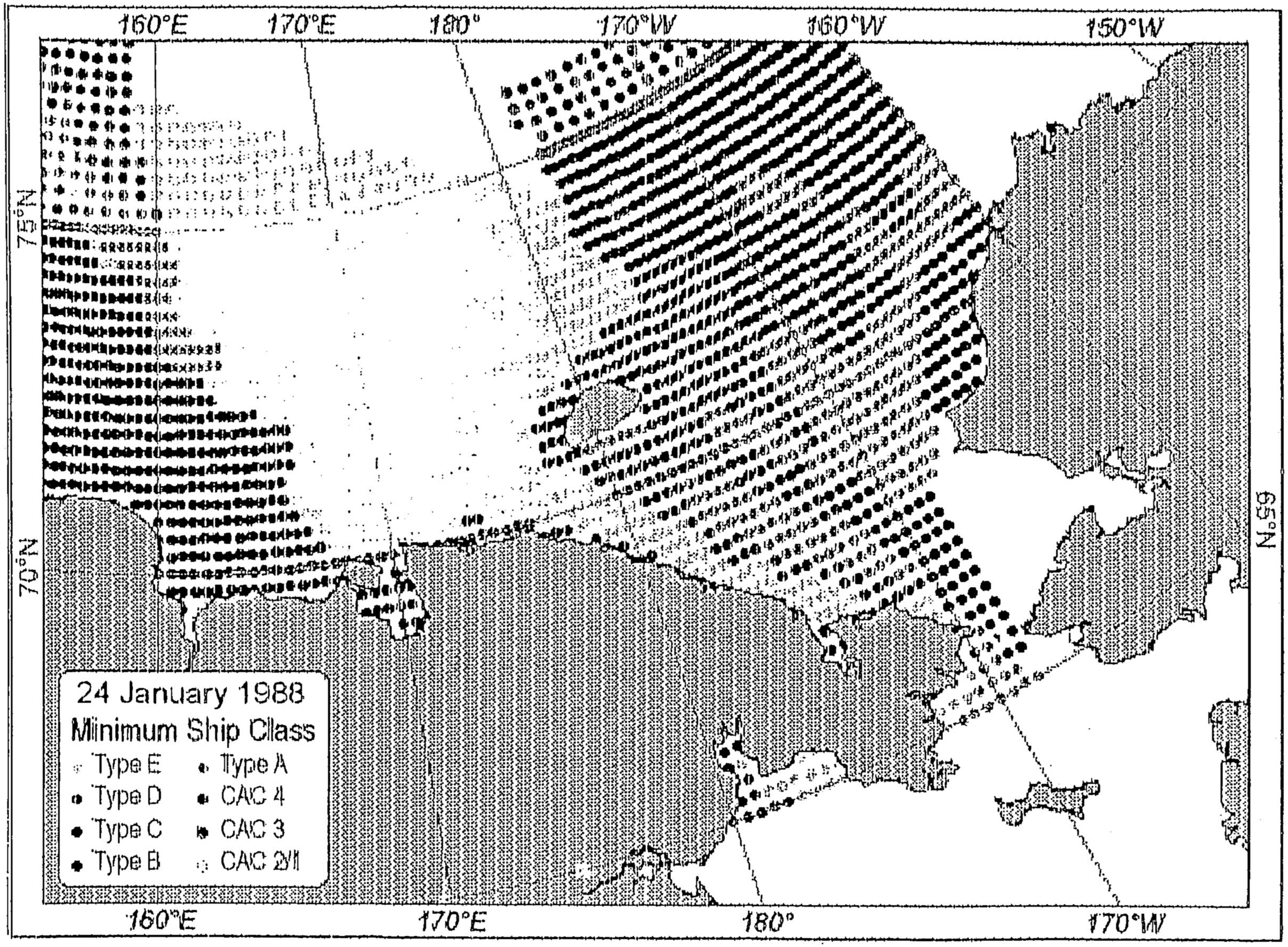
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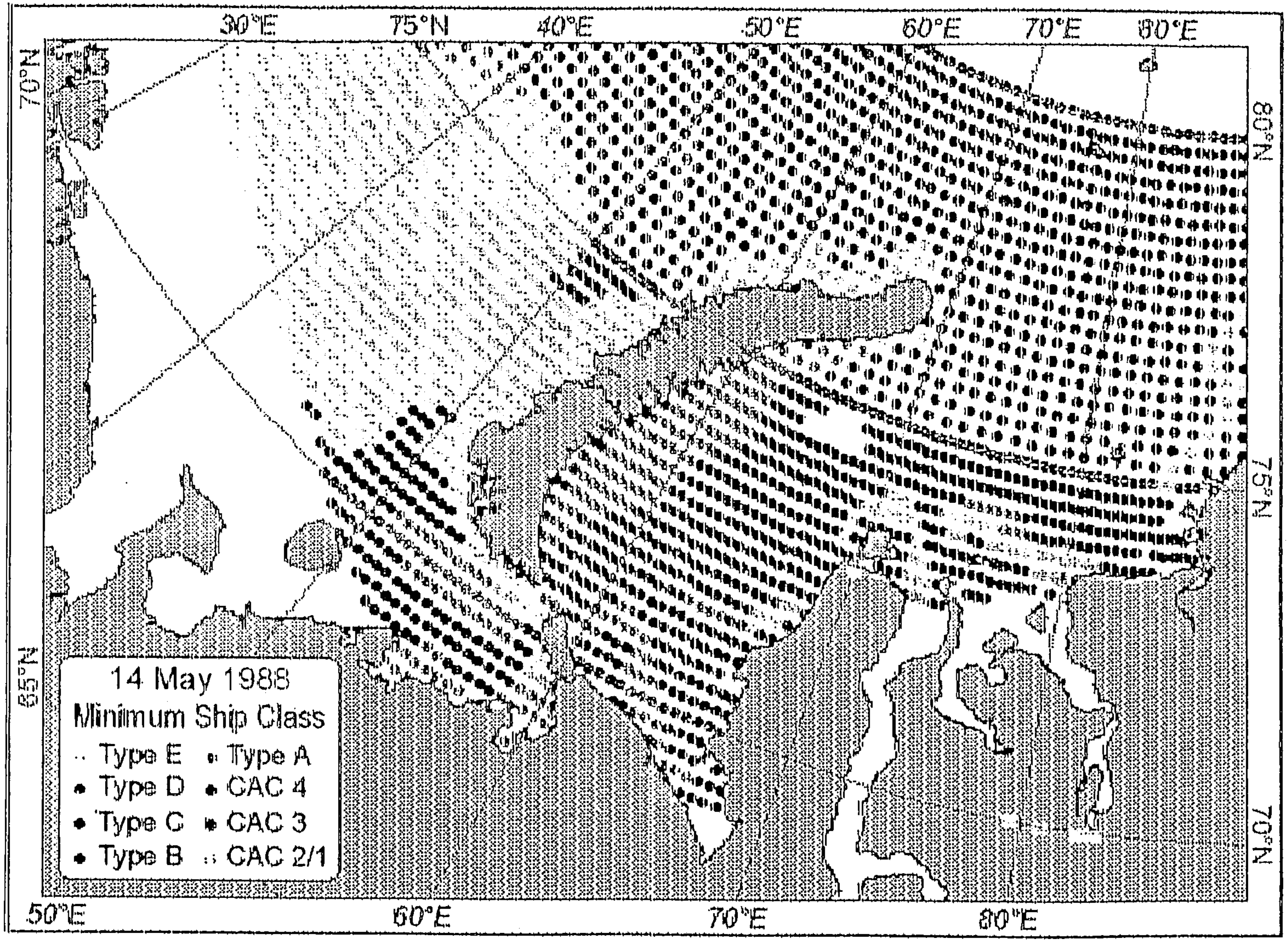
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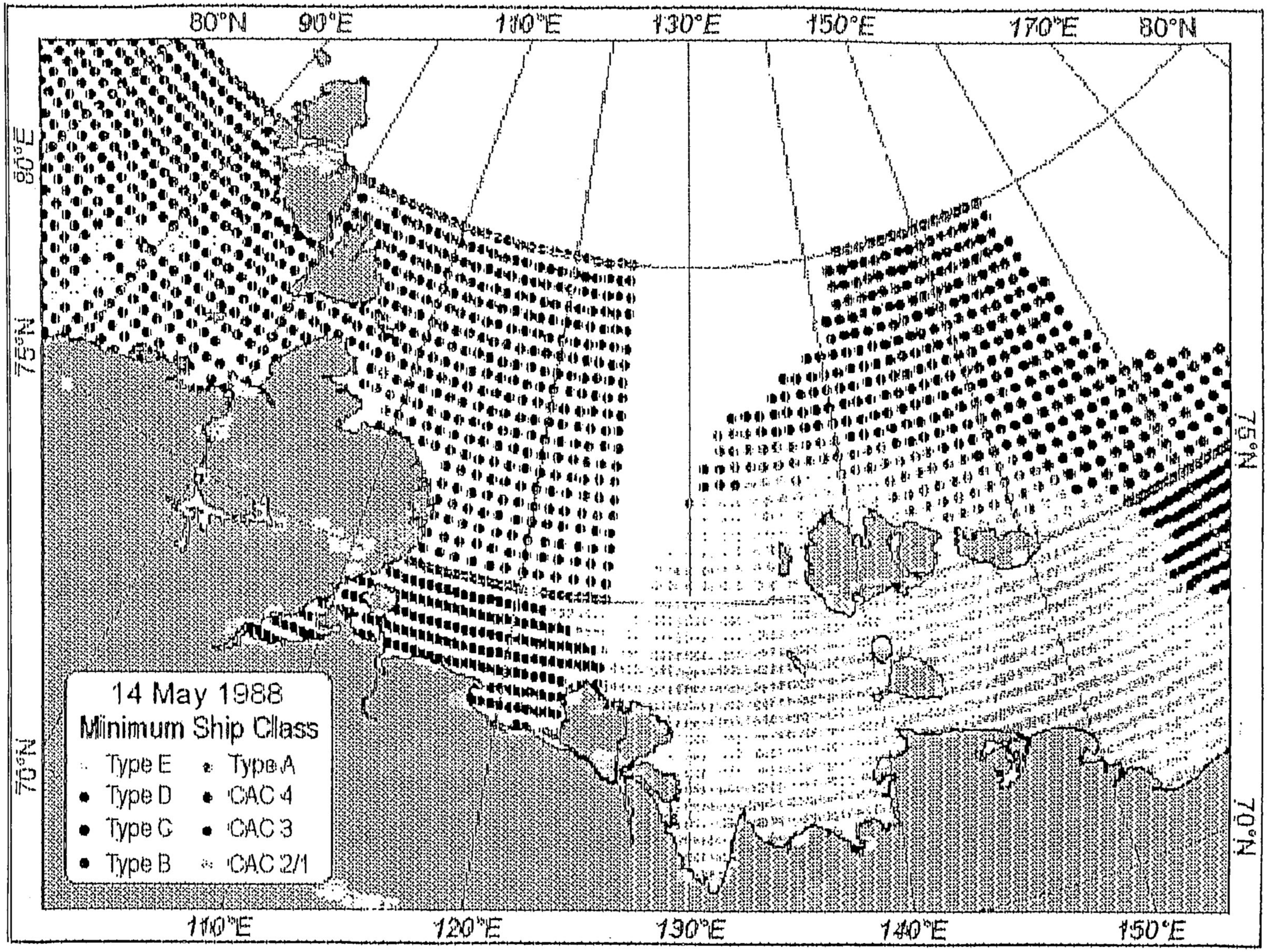
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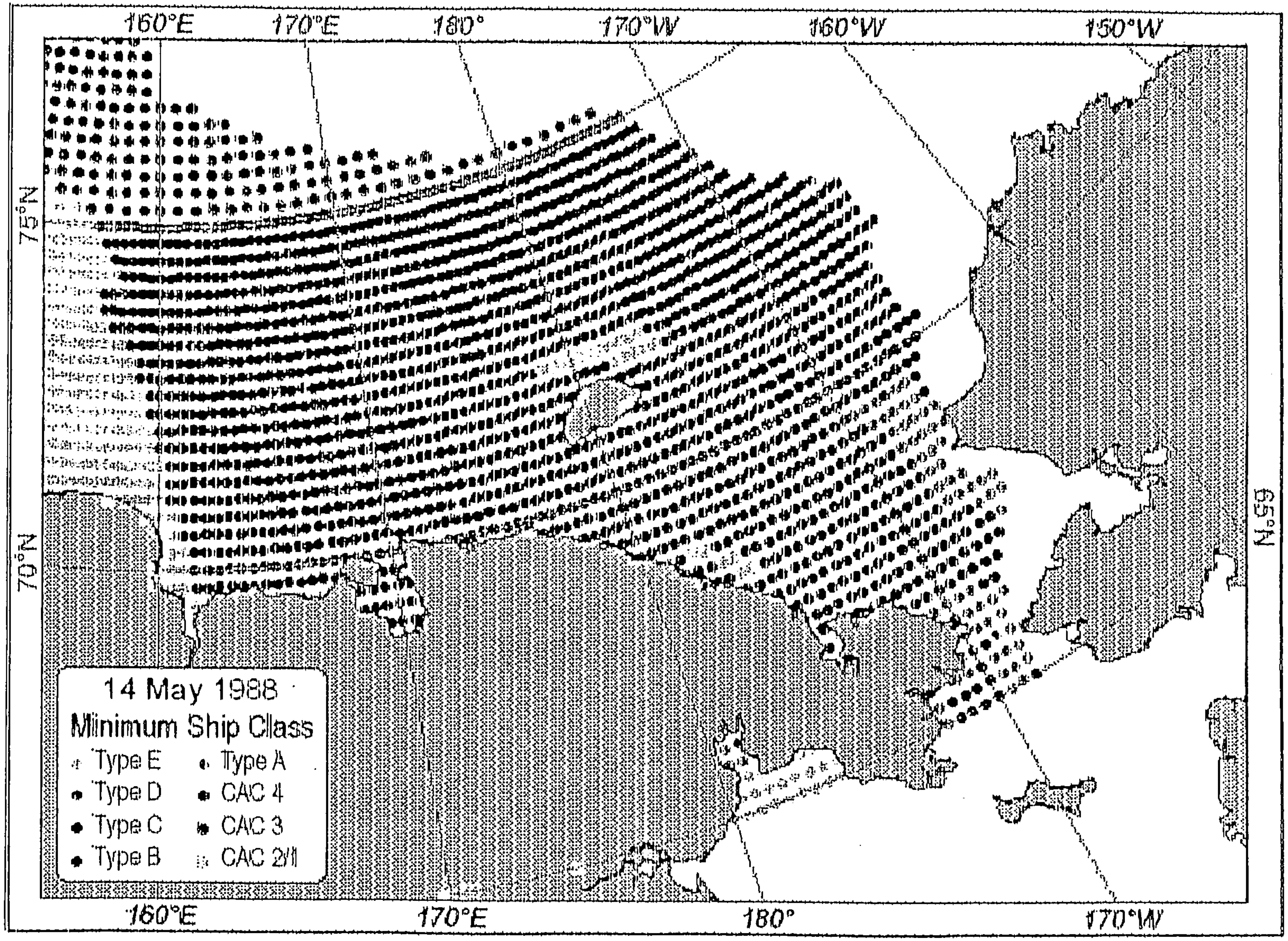
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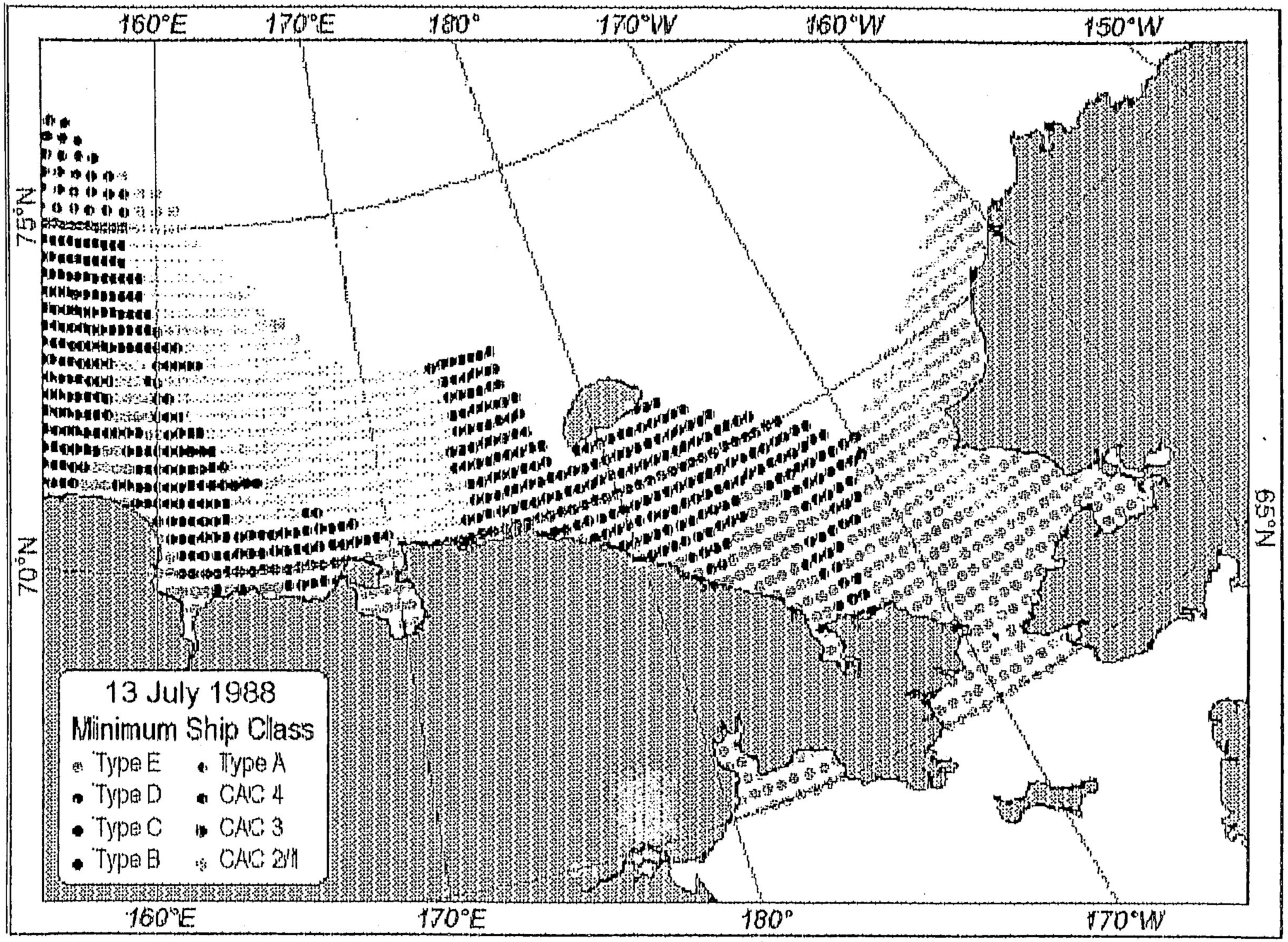
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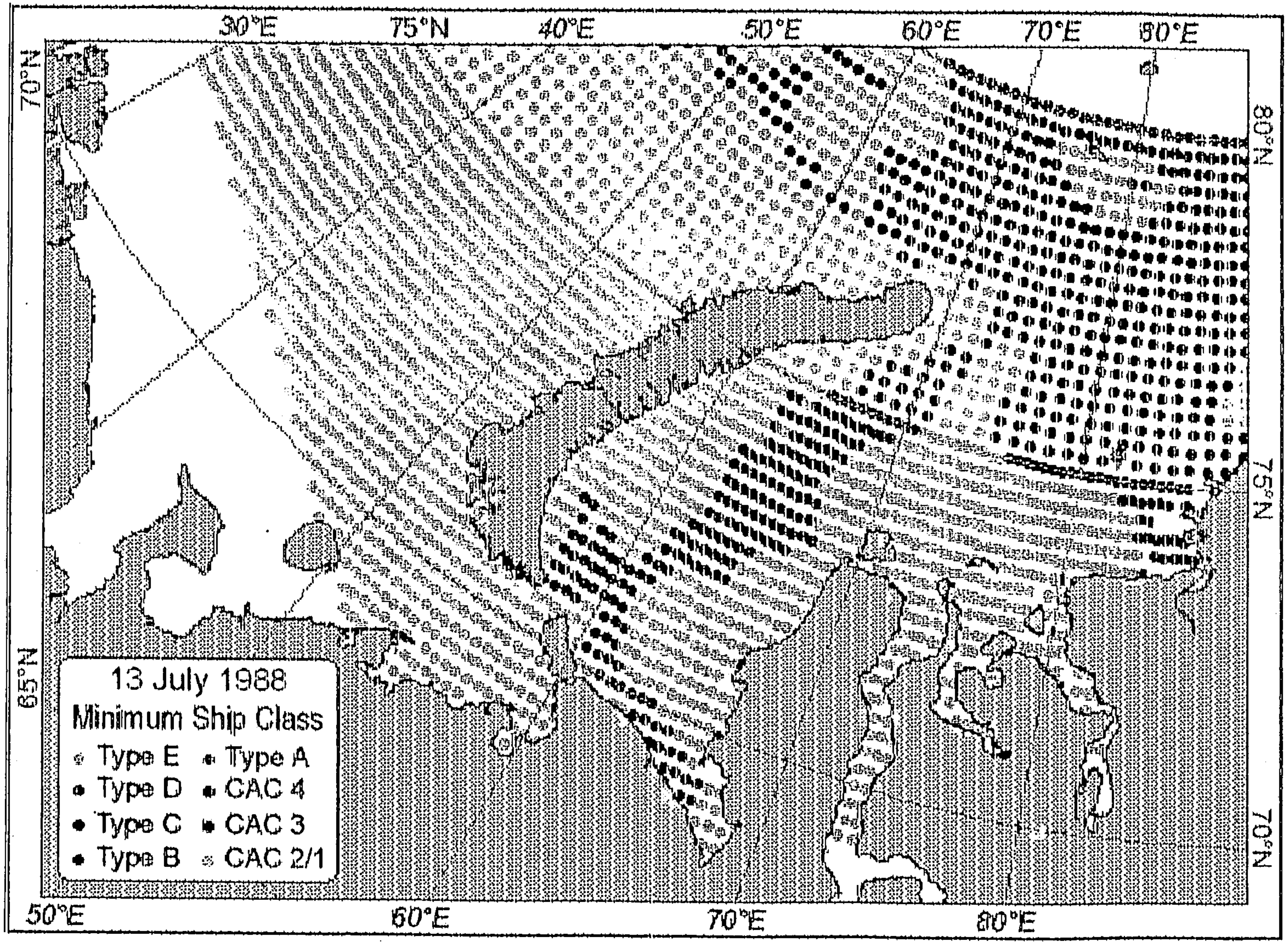
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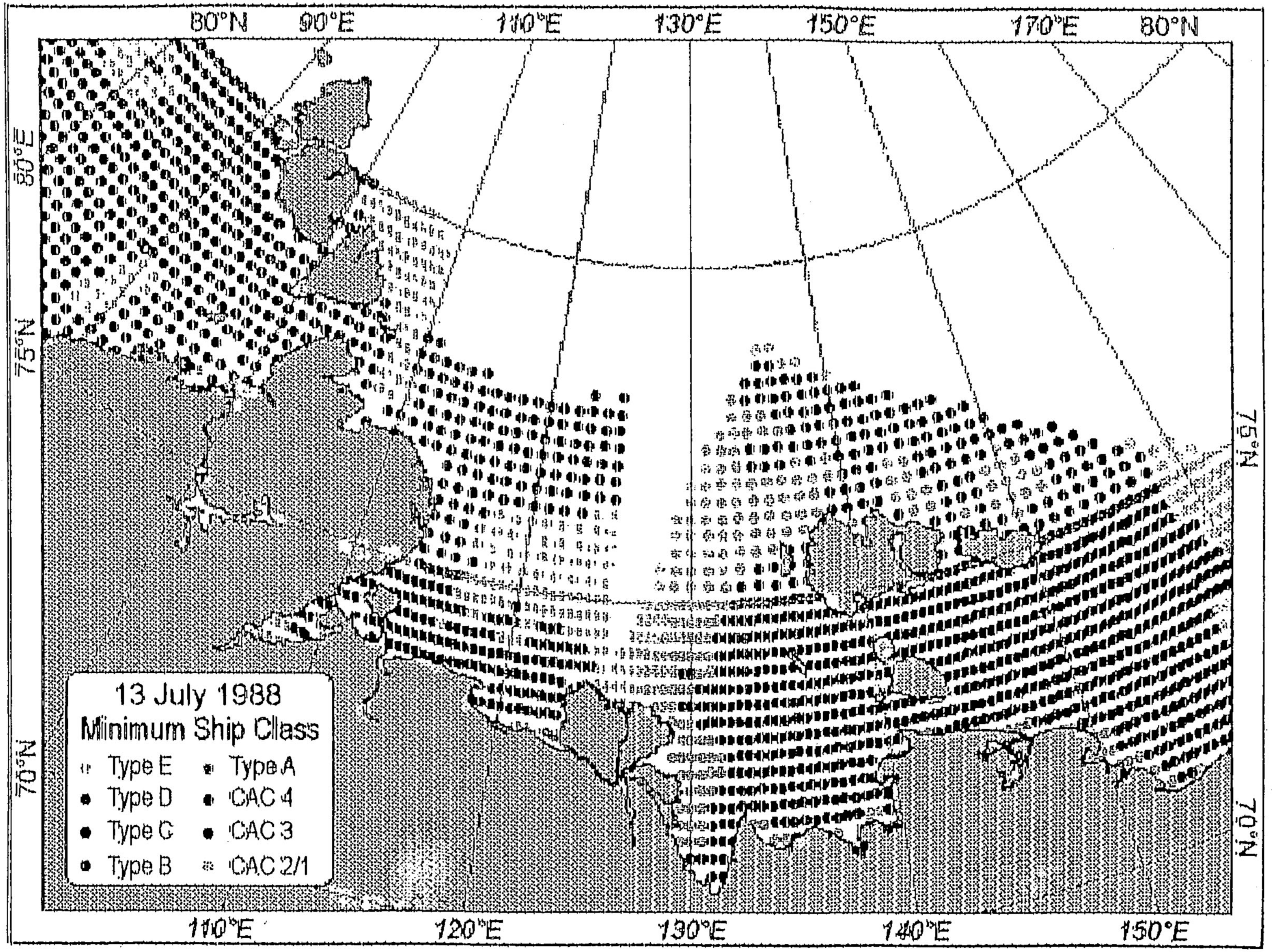
CAC 2/1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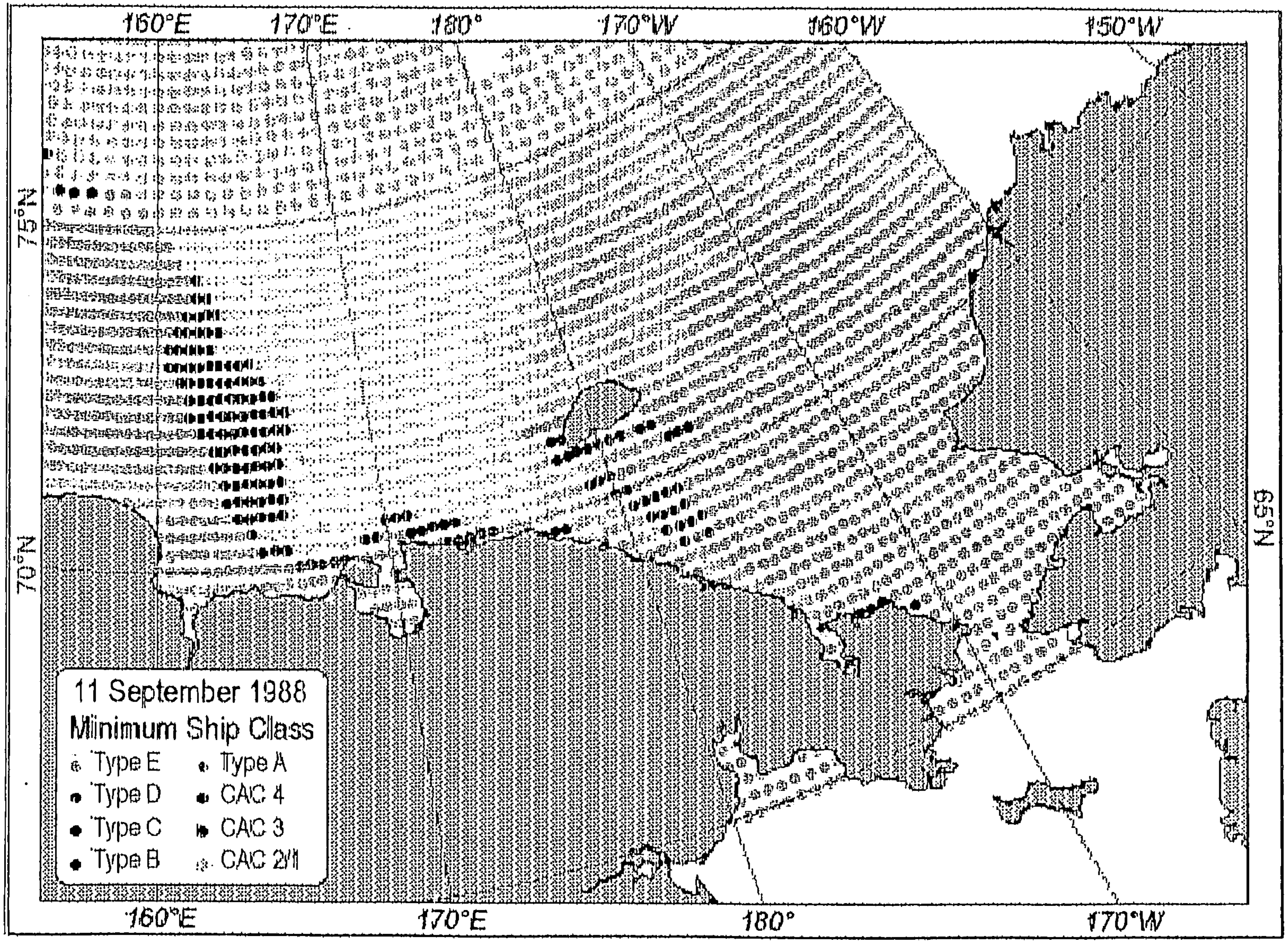
CAC 2/1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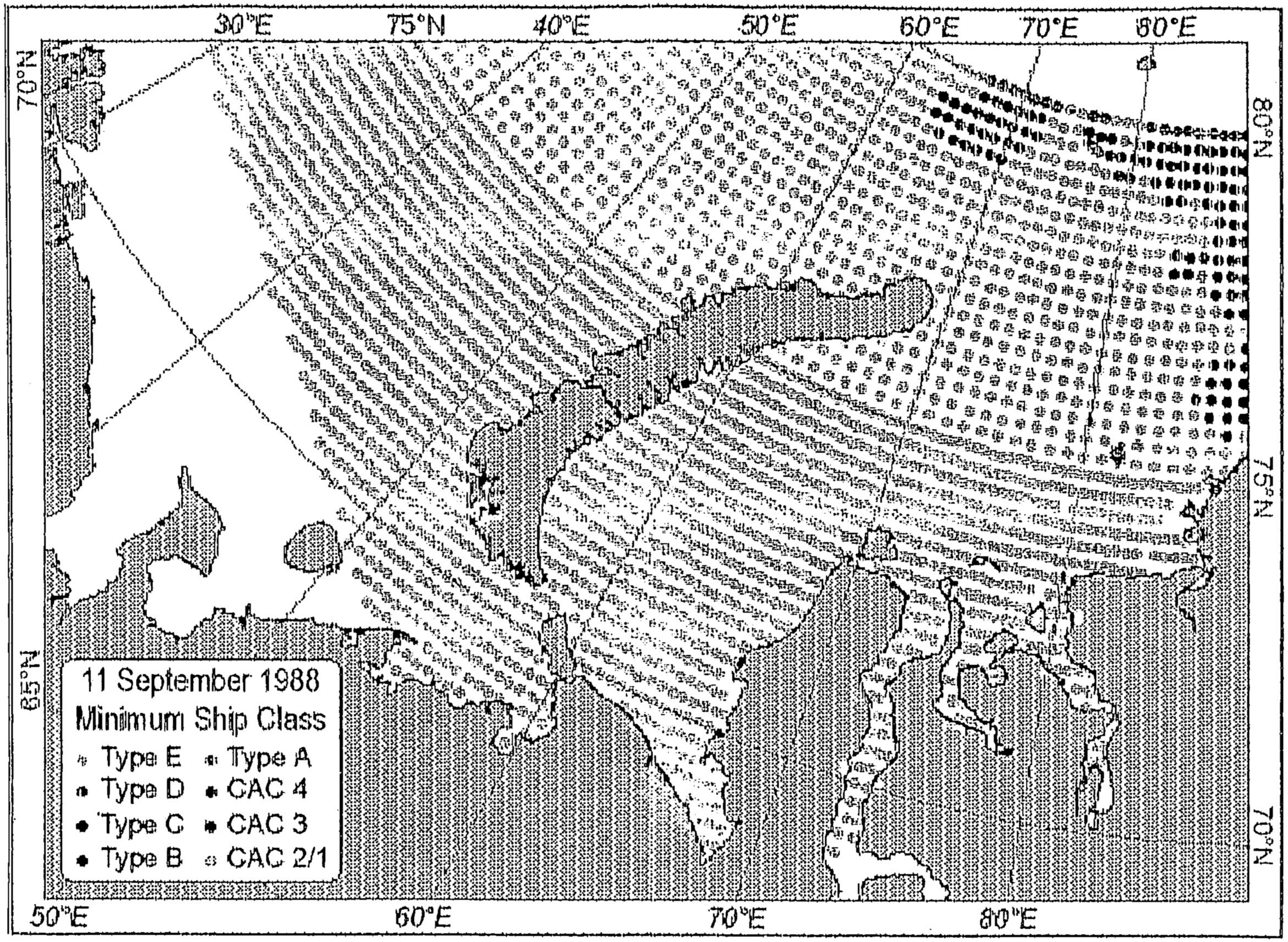
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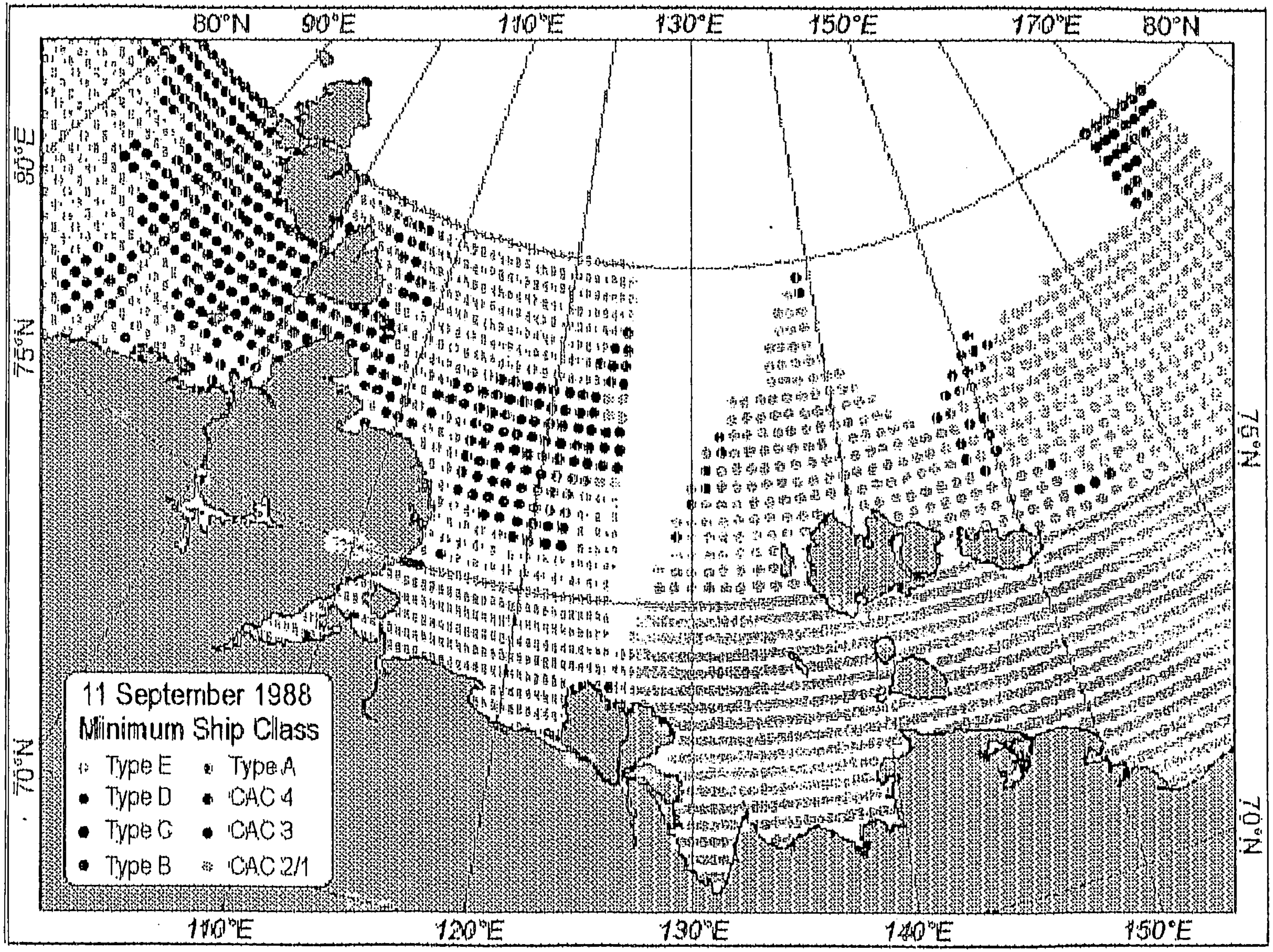
CAC 2/1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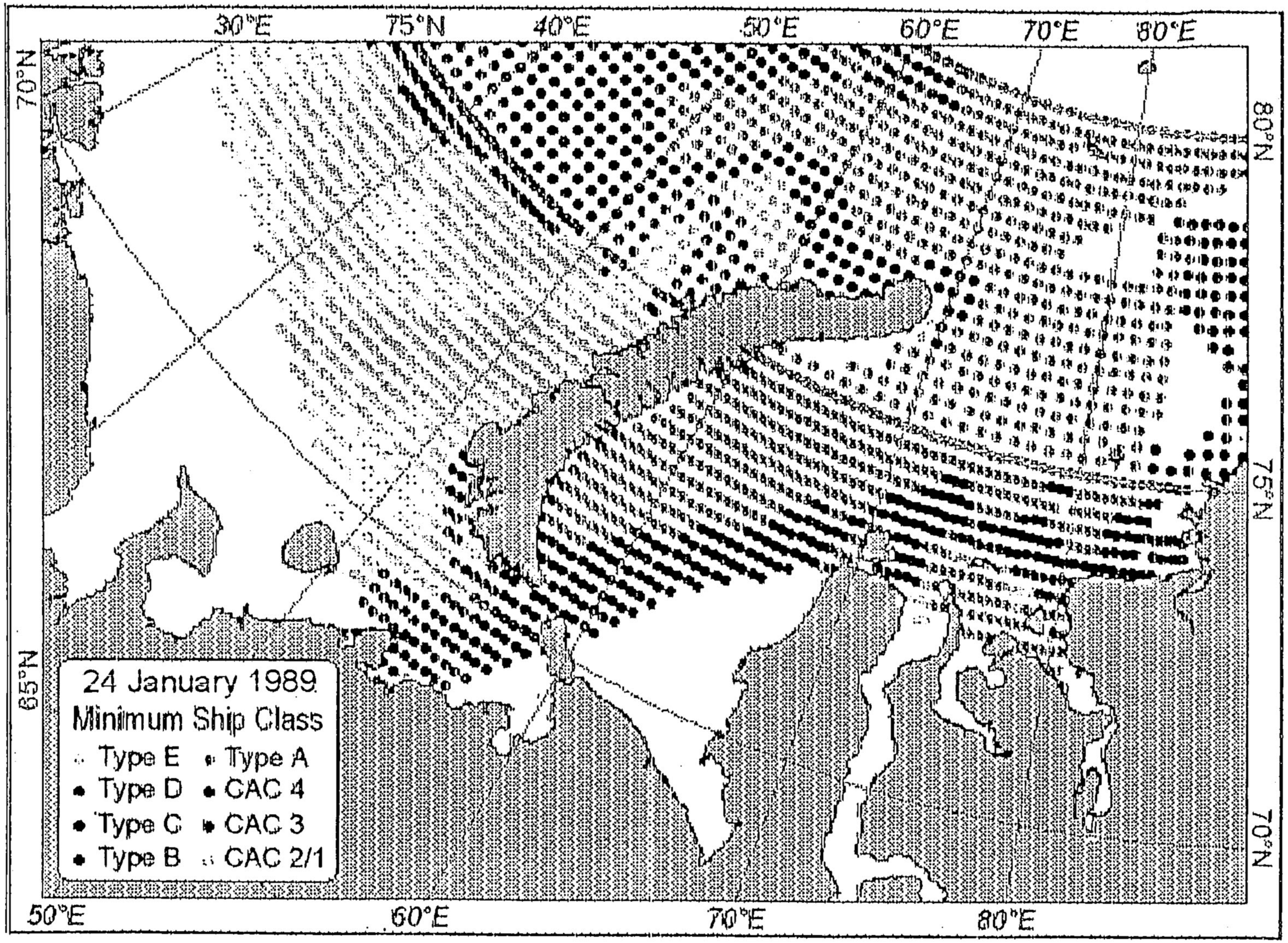
CAC 2/1



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CAC 2/1
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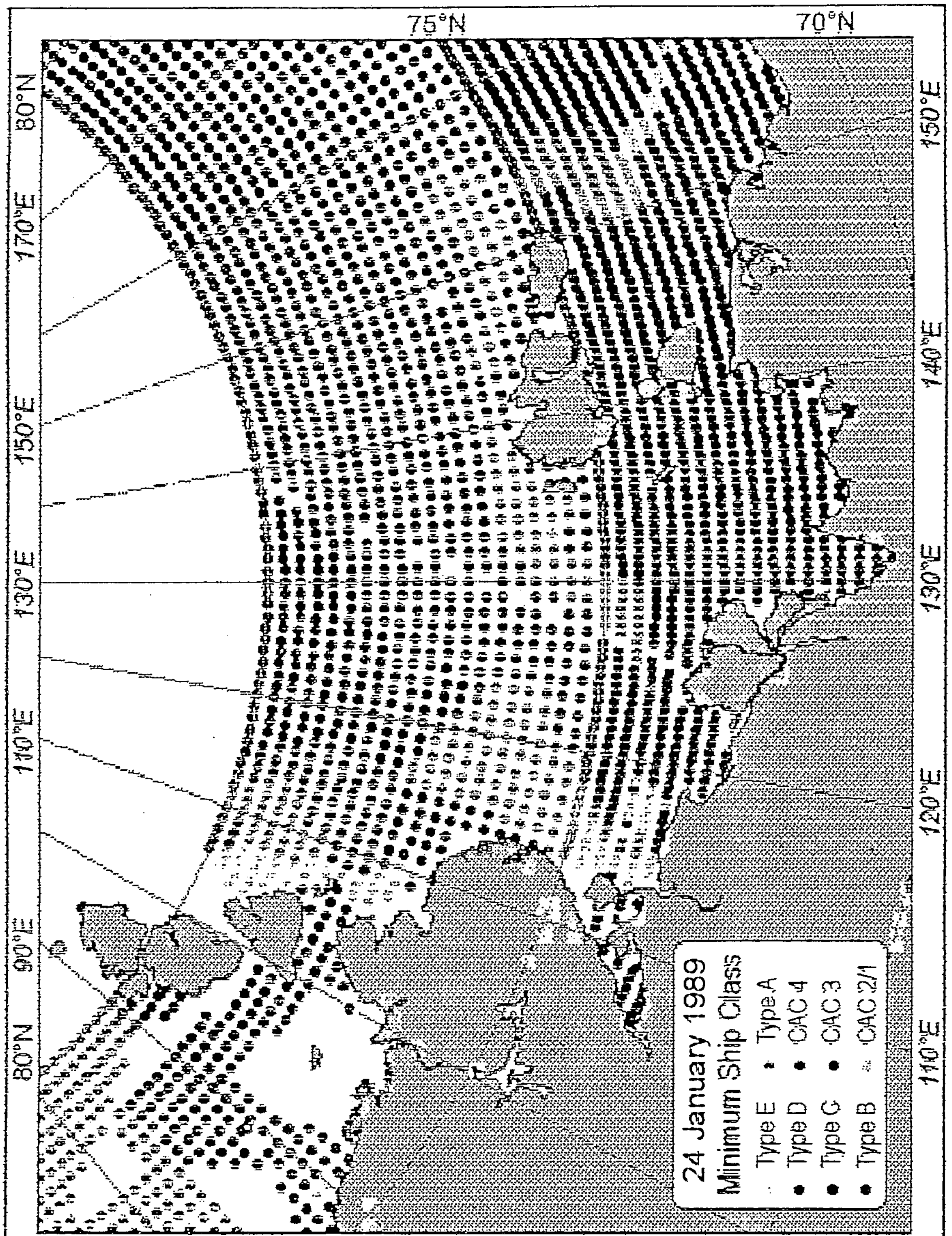
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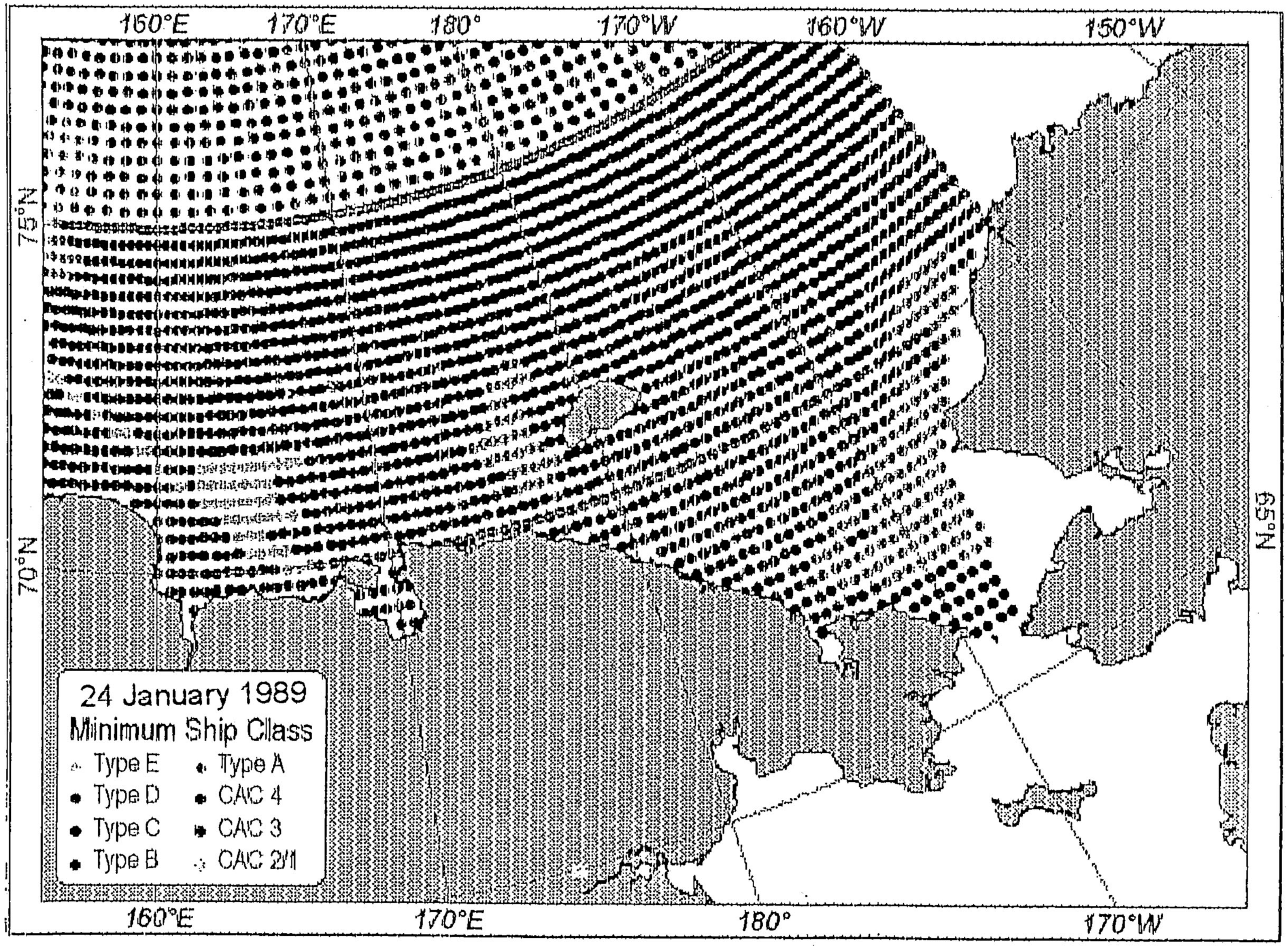
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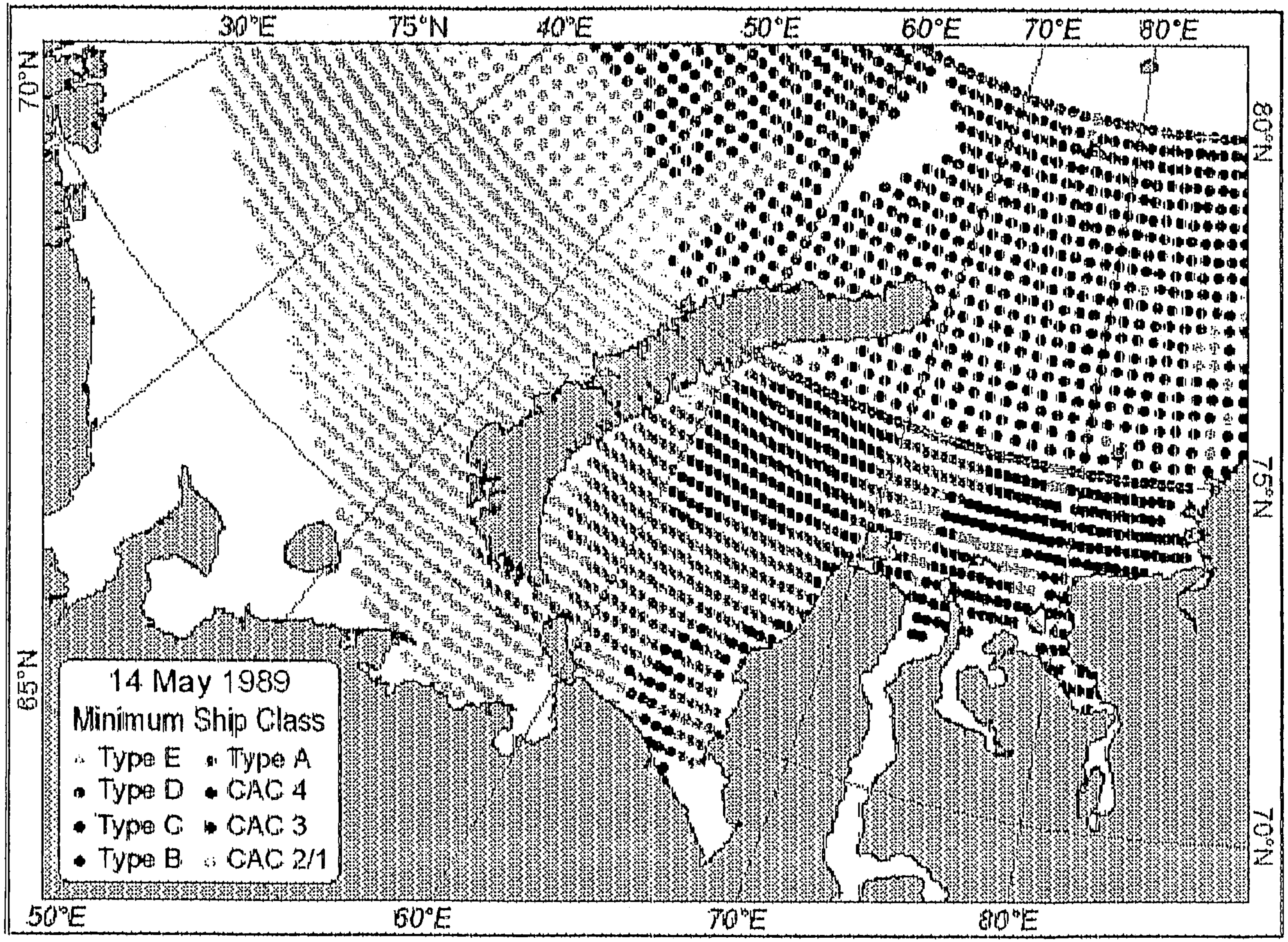
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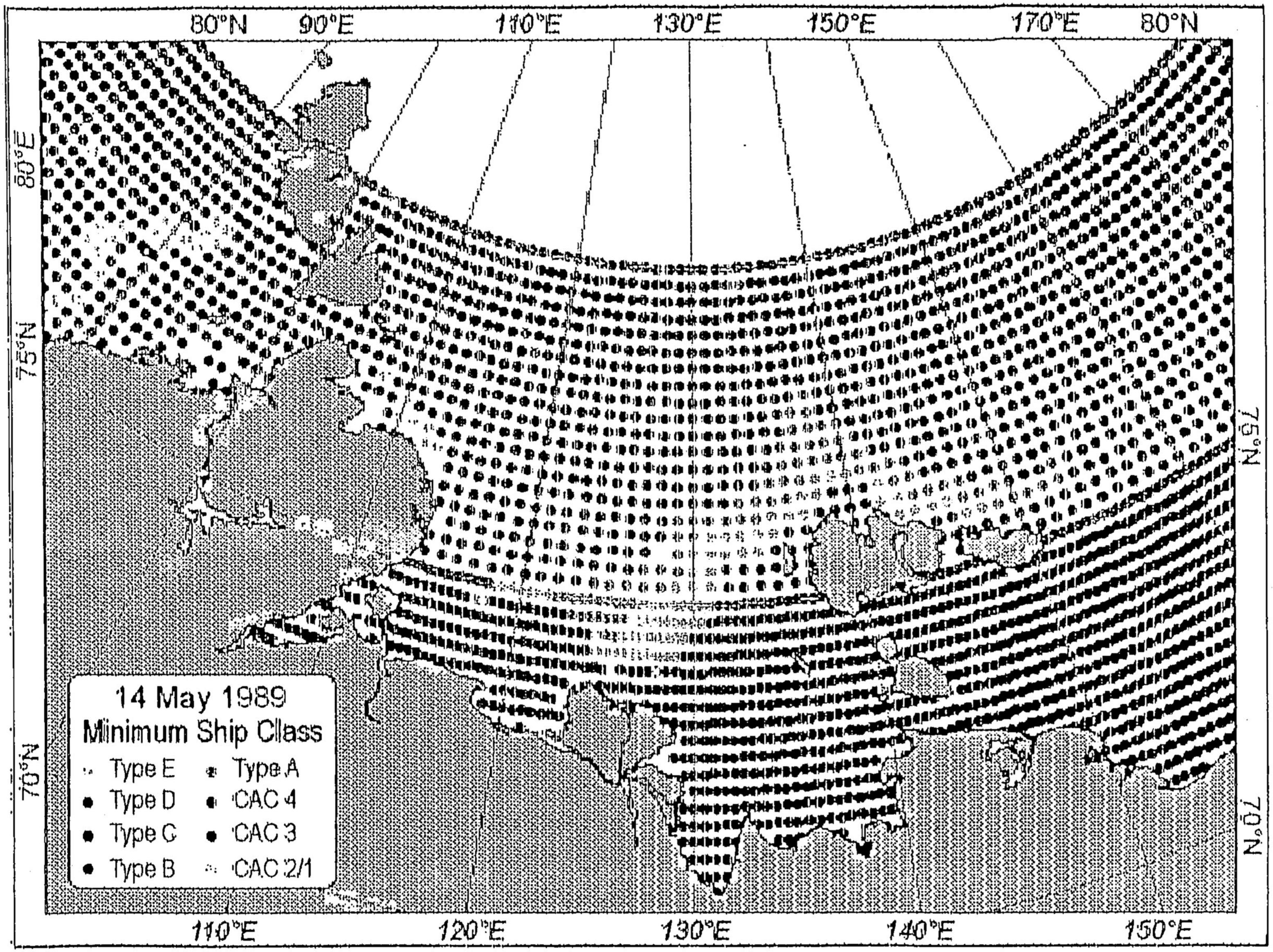
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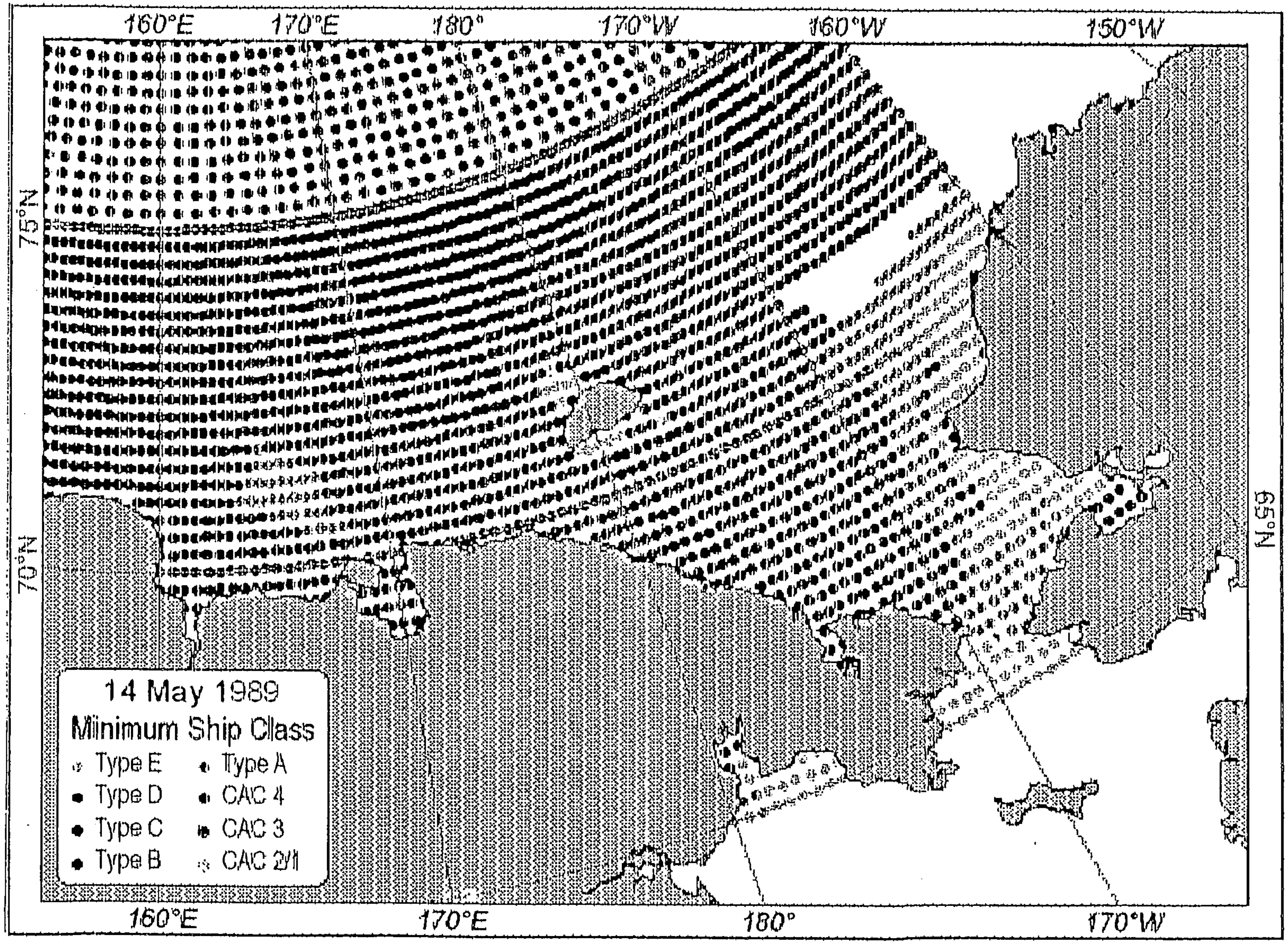
CAC 3
Type B
CAC 2/1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CAC 2/1

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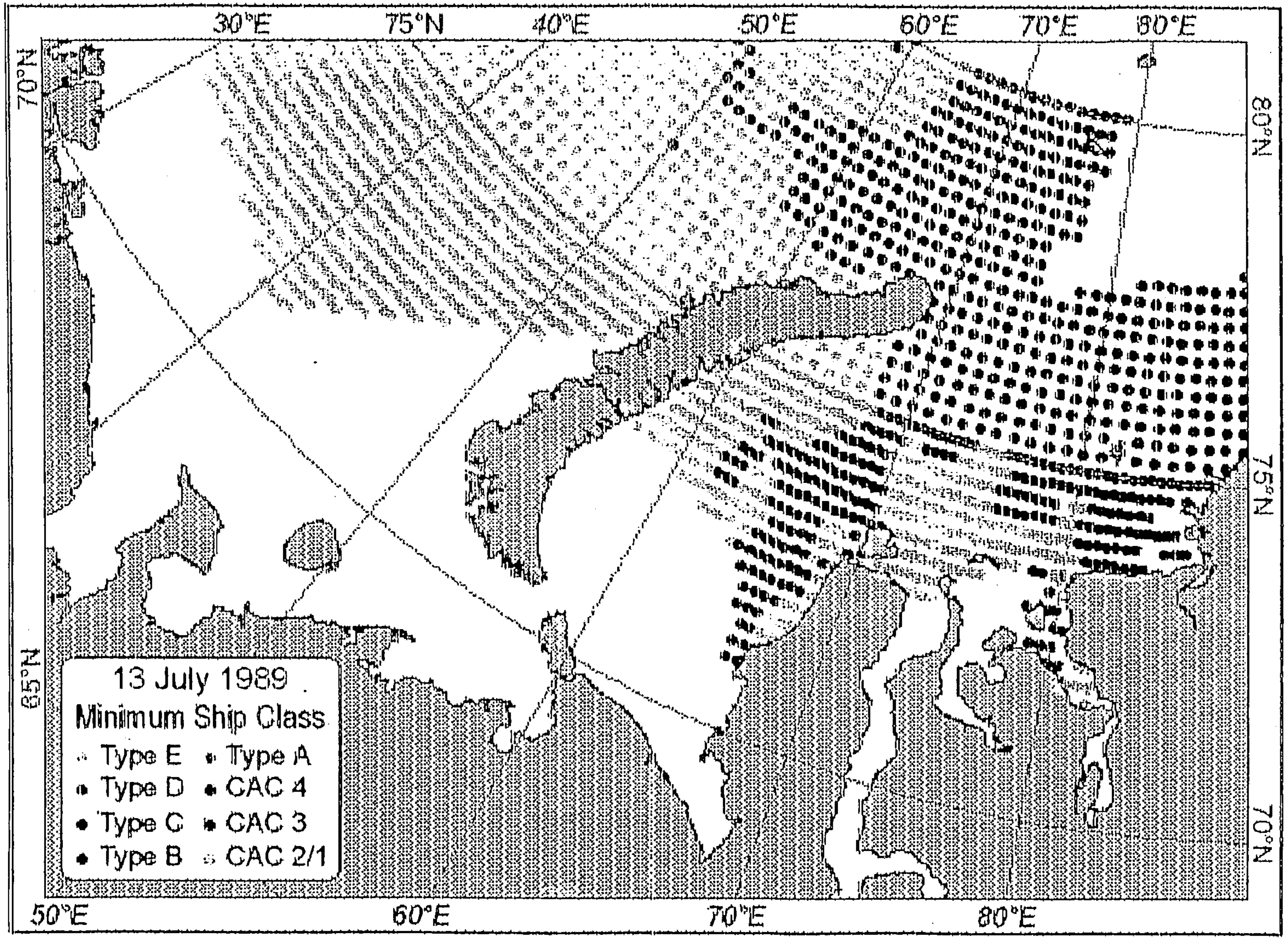
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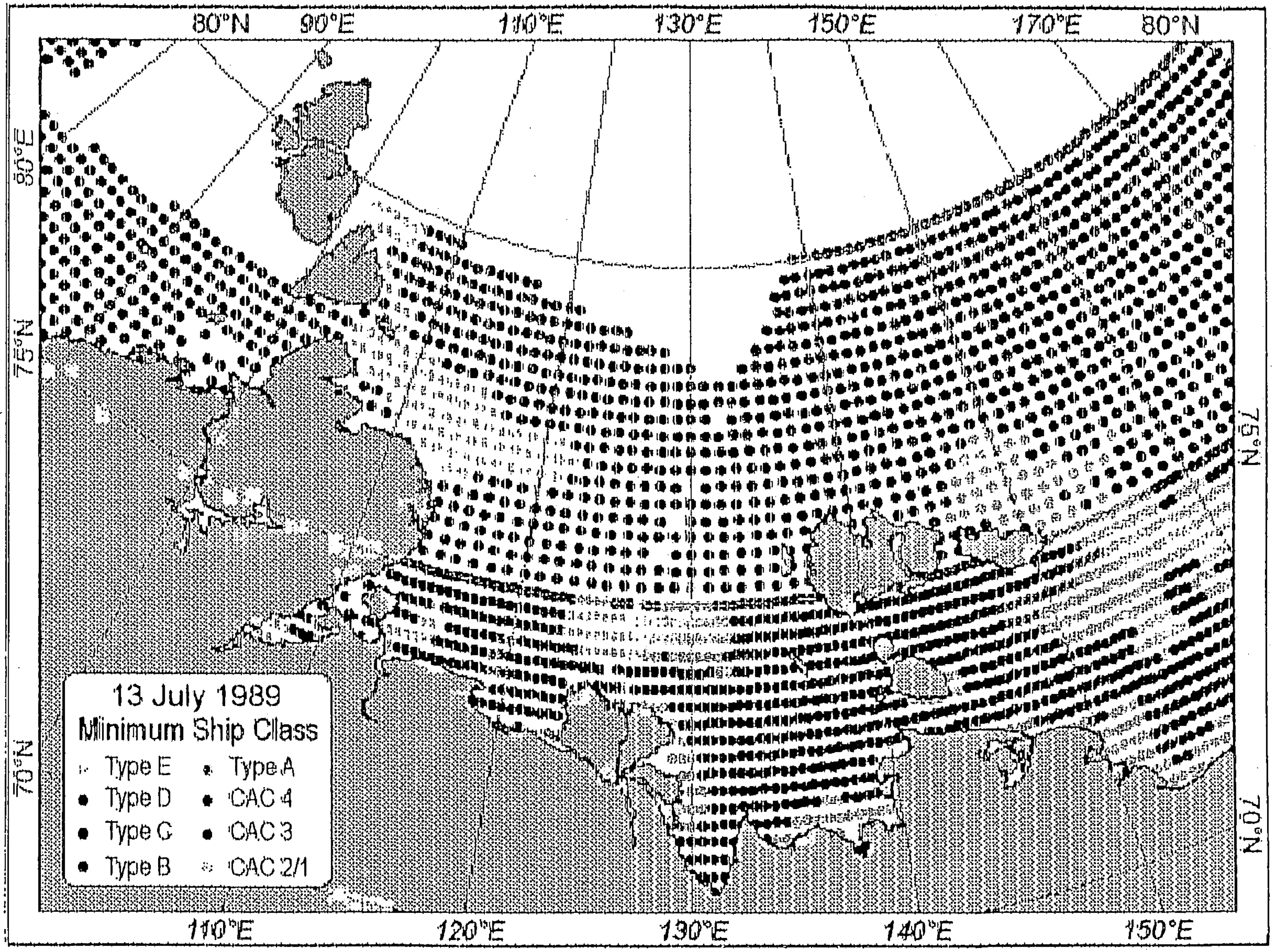
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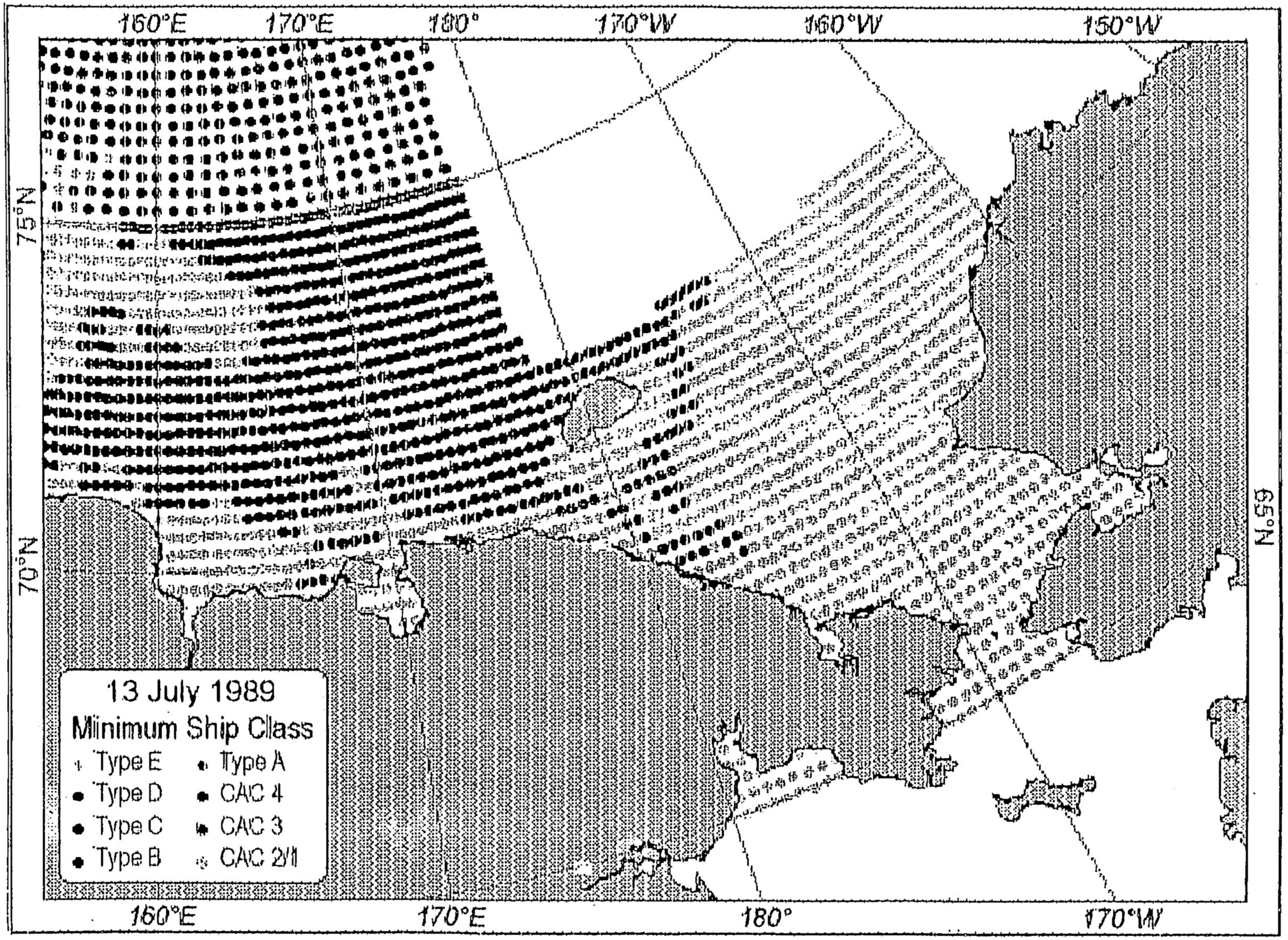
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CAC 2/1
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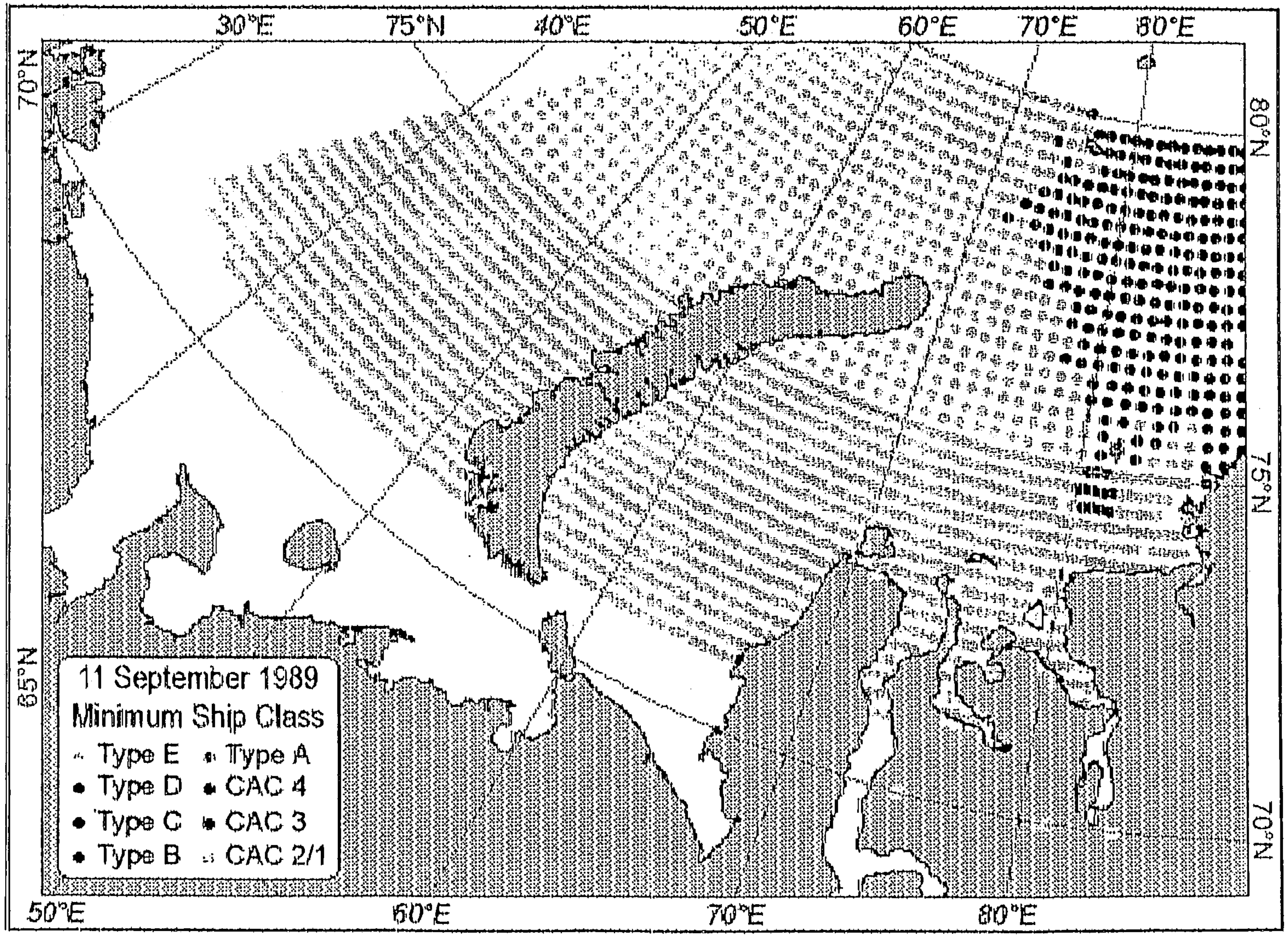
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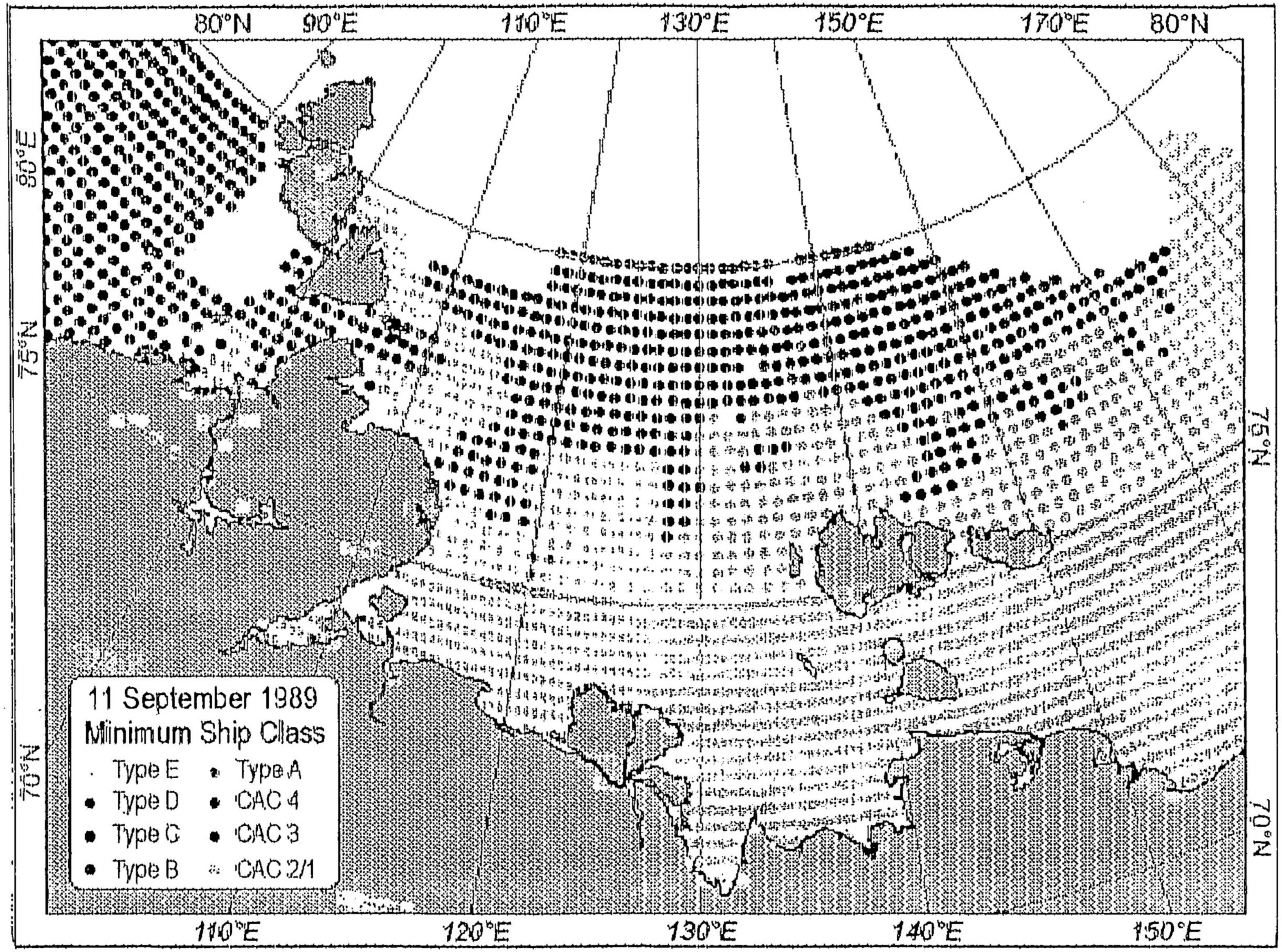

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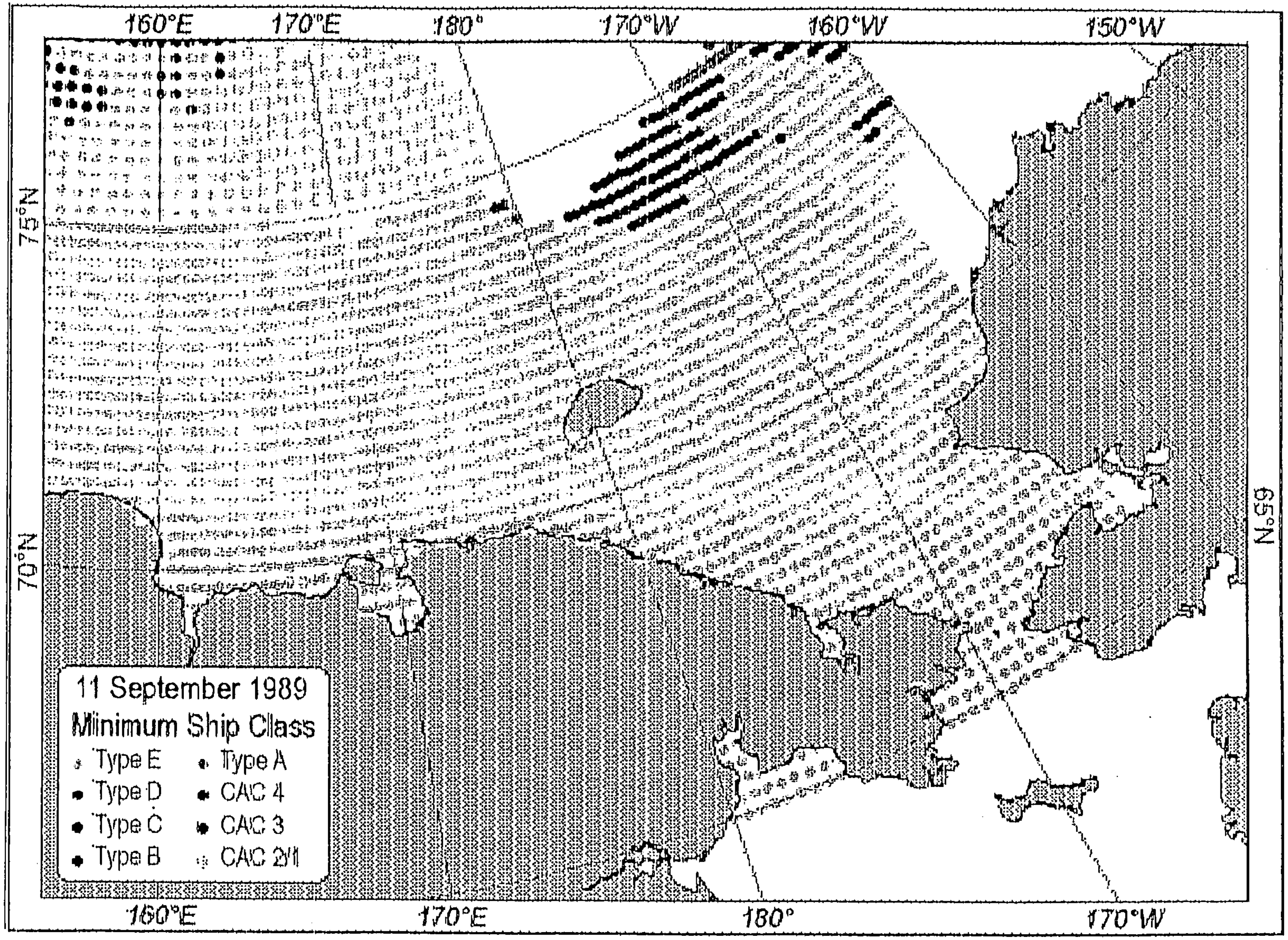
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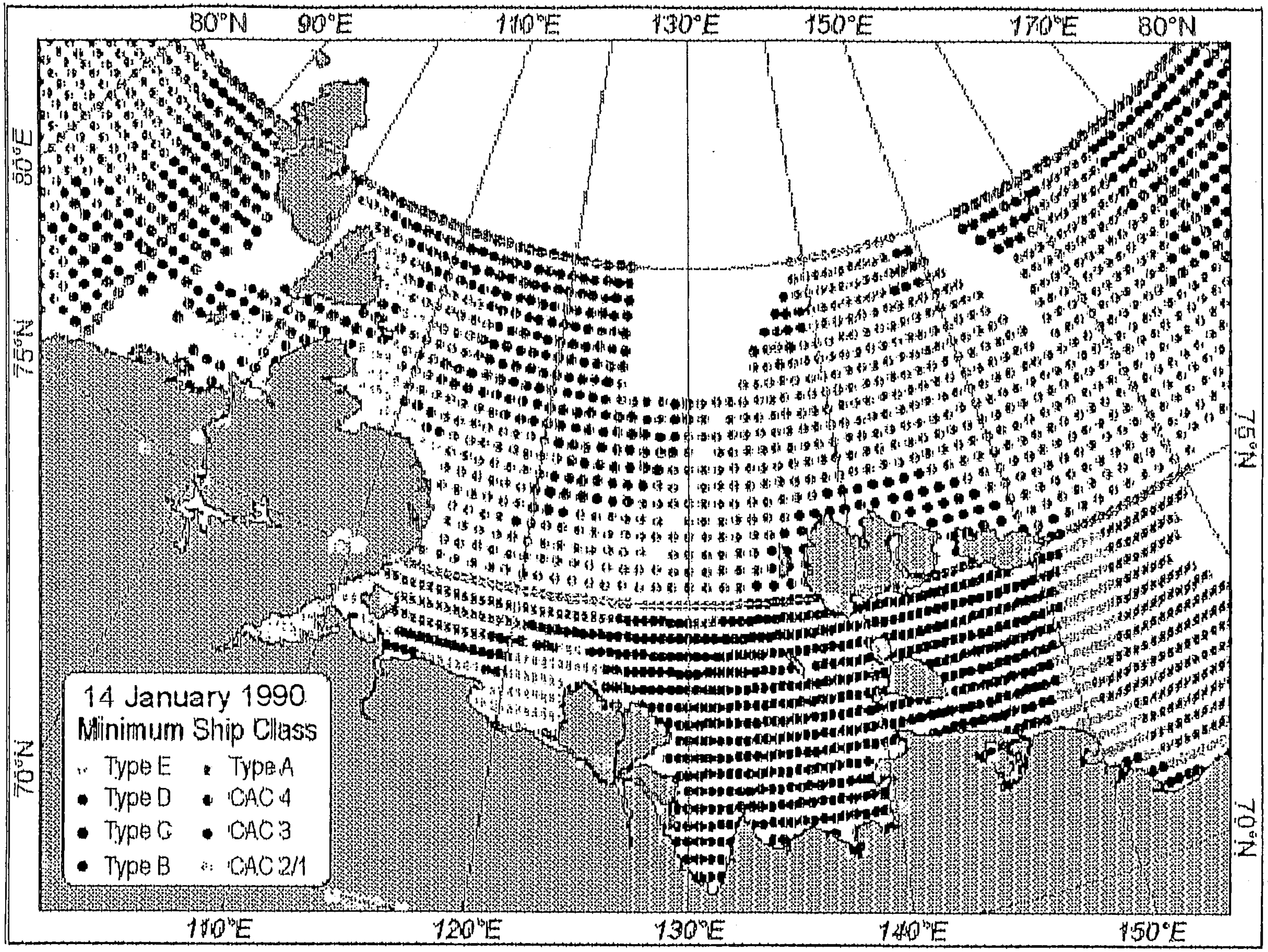
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CAC 2/1

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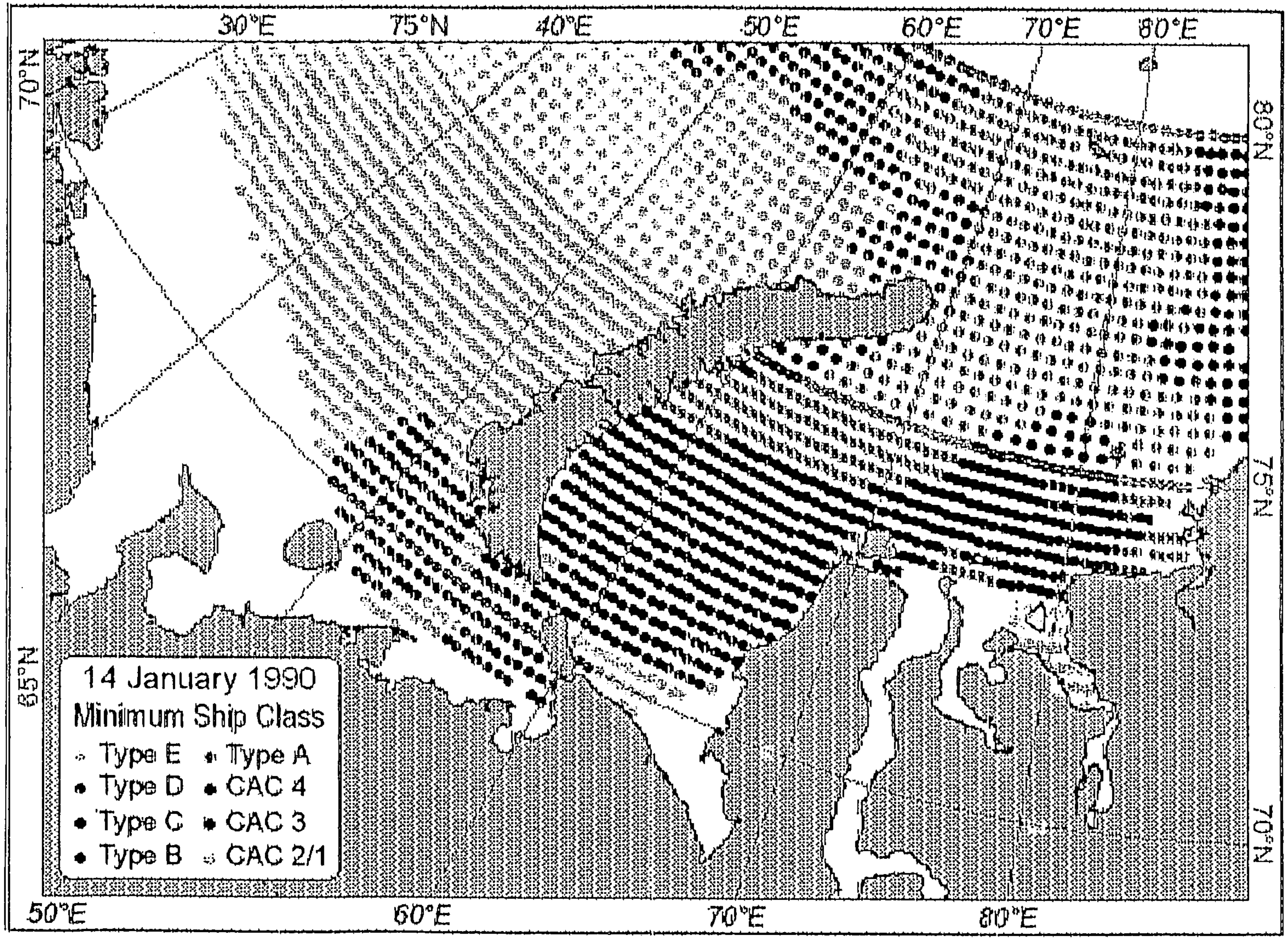
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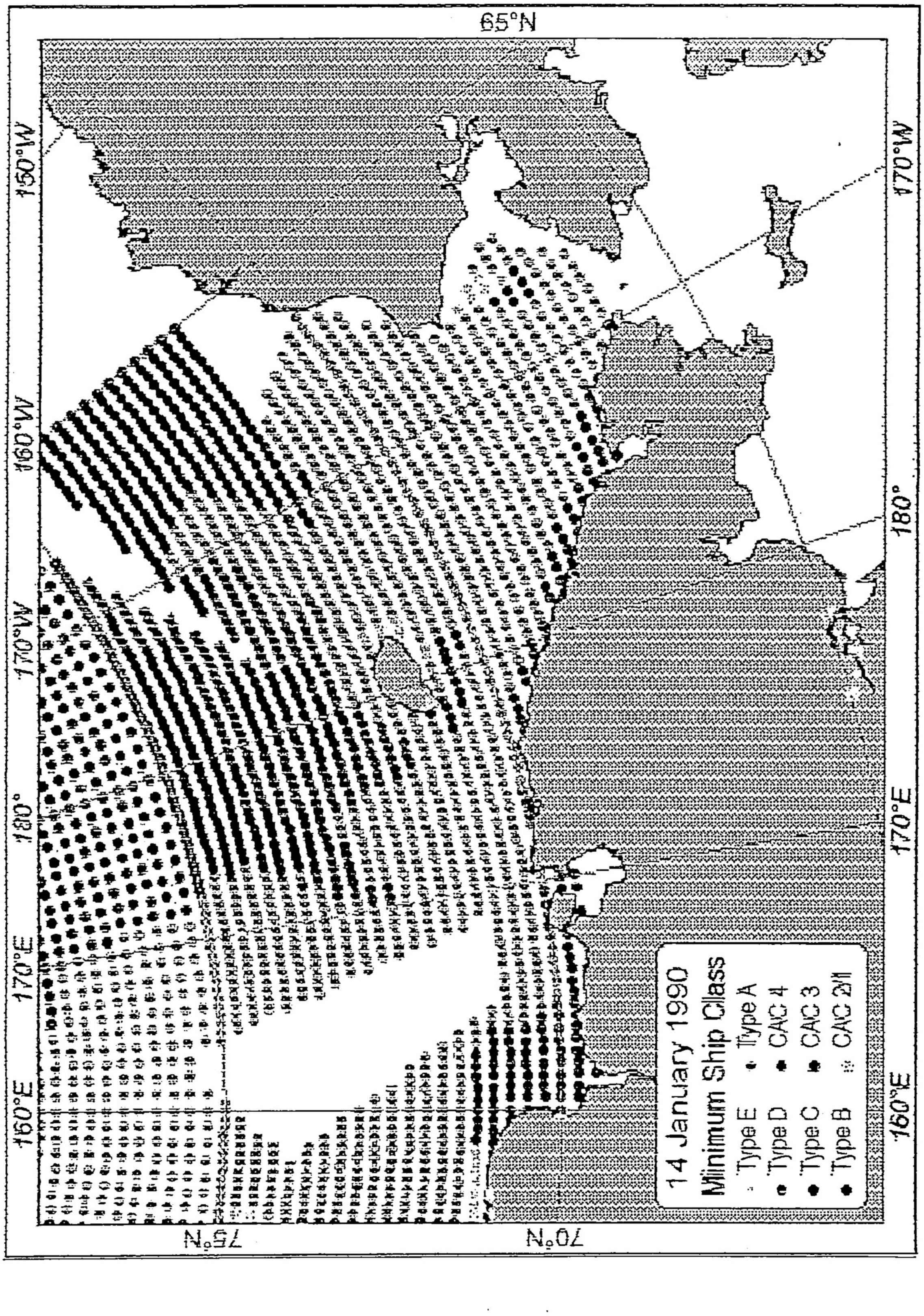
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CAC 2/1
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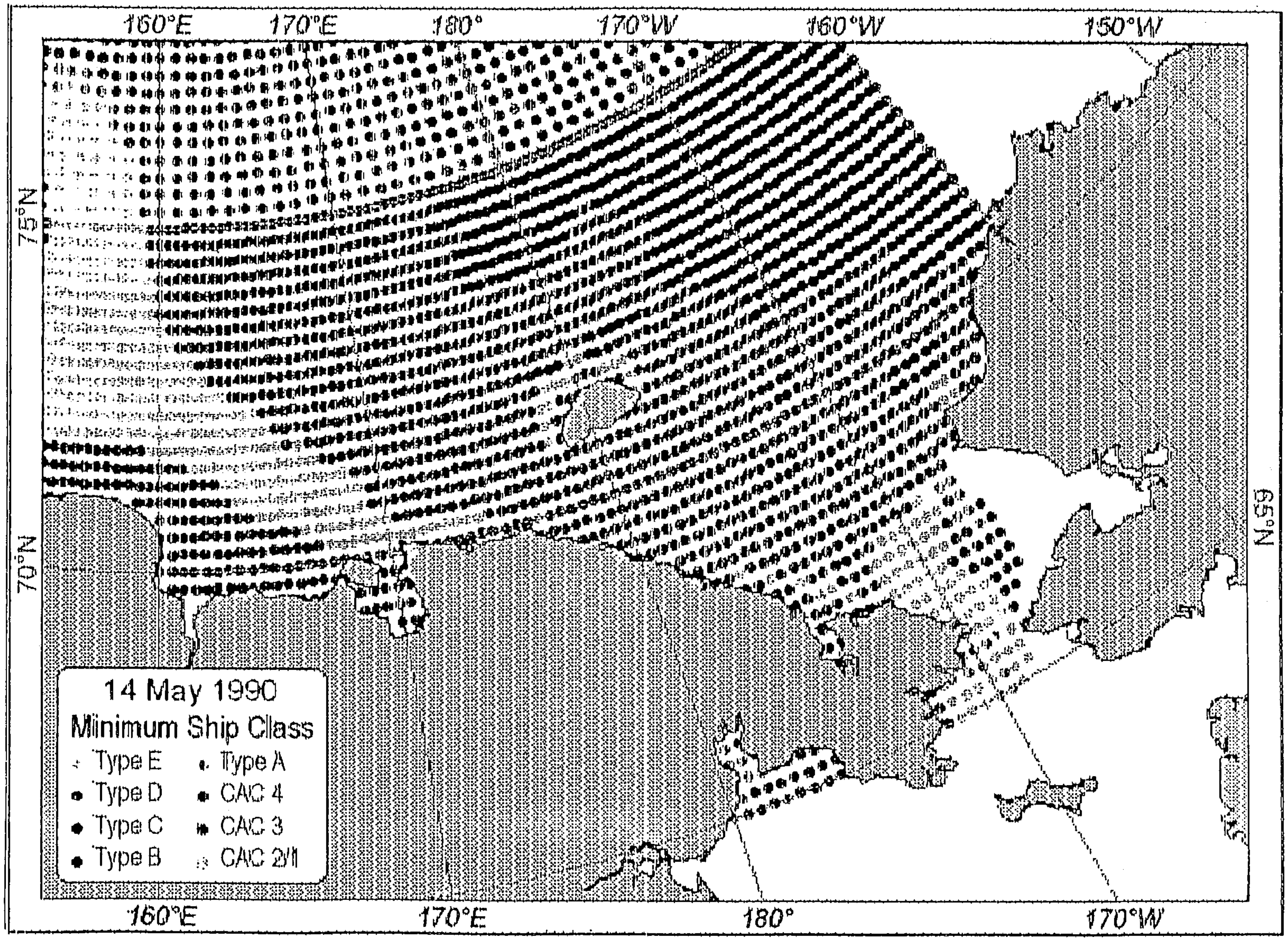
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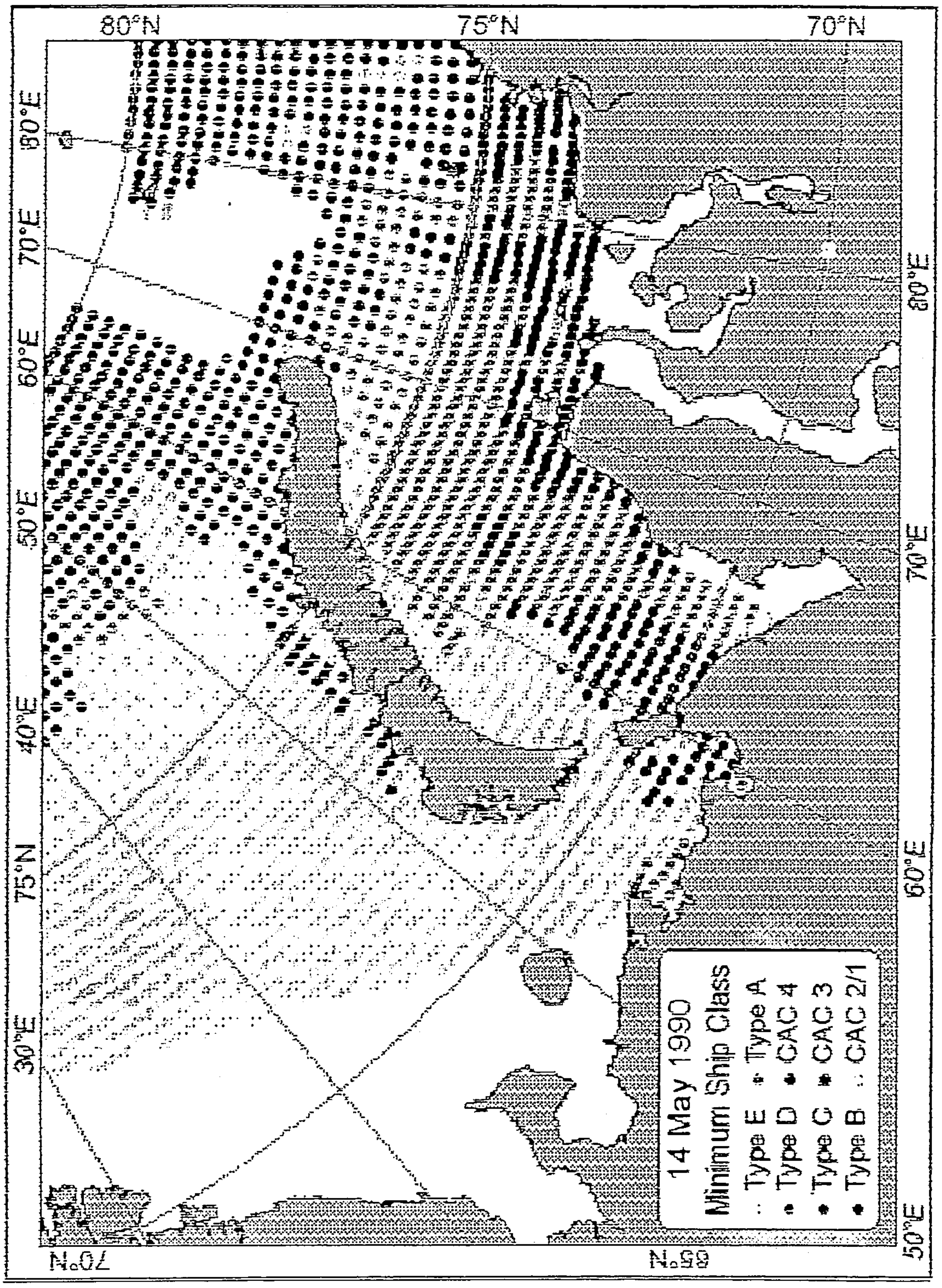
CAC 2/1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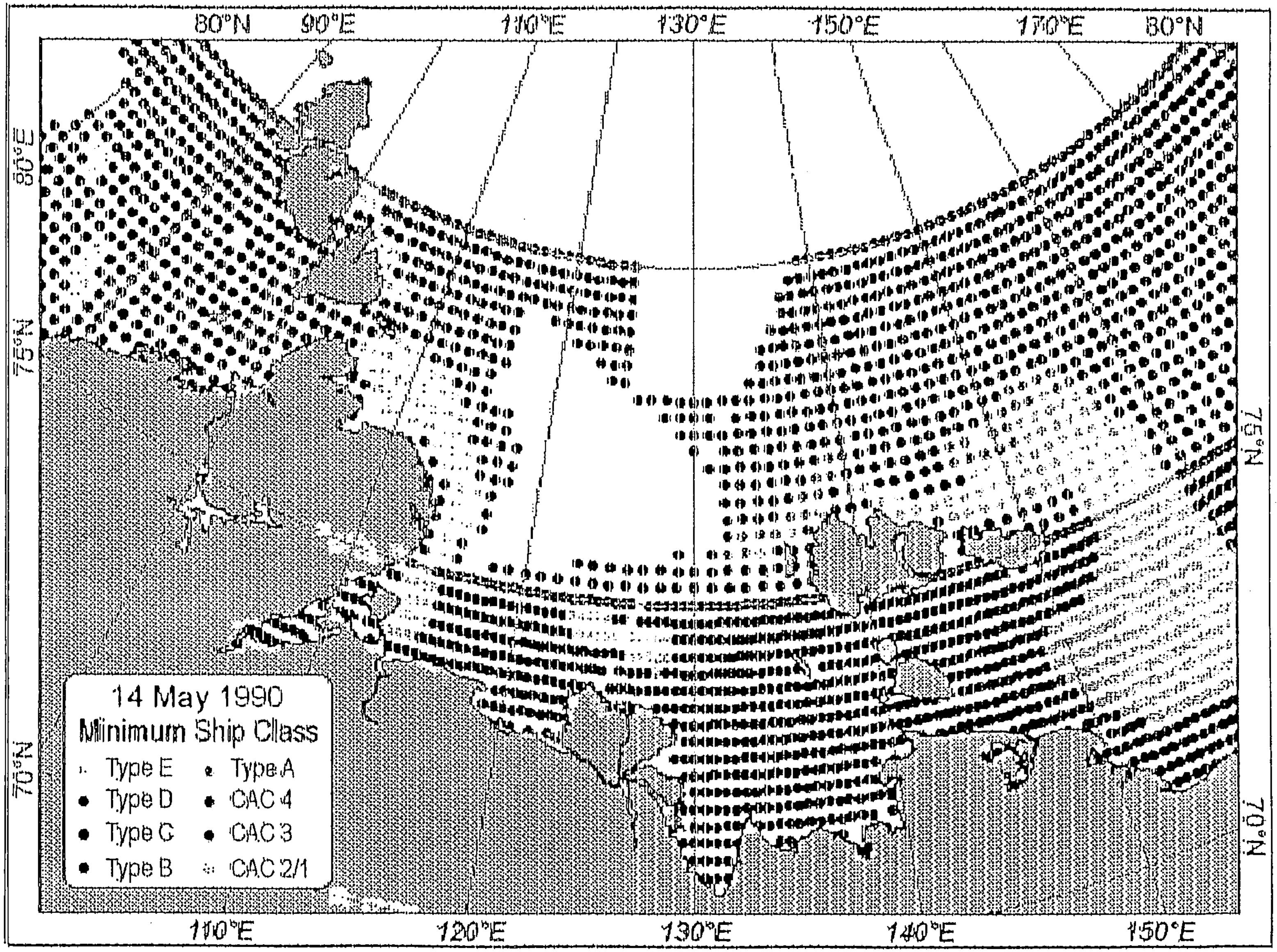
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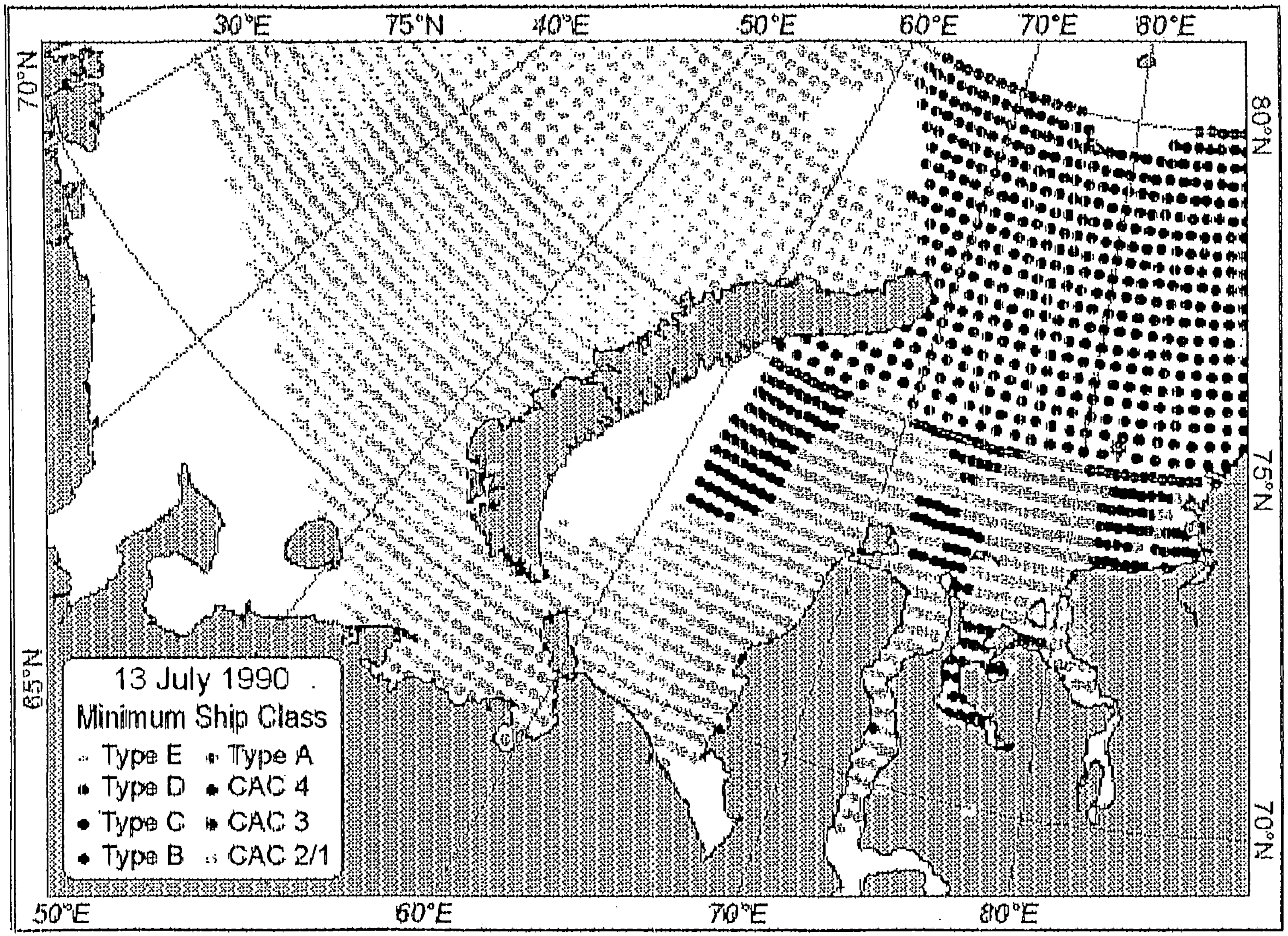
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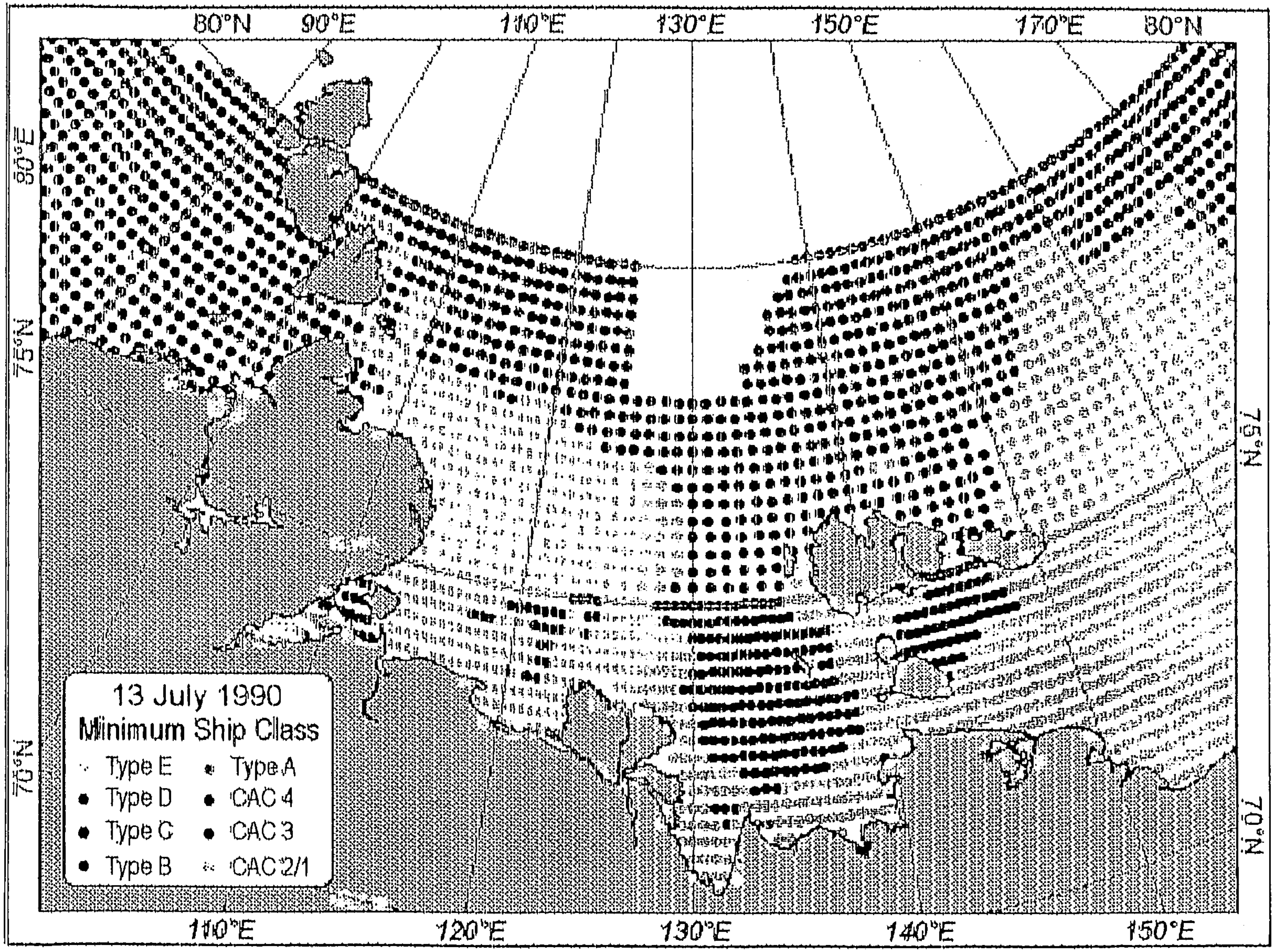
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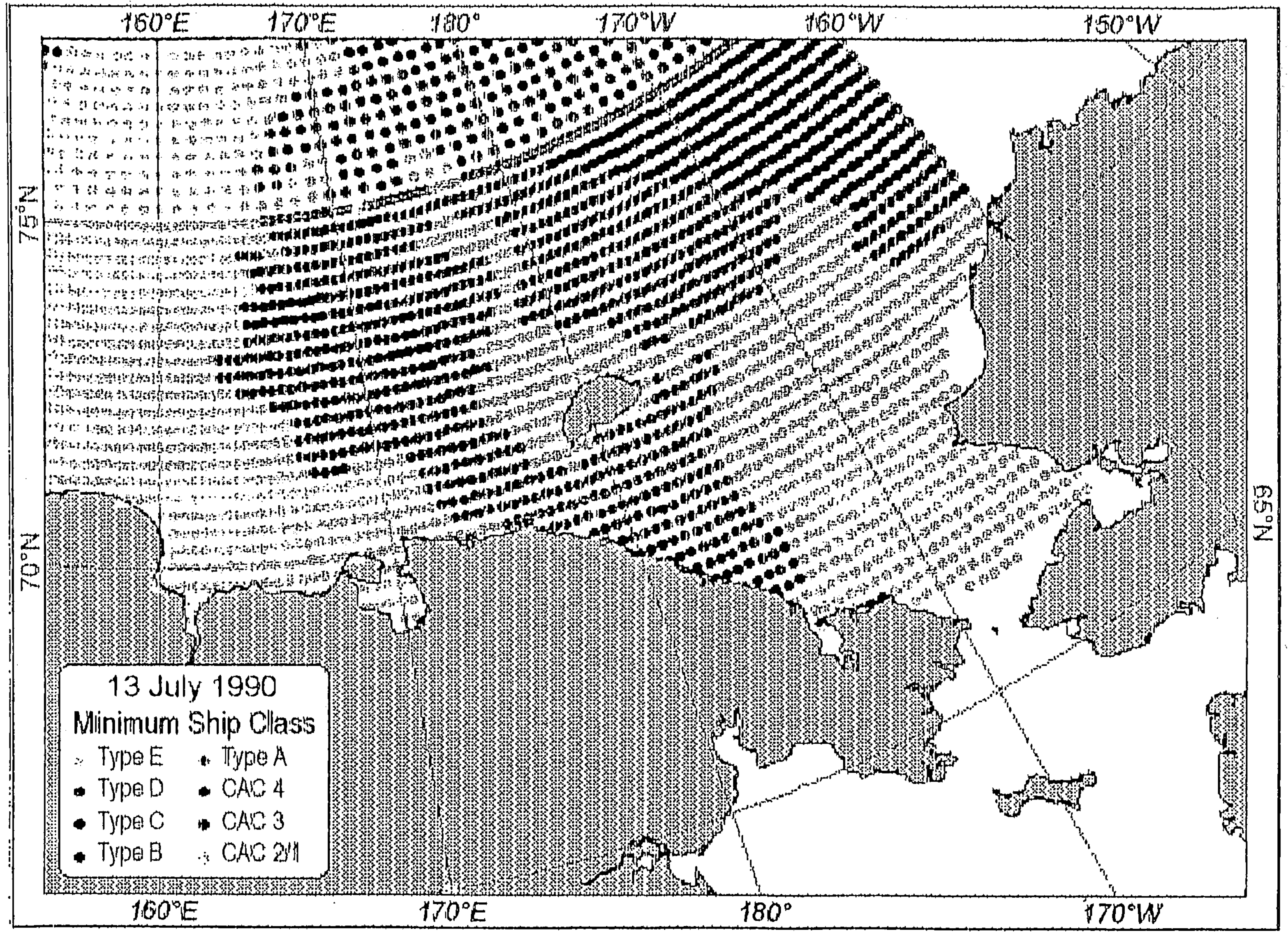
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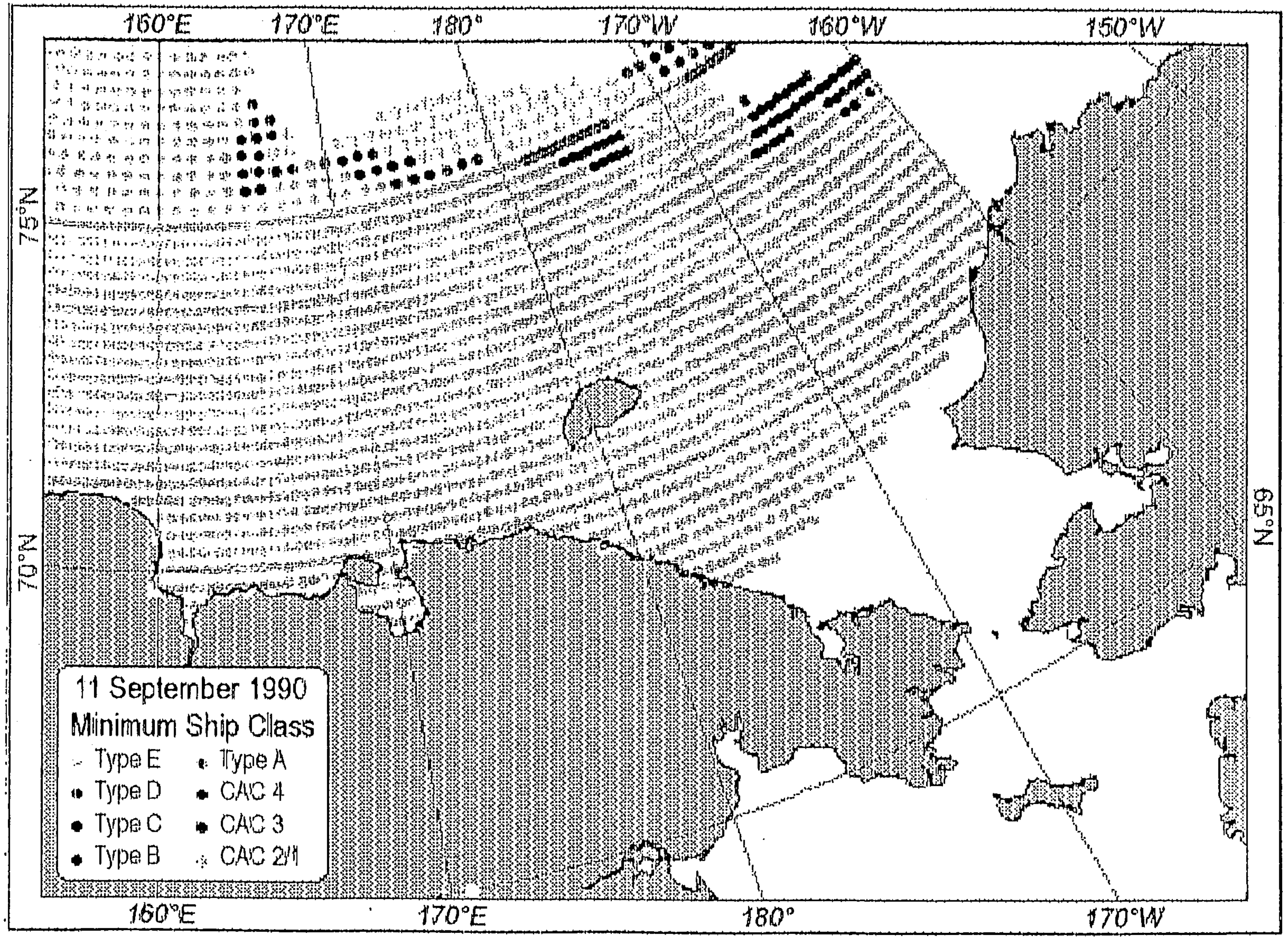
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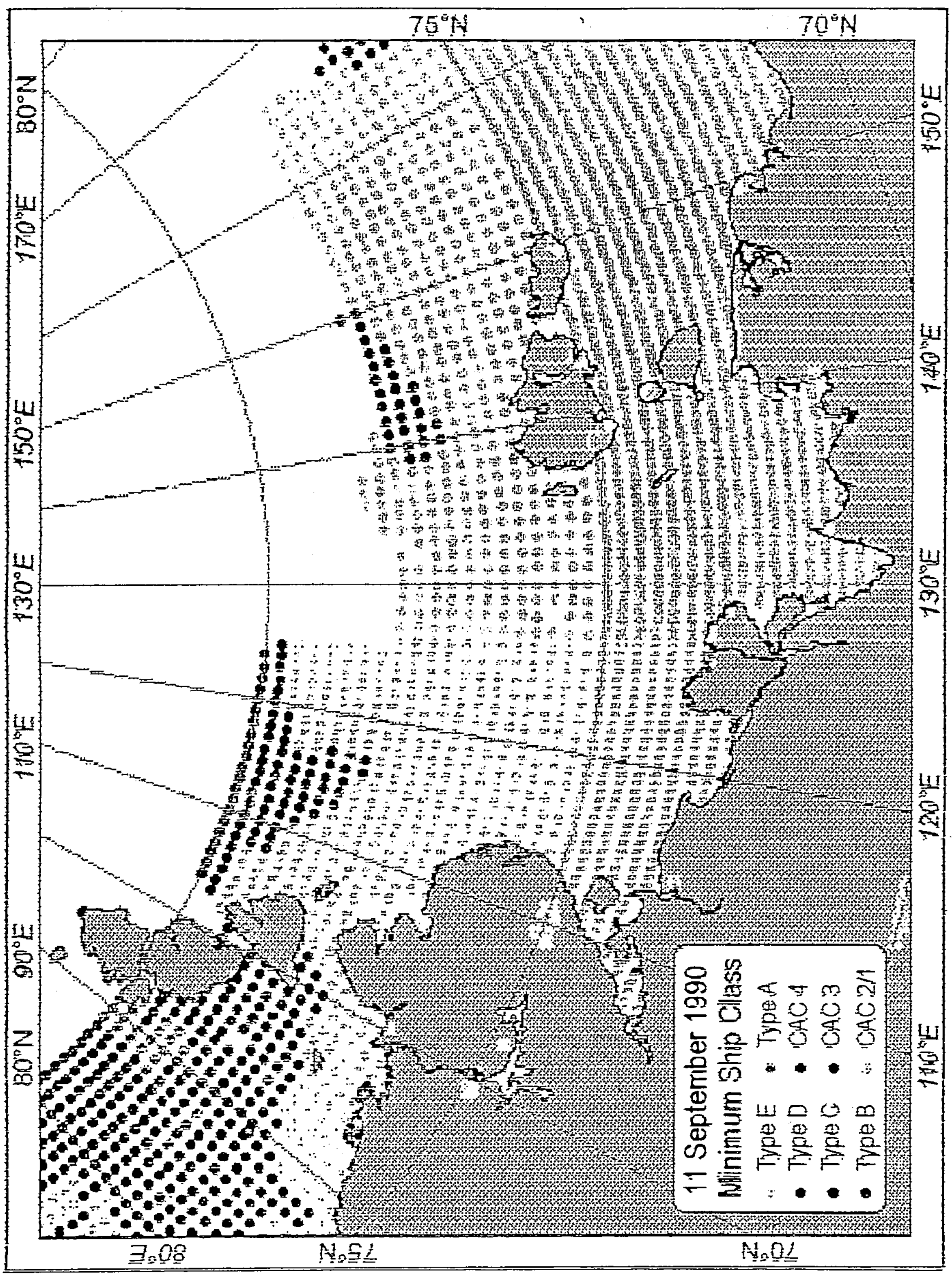
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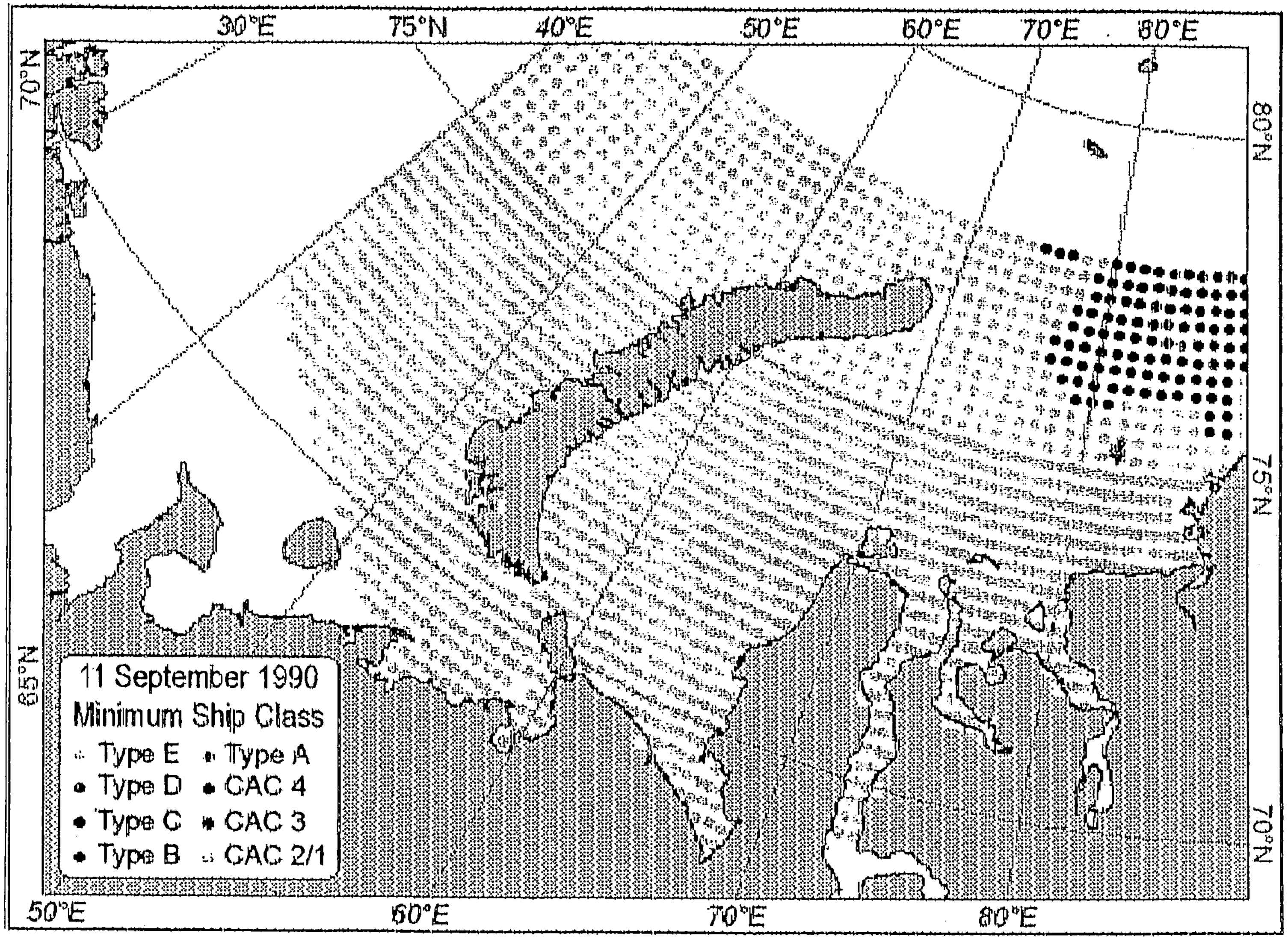
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70°E
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CAC 2/1

EVALUATION OF THE NORTHERN SEA ROUTE USING THE ICE REGIME SHIPPING CONTROL SYSTEM

NRC-IMD Report CR-1995-11

Review by **Peter Wadhams**

This is, on the whole, a good report on the application of an excellent system (IRSCC) to a new region, with very fruitful results. The IRSCC system has the two virtues of simplicity and of the possibility of future updating and refinement based on further observations and measurements of ship behaviour in ice. As more data are obtained, both the numerals and the multipliers may be changed, and it may also be possible eventually to go to a higher level of exactness (one place of decimals instead of whole numbers?). The basis of the system seems very sound: the only usage which I might query is that even in the most heavily ridged ice (shear zone of East Siberian Sea, comparable with the Alaska shear zone or the offshore zone north of Ellesmere Island) it is only possible to add one to the multiplier to account for the increased navigational difficulties. I really hope that the IRSCC system is widely adopted for the analysis of NSR conditions, as it seems just the right way to go.

The thing which I was looking forward to, but found missing, was an example of just how a data point for the maps was generated. I can understand the procedure, but it would have been good to have been shown a Russian ice chart so that we could see for ourselves how the data are coded on such charts, what kind of additional interpretation or "personal equation" is needed on the part of the analyst, and thus how the charts of Appendix B are generated. What kind of locational precision do the Russian charts give us, for instance - plus or minus one pixel, or more, or less? Do the Russian charts contain ice information which is not used, but which might be useful in a refinement of the system? Or are the charts to some extent inadequate, as the report suggests, so that supplementary sources must be consulted on such components as brash or decayed ice? It may be that the anonymous authors of the report are embarrassed about revealing the creaky-looking steps used in manual analysis: there is no need to be, since I think that deriving statistical conclusions from manual analysis of ice charts is perfectly OK (in fact I did it myself in a paper that I gave at ISOPE'95!).

Minor point: It is important to get spelling correct on maps. On fig. 2.2 "Severnaya" is spelt wrongly and on fig. 2.3 "Wrangel Island" is mis-spelt in a fairly blatant way (also on p.21). There are also various other spellings in use for the anglicised version of "Wilkitski Strait" (fig. 2.2). I believe that there exists a directory of preferred anglicised spellings of Russian place names; I can check up when I get back to Cambridge. If these maps are to be used widely within the NSR community there should be agreement on how the principal geographical features of the NSR are to be spelt.

Also, the first page of Appendix A has been photocopied badly in my copy, with partial obliteration of "Shipping Pollution Prevention Regulations".

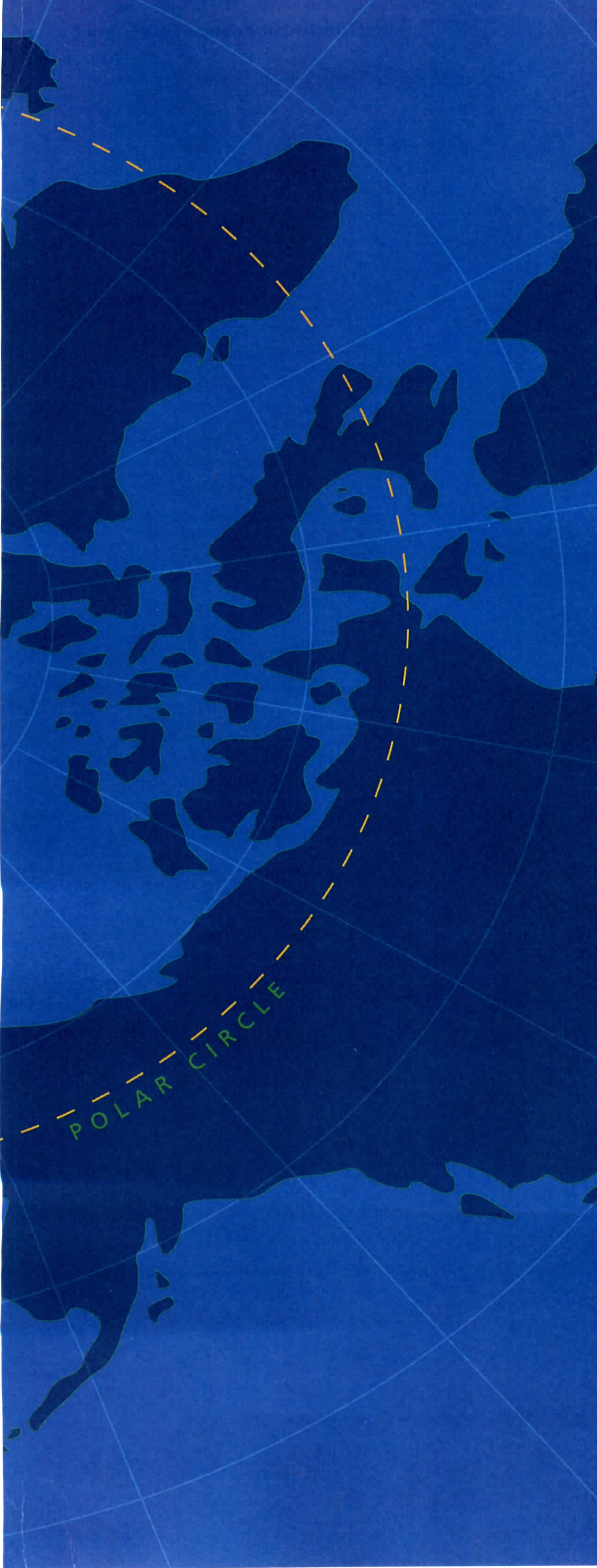
EVALUATION OF THE NORTHERN SEA ROUTE USING THE ICE REGIME SHIPPING CONTROL SYSTEM

Response to review by **Peter Wadhams, Scott Polar Research Institute, Cambridge, England.**

We thank Peter Wadhams for his review of our report, and hope, as he does, that future work will improve our first attempts. One area for study is definitely the effect of ship velocity on the calculation of an ice numeral.

In this version we have corrected the spelling mistakes pointed out by Dr. Wadhams.

There is always a certain amount of subjective judgement necessary when judging ice conditions. The location precision of the Russian ice charts was about ± 1 pixel, and they were deficient in that they did not contain information on ridging, the amount of brash ice, or the state of decay.



The three main cooperating institutions of INSROP

Ship & Ocean Foundation (SOF), Tokyo, Japan.
SOF was established in 1975 as a non-profit organization to advance modernization and rationalization of Japan's shipbuilding and related industries, and to give assistance to non-profit organizations associated with these industries. SOF is provided with operation funds by the Sasakawa Foundation, the world's largest foundation operated with revenue from motorboat racing. An integral part of SOF, the Tsukuba Institute, carries out experimental research into ocean environment protection and ocean development.

Central Marine Research & Design Institute (CNIIMF), St. Petersburg, Russia.
CNIIMF was founded in 1929. The institute's research focus is applied and technological with four main goals: the improvment of merchant fleet efficiency; shipping safety; technical development of the merchant fleet; and design support for future fleet development. CNIIMF was a Russian state institution up to 1993, when it was converted into a stock-holding company.

The Fridtjof Nansen Institute (FNI), Lysaker, Norway.
FNI was founded in 1958 and is based at Polhøgda, the home of Fridtjof Nansen, famous Norwegian polar explorer, scientist, humanist and statesman. The institute spesializes in applied social science research, with special focus on international resource and environmental management. In addition to INSROP, the research is organized in six integrated programmes. Typical of FNI research is a multi-disciplinary approach, entailing extensive cooperation with other research institutions both at home and abroad. The INSROP Secretariat is located at FNI.