EVIDENCE OF SEA ICE CONDITIONS IN HUDSON STRAIT, 1751-1870, USING SHIPS' LOGS

by

MARCIA-ANNE FAURER

A thesis presented to the Faculty
of Graduate Studies
University of Manitoba

In partial fulfilment of
the requirements for the degree
Master of Arts

Department of Geography
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ABSTRACT

The Hudson's Bay Company Archives contains a collection of log books from the Company's ships engaged in the fur trade in the past 200 years. The collection commences with the voyages made in 1751 and continues into the 20th Century. Log books are available for every year in that period with the exceptions of 1839, 1840, and 1841. These logs are used to study temporal and spatial variations in sea ice conditions in Hudson Strait for the period 1751-1870. The study focuses upon Hudson Strait since this area provides optimum circumstances in terms of the obstructive nature of sea ice, and the ease of establishing the locations, and patterns of navigation of the ships.

The method used to derive ice data is based upon references in the log books to ships being enclosed by ice and the activities employed to navigate through the ice, as well as the durations of the voyages.

Correlation coefficients are calculated to determine the extent of the relationships between the variables. The frequencies of the occurence of the activities, and the durations of the voyages are plotted graphically, and cartographically to illustrate relative amounts of sea ice, both temporally and spatially.

CHAPTER I

INTRODUCTION

There currently exists virtually no scientific information pertaining to the environmental conditions which prevailed in Hudson Strait in the historical past. The research presented here will identify and analyze a data source which is able to significantly remedy this deficiency. The Hudson's Bay Company's Archives house a wealth of heretofore unused information regarding the environment of Hudson Strait in the period 1751 to 1870. This exists in the log books of the Company's trading ships.

By examining the contents of these log books, this thesis will attempt to fulfill a twofold purpose. The most fundamental aim will be to derive a methodology whereby the contents of the logs can be made to yield information about the severity of sea ice in Hudson Strait for the 18th and 19th centuries. This method will then be applied in an attempt to determine the fluctuations of sea ice both annually and spatially within the Strait.

The approach to be taken in the development of a methodology hinges upon the hypothesis from which this thesis stems. The hypothesis states that, if the navigation of the ships was influenced by sea ice in Hudson Strait, then certain navigational practices may yield evidence of sea ice.

One main limitation was foreseen and this is related to the nature of the data rather than to the hypothesis. A method of validation of the sea ice information derived in this study has not yet been identified. The results must therefore be interpreted as relative, not absolute indices of ice conditions.

While it is important to note the limitations of the research at this stage, it is equally important to identify its strengths. The limitation described above pales beside the strengths inherent in this source of data. The log books are comparatively uniform in their content and format since they were all kept by employees of the Hudson's Bay Company. In addition, because the Company had a rule to the effect that its ships should leave England at the same general time each year, their arrivals at Hudson Strait were also at approximately the same time of year. A further factor which adds to the homogeneity of the log books arose from the fact that the winds and currents carried the ice to the south shore. As a result, the ships followed essentially the same route through the Strait annually, and therefore, the same landmarks in the Strait were referred to throughout the entire 120-year period. All of these factors combine to create a source of data which has a high degree of homogeneity, and is therefore well-suited to systematic study.

In addition to these advantages is the fact that the Hudson's Bay Company usually dispatched a convoy of ships from England thereby providing more than one log book each year. Further additions to the collection are also frequently available since more than one crew member generally kept a log book on a ship. Consequently, a choice of log books, a means of cross-checking, and of filling gaps exist in most years.

1) REVIEW OF PERTINENT LITERATURE

Whereas much work has been done regarding the interpretation of the historical evidence of climatic change, there is virtually no literature directly related to the use of ships' log books in the study of historical sea ice conditions. Much of the research which has been conducted in the field of historical climatology in general, has been confined to land-based observations either in the form of weather journals or diaries, or in the form of other documentary sources the prime concerns of which were not oriented towards the climate.

Historical weather journals appear, at first, to have the obvious advantage of being direct sources of climatic information in a numerical form. While these sources have some uses, they are however, fraught with many disadvantages arising from a lack of standardization of the instruments and observational practices. As Lamb points out:

> "Use of the early observations for comparative studies involves many problems of antiquated units, different in each country, antiquated instrument scales, the actual performance of the instruments, and how they were exposed."
>
> (1974: 42)

These problems can be dealt with, but not without considerable work and speculation. This was made clear in the research conducted by Manley (1946) on the temperature trends from 1753 to 1945 in Lancashire, England. In this study, Manley was confronted with several documents containing temperature records of varying durations and degrees of reliability. In order to utilize these data, it was necessary to reduce all of the observations to a common standard in order to homogenise the results. In a later study, Manley (1953) again reduced the observations of several different weather journals in the reconstruction of mean monthly temperatures for central England for the period 1698 to 1952.

Kington (1970) utilized a source of historical weather data for the late 18th century which was much more homogeneous than that used by Manley. These records were kept by the members of the Société Royale de Medecine, to provide a means of ascertaining the relationships between illnesses and epidemics, and the weather and seasons. A degree of standardization of these observations was ensured by the fact that the Société provided instructions for those performing the observations.

> "The first volume of the official history of the Society contains a section on meteorological observations in which it was ensured that standardized and comparable reports would be made by discussing in detail both instrumental equipment and observing technique."
>
> (Kington, 1970: 70)

These records of the Société exist not only for

France, but also for the Low Countries, Italy, Switzerland, and England.

Historical evidence of climatic conditions has also been found in numerous indirect sources, which make incidental references to weather. These sources of data are much more extensive in occurrence than historical weather records and vary widely in their origins and degrees of reliability. Some of the earliest sources are from China and are found in the carvings on oracle bones. These carvings describe harvests, agricultural practices, and predictions of snow and rain for the period 1400 to 1100 BC (Chiao-min Hsieh, 1976). References to natural phenomena in Chinese poetry have also been interpreted, and date back to C.3000 BC (Chiao-min Hsieh, 1976).

In Canada, the longest and most complete source of historical documentary data is contained in the records of the Hudson's Bay Company. MacKay and MacKay (1965) used the journals of the Company's posts to derive dates of freeze-up and break-up of the Churchill and Hayes Rivers for the 18th to the 20th centuries. A subsequent study by Moodie and Catchpole (1975) employed the post journals of Churchill Factory, York Factory, Fort Albany, and Moose Factory in deriving the freeze-up and break-up dates of the four rivers on which these posts were located. They also presented a detailed discussion of the difficulties encountered in defining the terms freeze-up and break-up. A major portion of this study was devoted to the testing of the reliability and validity of the data, which is of importance in any study employing the methods of content analysis.

Any review of the literature pertaining to the historical evidence of climatic change would be incomplete if it ignored the research of LeRoy Ladurie (1971) in which the climate of France since the year 1000 is reconstructed. This study was based primarily on the records of wine harvests with additional information provided by glaciology and pollen studies. The most valuable contribution made by this study is not in its conclusions about the climate per se, but rather in its insights into the methodologies and means of utilizing the data sources which are available.

The scope of the direct and indirect data sources has been well documented. A noted authority in historical climatology, H.H. Lamb has done a considerable amount of work in making known the importance of this type of research, its data sources, and the means of using the data (Lamb, 1974 and 1975). His research culminated in two volumes entitled Climate: Present, Past and Future (1977), the second volume being devoted to "Climatic history and the future". This volume combines the work of numerous researchers, data sources, and methodologies in describing global climates since the Quaternary ice ages.

This is by no means an exhaustive review of the literature in this field but is a brief summary of the more noteworthy studies. A large proportion of the remaining literature has been discussed by Lamb (1977).

It is apparent from the foregoing discussion that the role of historical evidence of climatic change in general is well documented. However, there have been very few studies relating specifically to historical sources of sea ice data, or to the use of ships' log books.

Much of the previous research into historical sea ice conditions has been done in

Iceland, and published in Icelandic. One of the Icelandic studies, by Fridriksson (1969) examines "The Effects of Sea Ice on Flora, Fauna, and Agriculture" in Iceland since the last ice age, but is not based on documentary historical evidence. Another Icelandic study which does use historical documents in an examination of sea ice has been done by Bergthórsson (1969), and is often cited as a reliable study of historical sea ice conditions. This research investigates the relationships between drift ice and temperature in Iceland for 1000 years. In this concise report, Bergthorsson not only presents his methodology and conclusions, but also provides a discussion of his data sources and the difficulties arising from them, and how these problems were solved.

An early historical climatological study based on the movements of sailing vessels was undertaken by Privett and Francis (1959). Their data were obtained from Lloyd's Lists, published since 1734, by Lloyd's of London. By using dates of departures and arrivals an attempt was made to "...use the speeds of sailing ships crossing the North Atlantic Ocean during the eighteenth and nineteenth centuries to infer secular variations in the strength of the Trade winds" (1959: 292). Many difficulties were encountered owing mainly to the fact that the actual log books were not used and therefore, the speeds had to be calculated by using the time of passage and the sailing distance.

A recent study by Douglas, Lamb, and Loader (1978) was based, in part, on the contents of log books. This research is concerned specifically with the state of the weather during the voyage of the Spanish Armada. Although a portion of the information was obtained from log book accounts, much of the data were derived from letters and diaries, and were then compared with Tycho Brahe's weather observations in Denmark. The product of this research was the construction of maps depicting the pressure systems from July 22 to October 1 of 1588.

The only known study which uses ships' log books in the analysis of past climates was conducted by Oliver and Kington (1970). This research examined the log books of the Royal Navy which are available for the period 1678 to 1809. By using mainly references to winds, the synoptic conditions for the period were mapped and analyzed. Although the methodology employed was not presented in detail, the discussion regarding the advantages and disadvantages of the log books, as well as the definition of terms used in them, proved to be very useful.

2) PLAN OF THESIS

Chapter II presents a description of the Hudson's Bay Company's log book collection, and discusses the considerations leading to the selection of the data used in this study.

The retrieval of the data and the methodology employed in the analysis of the data are the focus of Chapter III. Some of the difficulties and theoretical problems which were encountered are also given in this chapter.

The results derived in Chapter III are presented in Chapter IV.

CHAPTER II

BACKGROUND INFORMATION AND DATA SELECTION

1. EXTENT OF RECORD AND SURVEY OF LOG BOOK CONTENTS

Contained within the Hudson's Bay Company's Archives are the actual log books of the Company's ships which were engaged in the fur trade and served to supply the posts on Hudson Bay. The earliest log book of this collection dates back to 1751, and the record continues virtually unbroken to 1870. The only gap exists for the years 1839, '40, and '41, therefore the record for the 120-year period is approximately 98% complete. In fact, more than one ship often yielded a log book each year. This serves to increase the number of log books available to 316. The frequency distribution of the numbers of ships yielding logs in each year is given in Table II.1.

One may add to this number of ships per year yielding logs, the fact that quite often more than one person kept a log on each ship. By the addition of these documents, the number of books increases to 485. As a result of this multiplicity of log books, cross-checks are made possible for both a given year, and a given ship. The numbers of ships per year, their names, and destinations

TABLE II.1: FREQUENCY DISTRIBUTION OF SHIPS YIELDING LOG BOOKS PER YEAR

NUMBER OF SHIPS PER YEAR, YIELDING LOGS	NUMBER OF YEARS
0	3
1	4
2	46
3	54
4	12
5	2

(Catchpole and Moodie, 1978:129)

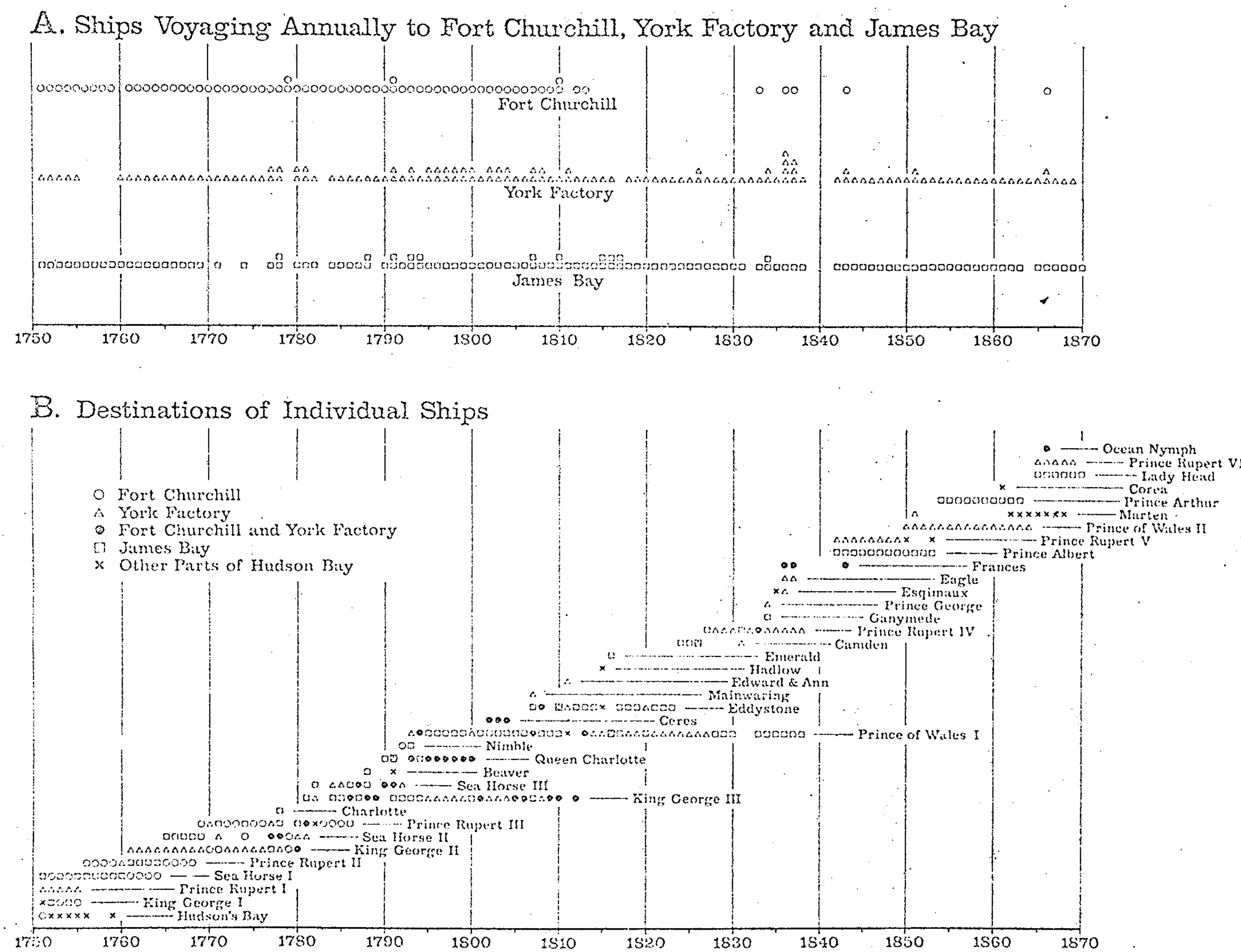
can be seen in Figures II.1 (a) and (b).

Not only are the Hudson's Bay Company log books a valuable data source in terms of their extent and overlap of coverage, but they are also of value with respect to the high degree of uniformity with which the entries were made. This characteristic can be attributed to three fundamental factors.

The first factor arises from the disciplined way of life required of a seaman involved in as hazardous a voyage as was undertaken in the journey from Britain to Hudson Bay, and back. A part of this discipline is evident in the requirements put forth governing the contents of the log books, such that all activities and occurrences of the voyage were to be recorded. This is apparent from the instructions for the keeping of logs that were handed down by the British Admiralty in the eighteenth century:

> "He [the Captain or Commander] is, from the time of his going on board, to keep a Journal, according to the Form set down... and to be careful to note therin all Occurences, viz. Place where the ship is at Noon; changes of wind and weather; salutes with the reasons thereof; remarks on unknown Places; and in general, every Circumstance that concerns the Ship, her Stores, and Provisions."
>
> (Oliver and Kington, 1970 :522)

The second factor leading to the high degree



FIGURES II-1 (a) AND (b)

(From: Catchpole and Moodie, 1978, p.128) of uniformity found amongst the log books is that the ships followed essentially the same route each year, as is illustrated in Figure II.2. There are two reasons for this yearly similarity in the routes, and these are best explained if the voyage is divided into two segments. The first segment constituted the Atlantic crossing, and the second involved the passage through Hudson Strait and into the Bay. Within the first segment, the use of latitudinal navigation necessitated adherence to a particular route. This method of navigation was necessary since it was impossible to determine longitudinal positions accurately before the invention, and widespread use of the chronometer. Therefore, by sailing along an approximately constant line of latitude, the gap between the Orkneys (59°01'N) and Cape Farewell, Greenland (60°00'N) could be fairly accurately bridged. This method of navigation was not infallible (even after the invention of the chronometer) as was evident in the following situation described by Lieutenant Edward Chappell in his narrative of an 1814 voyage:

> "The Victorious had struck on a rock, in latitude 66°21'N, longitude 53°47'W; entirely owing to the coast of Greenland having been laid down four degrees wrong in the Admiralty Charts."
>
> (Chappell, 1970 :37)

The primary reason for the similarities in the routes followed in the second segment of the voyage (through

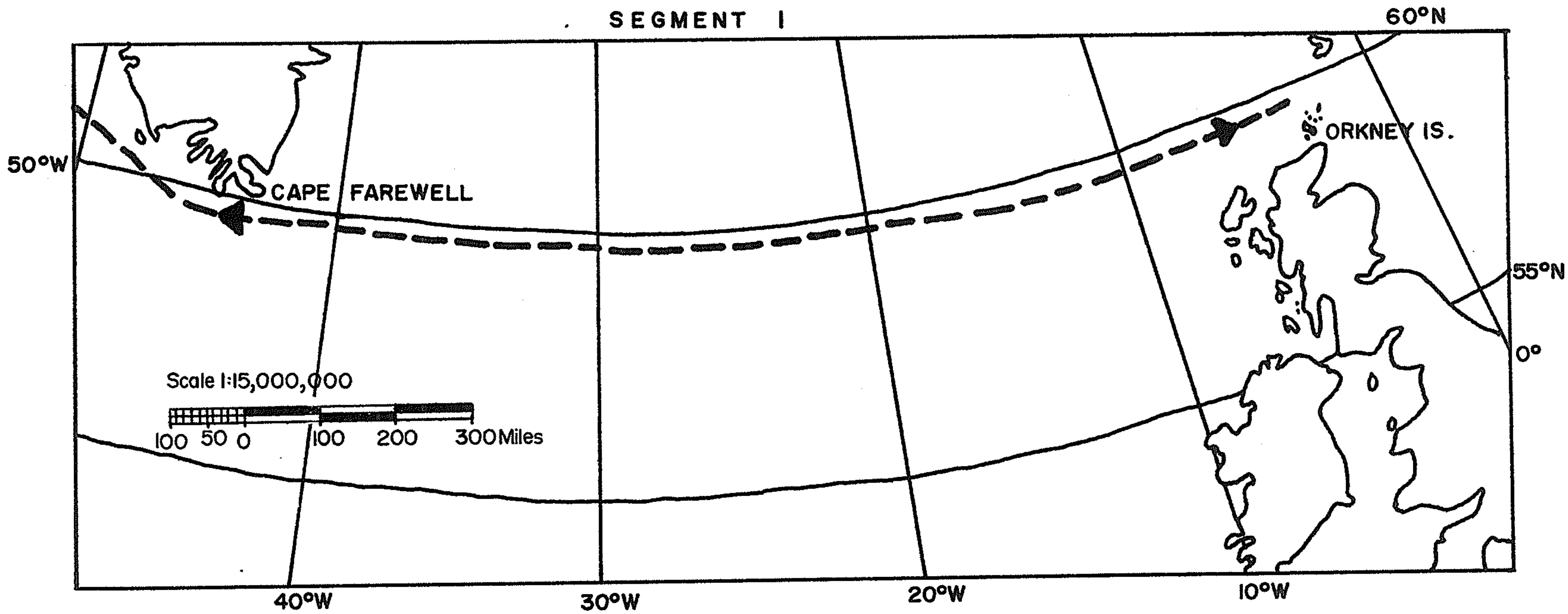
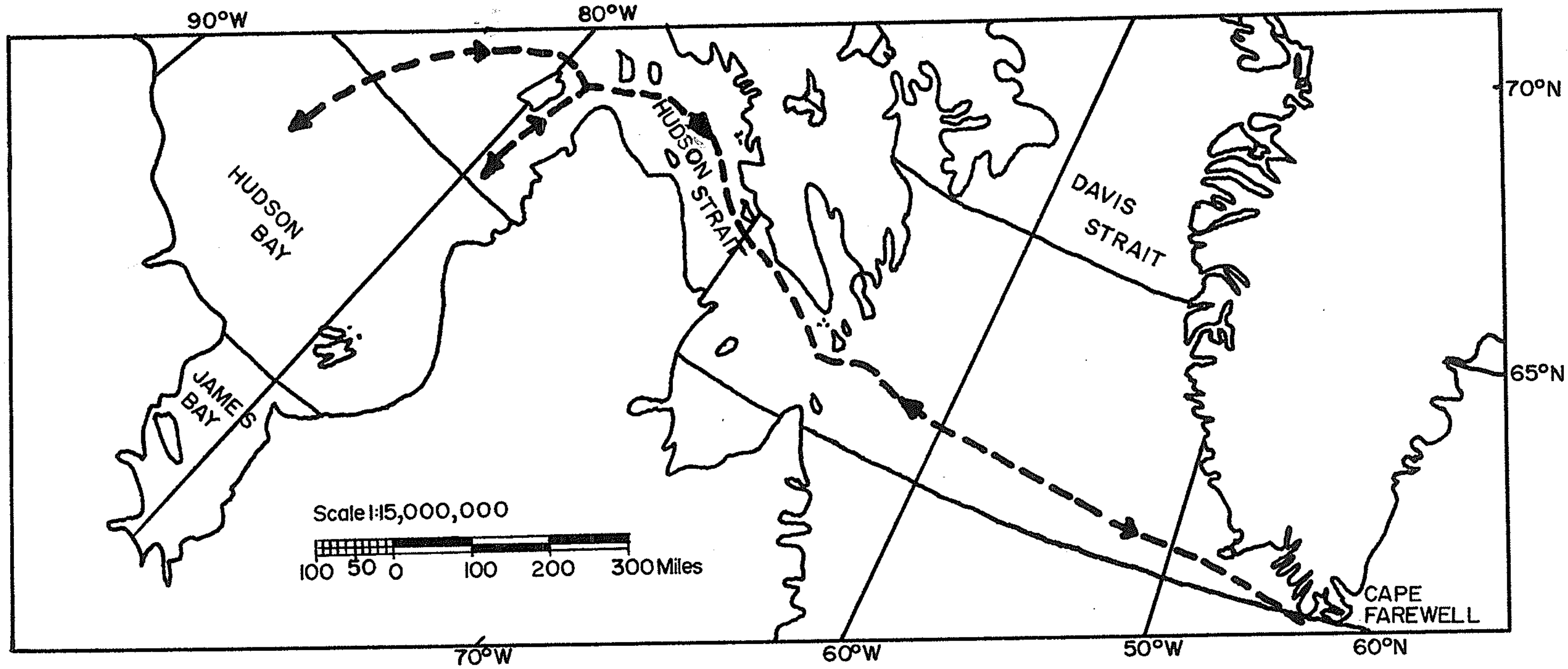


FIGURE II-2 ROUTE BETWEEN ENGLAND AND HUDSON BAY (EASTWARD AND WESTWARD)

FIGURE II-2 (cont'd)

SEGMENT 2



Hudson Strait in particular) is simply the result of the avoidance of ice:

> "Entering HUDSON'S STRAITS, it is a necessary precaution to keep close in with the northern shore; as the currents out of HUDSON'S and DAVIS' STRAITS meet on the south side of the entrance, and carry the ice with great velocity to the southward, along the coast of LABRADOR."
>
> (Chappell, 1970 :40-41)

Although this fact applies primarily to the westward journey, the landmarks established as a result of this practice of hugging the north shore aided in the navigation of the eastward voyage as well.

The third characteristic which was found to be a common element of the contents of the log books is the time of year in which the ships sailed. As was the case with the similarities found in the routes, it was primarily the presence of ice in Hudson Strait and Bay which required that the ships sail at a particular time of year. The following quotation from Edward Chappell's narrative serves to illustrate this point:

> "It is a rule with the Hudson's Bay Company to make their ships always break ground on the 29th of May; although sometimes, they do not leave the river Thames before June."
>
> (Chappell, 1970 :8-9)

In summary therefore, there are two basic characteristics which favour the use of the Hudson's Bay

Company's ships' log books in an historical environmental study: the extent of the record, and the consistencies within the log books. The record is both comprehensive in terms of the actual number of consecutive years of log book availability, and it is also extensive in terms of the number of logs available in each year. Secondly, the high degree of consistency found within the contents of the log books is advantageous. This factor is the result of the combination of the following three circumstances:

i) the existence of regulations governing the information which was to be contained within the log books;

ii) limitations which were imposed by both the prevailing state of navigational technology and by the presence of ice in Hudson Strait causing the same route to be followed each year;

iii) the seasonal presence of ice which caused the ships to sail at approximately the same time each year.

2. CONTENTS AND FORMAT OF THE LOG BOOKS

Although the instructions from the Admiralty required that all activities and events which occurred on the voyage be recorded, various aspects of the contents of the logs differ from book to book. These variations arose as a result of the personal perceptions of the individual keeping the log book. One individual might place more emphasis on the actual sailing activities (such as the raising and lowering of sails), whereas another might focus more attention on the activities of the crew, or on the description of the state of the weather. The one element common to all of the log books however, was the frequent description of ice, and the activities required to deal with the ice in Hudson Strait. This is expected in view of the hazards to sailing imposed by ice.

Figure II.3 illustrates a typical page of a log book, which represents one 24-hour period. The common practice was to let the top half of the page represent 1400h to 2400h, and the bottom half extend from 000h to 1200h in the next day. Therefore, in Figure II.3, the upper half of the page refers to 6 August and the bottom half to 7 August. The problem of separating days is not apparent in this example as the change of days has been recorded. This was not the case however, in the majority of the log books.

Each log book page was ruled into 7 columns, the first three columns (from the left-hand side)

H	K	F	Courses	Winds	Weather	Remarks Thursday y 6 August 1761
2				NWbN	Foggy	At grappling the Ice Horse to the same piece
4						
6						
8				NW	do	do
10						
12				WNW	do	do
2						
4				do	do	do
6	At ½ past 5 Un			grappled	& stood to	the Southward thro' thick Ice
8				W	Foggy	Turning thro' thick Ice
10						do
12				Calm	Hazy	do. the other Ships Grappled

H	K	F	Courses	Winds	Weather	Remarks Friday y 7 August 1761
2				Calm	Clear	Rowing & Towing in Open Ice,
4	At ½ past 2			Stopt to	a piece of	Ice & at ½ past 3 cast off
6		Light breeze		Southerly		Forcing thro' thick Ice
8						Running in open Ice
10	4		NWbN			
12	2	5		ENE		Lay too one hour for day light, and made
2						Sail, At 3 AM
4						At 4 was set fast by a strong Run of the Tide
6						At 5 forced thro' fast Ice into open Water
8						Lay too till 9 AM for the other Ships then
10		Forced thro' another		thick Skin of Ice into clear Water and fil-		
12		[illegible]			the other Ships being near	

FIGURE II-3 SAMPLE LOG BOOK PAGE (Hudson's Bay Company Archives, c1/365) which are headed 'H', 'K', and 'F' represent hour, knots, and fathoms, respectively. Routine entries were made at 2 hour intervals. Winds were quite faithfully recorded in terms of the directional component. It was unclear however as to whether the column headed 'K' (knots) referred to the speed of the wind or of the ship (but it was presumed to be the speed of the ship). The next column, 'Weather' generally referred to conditions of visibility with more detailed references being found under the heading of 'Remarks'.

In many logs there was also a noon entry of location, a summary of important events (of the preceding 24 hours), and a description of the sailing conditions of the ship at noon. This information was usually found at the bottom of the page in a space which was set aside for this purpose. Comments which referred to ice conditions were also often found in this section, however most ice information was contained in the Remarks column at the hour at which the observation was made. A few typical comments which refer to ice conditions can be found in Figure III.3, for example:

"'Ungrappled and stood to the southward thro' thick Ice.' 'Turning through thick Ice.' 'Rowing and towing in Open Ice.' 'Forcing thro' thick Ice.'"

(Log of the ship King George, August 6 and 7, 1761, Hudson's Bay Company Archives C1/365)

It is interesting to note that throughout the log books the capitalization of words seemed to be somewhat arbitrary. It appears however, that the word 'Ice' was commonly capitalized and it is tempting to assume that this was done to give a distinct importance to the word.

3. SAMPLING OF THE DATA

Since the Hudson's Bay Company's collection of log books is a highly diverse source of environmental information, it was important that the data to be used were carefully selected. The major advantage of this selectivity is the elimination of extemporaneous information which could only serve to confuse and complicate the retrieval and analysis of the relevant data.

The following is a list of questions which serve to point out the procedure by which the data to be retrieved from the log books were selected.

- WHAT environmental factor should be chosen, and WHY?

- WHERE would be the most appropriate location to investigate the particular factor, and WHY?
- WHEN would this element be most evident, and WHY?
- HOW should the data collection proceed, and WHY?

There are essentially three types of environmental information available in the log books: sea ice, meteorological conditions (particularly winds), and sea currents. Of these three, sea ice was chosen as the focus of this study. This decision had its foundation in two fundamental factors. Because sea ice posed a definite threat to the success of the voyages and to the lives of the crew members, it was assumed that the ice conditions would be recorded carefully and faithfully. The obvious advantage of this premise may be tempered by the fact that not all sea ice conditions were hazardous. Regardless of this fact, a cursory examination of the log books definitely indicated a persistence in the noting of ice conditions. It was also anticipated that even if the persons recording the ice conditions ignored the non-hazardous situations, they would most likely be 'sensitive' to the moderate and/or severe situations.

The second element which contributed to the selection of sea ice was its potential uses in future studies. In a study of drift ice and temperature in the past millenium, Bergthorsson, found that it is possible to derive a temperature record from studies of the amount and frequency of the occurrence of drift ice. Bergthórsson (1969 :94) stated:

> "A fairly good correlation has been found between temperature and the incidence of drift ice in Iceland. This relation is used to estimate the temperature in Iceland in the period 1591-1846."

Although the ice found in Hudson Strait was not formed there, by knowing its place of origin, one might be able to reconstruct a temperature record for that region. (See Appendix C for further discussion)

In summary, sea ice was chosen as the focus of this study as a result of the following:

i) as it posed a hazard, or at least an obstacle to navigation, it was felt that sea ice conditions would be frequently recorded; and

ii) since meteorological records for the 18th and 19th centuries (for the region encompassed by the log books) are virtually non-existent, sea ice information could prove useful as a means for inferring temperatures.

The second question asked which geographical area, in the voyage from Britain to Hudson Bay and back, would be the most appropriate to investigate sea ice conditions. Once the first question had been answered, the options for the second were greatly reduced. The only two locations which could be considered became Hudson Strait and Hudson Bay. The former was selected as a result of two factors characteristic of Hudson Strait. The fact that the Strait is a confined channel is the most significant factor on which this decision was based. In the restrictive bounds of the Strait, ice posed both a hazard and an obstacle to navigation, and therefore it was once again assumed that much care would have been taken to describe the ice and the actions taken to avoid it. In Hudson Bay, encounters with ice could be avoided with greater ease due to the leeway afforded by the unconfined Bay. In the Strait however, it was less often possible to change course, and it was not inconceivable to find that a portion of the channel, ahead of the ship, had become completely blocked by ice.

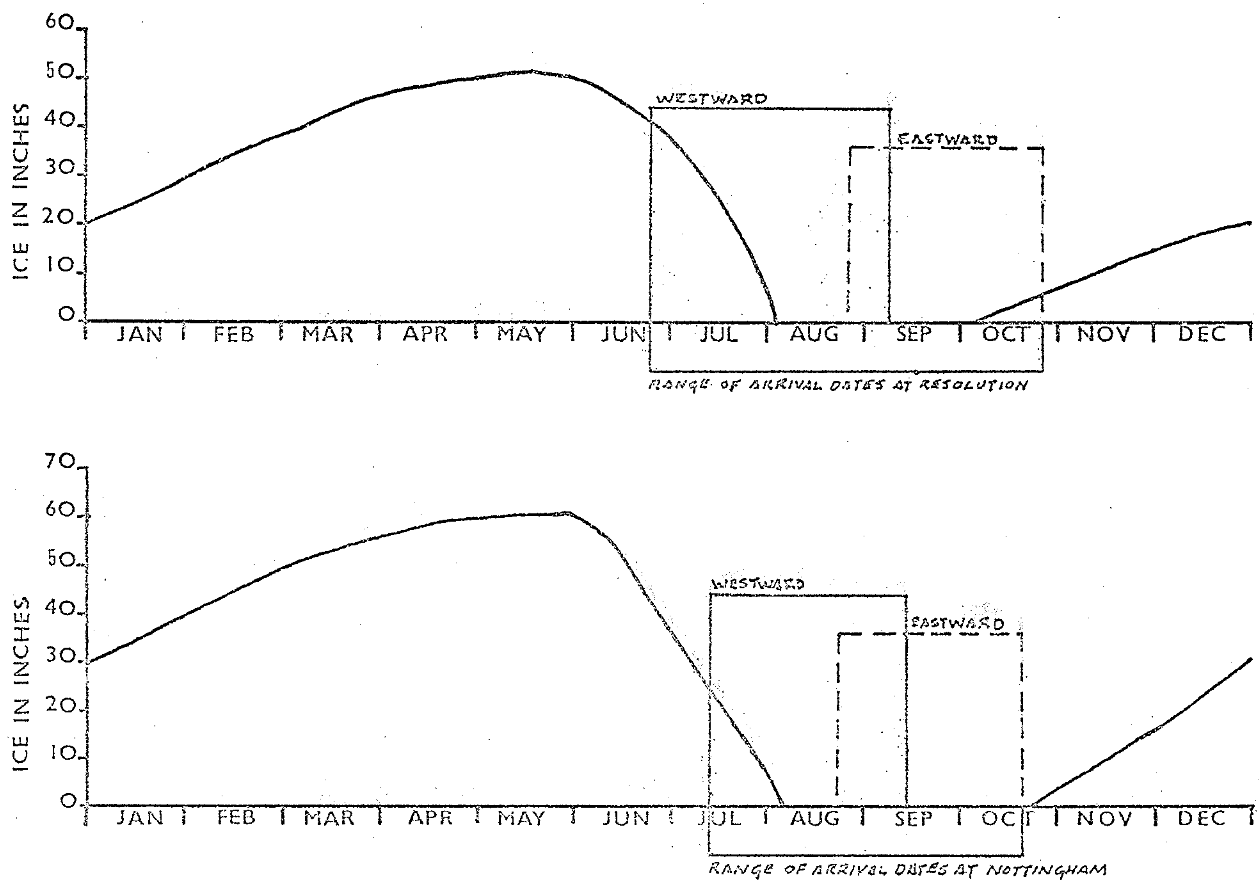
Secondly, the choice of Hudson Strait was based upon the fact that an accurate locational fix was more easily determined in the Strait than in mid-ocean, or in the crossing of Hudson Bay. The locations in the Strait were given in terms of landmarks on the shores and on islands in the Strait.

The time of year in which ice conditions would be most evident was the next point to be resolved. The most obvious time to choose was one in which the greatest problems with ice were expected to be encountered. Following a basic examination of the log books, and paying particular attention to the voyages through Hudson Strait, it appeared that the greatest amounts of ice were found during the outward or westward portion of the voyage. The average date of entry into the Strait, during the westward voyage was found to be 27 July. As indicated in Figures II.4 (a) and (b), this period is one in which ice amount is declining and therefore is broken and in movement (according to modern data). The average date of entry into the Strait on the eastward voyage was 20 September, a period which, according to Figures II.4 (a) and (b), was virtually ice-free. Consequently, the westward portion of the voyage (through Hudson Strait) was chosen as the prime focus of this research.

The methods of data collection and analysis were the final questions to be resolved. It was decided that the collection of locational data should

FIGURE II-4

ICE FORMATION AND DECAY



(After: Warnock and Hersey)

be the point of departure for three reasons. The fundamental basis for this decision was that it was known that locational fixes were provided either throughout each day, or were contained at least within the noon entry. It was also found that this practice was performed in a routine manner by referring to a somewhat selective group of landmarks. By contrast, the exact manner in which ice conditions were recorded was not initially known.

Furthermore, it would eventually become necessary to collect this locational data since information regarding the nature of ice conditions would be somewhat out of context if it were not known where these conditions occurred.

Finally, it was felt that it might be possible to make preliminary assumptions about sea ice from the locational data. It was strongly advised, for instance, that the ships should follow the north shore of the Strait as closely as possible in order to avoid the ice which drifted to the south shore. If the locational data revealed that a migration of the normal northern route to the southern shore had occurred, then two assumptions could be made:

i) ice was not being carried to the south shore due to a change in the currents; or

ii) there was a decrease in ice amounts. Other assumptions could be made based upon the number of days which were spent at any one location. As a result of unusually frequent references to the same location, one may be led to assume that the postponement was due to ice. This assumption would arise only if there were no accompanying comments concerning adverse weather, or delays due to trade.

Essentially then, locational information was collected initially to serve a threefold purpose:

i) to provide familiarity with the methods of recording sea ice information in the log books;

ii) to fulfill the eventual necessity of knowing where the particular ice conditions occurred;

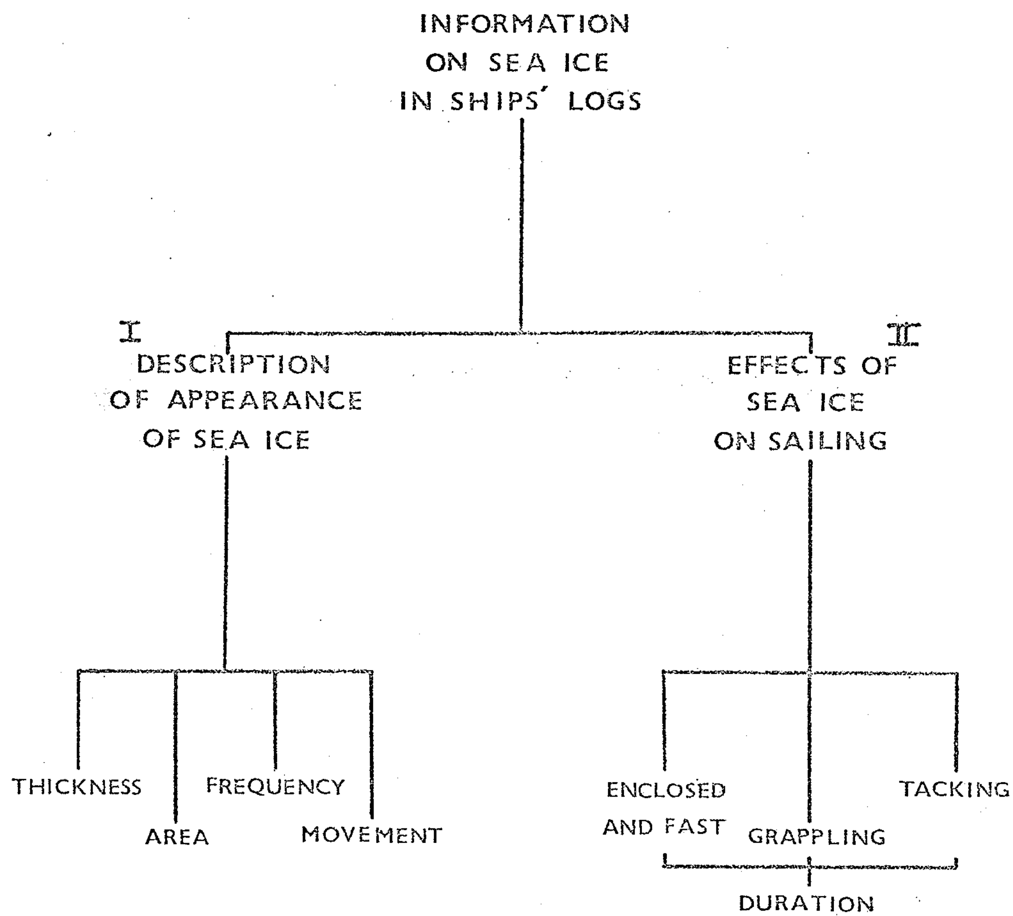
iii) to allow preliminary assumptions to be made about sea ice in order to gain an impression of the ways in which ice conditions might be expected to vary.

The above discussion represents the first phase of the data retrieval process, and served as a foundation for the second phase on which this thesis is primarily focussed.

There are basically two avenues of approach open in attempting to glean information on sea ice from the log books, as Figure II.5 illustrates. The

FIGURE II-5

TWO METHODS OF OBTAINING SEA ICE INFORMATION FROM SHIPS' LOGS



first, and most direct method employs the use of actual descriptions of the ice. Descriptions of this nature include its: thickness, aerial extent, frequency of occurrence, and speed and direction of movement. These elements were all found to be available in the log books in varying degrees of frequency and standardization. The second, and more indirect approach is one which makes use of the comments referring to the effects of the ice on sailing activities. In this regard, all comments referring to navigational practices, which were necessitated by varying degrees of sea ice severity, are relevant. These comments include references to such events as being enclosed by the ice or fast in ice. It was this second procedure which was chosen for the following reasons.

Although the first approach may seem more likely to generate direct ice information, it has its main weakness in the fact that it is highly subjective. Because sea ice amounts were not measured instrumentally, all descriptions of ice were based entirely upon personal observations. It is also possible that many ice conditions might not have been included at all (in a descriptive sense) in some cases, owing to the fact that the particular captain may not have considered them important. Should special navigational measures been necessary to deal with the ice however, an accurate recording of those activities would have been required. This record would lack the subjectivity of ice observations since it was simply a report of the activities taking place on board the ship. This does not necessarily mean that the navigational activities which were recorded lack any subjectivity. The weakness here lies in the fact that the activity chosen was based, to some degree, upon the captains' experience and perception of the situation. A partial redemption of this weakness lies in the assumption that the captains were motivated to act in a manner such that the ship and her crew would be brought to safety and returned to its course with the least amount of risk and delay in time. By accepting this premise, one might also expect certain actions to coincide with certain situations, and since these were 18th and 19th century sailing ships, it would seem that there were very few options available for coping with the varying degrees of ice severity.

The next reason for selecting this path of investigation is, in essence, a restatement of the hypothesis which was presented in the introduction to this thesis. This factor follows quite closely from the hypothesis in that if there were a small number of choices available as responses to ice conditions, then one may be able to work 'backwards' and arrive at the initial situation by knowing the reaction. Since the presence or absence of sea ice in Hudson Strait was likely to influence navigation, then it would follow that the methods of navigation, which were employed, ought to yield evidence of the nature of the sea ice.

One further reason for embarking on this line of investigation is somewhat more indirect, but is nevertheless significant. In Figure II.5, the fourth component under the heading "Effects of Sea Ice on Sailing" is 'duration', which essentially bridges the other three since they, in turn, are reflected in the duration. This factor represents another possible indication of the severity of sea ice which is based on the supposition that it was desirable for the ships to pass through the Strait as quickly as possible. It will be shown in Chapter III that adverse weather and trade generally caused no delays exceeding one or two days. Therefore, should the duration of the voyage have been retarded to any great degree, then the probable cause would have been ice. The role played by trade and severe weather in the dealy of voyages through the Strait was unknown until the analysis was in progress, and therefore, both meteorological and trade events were also transcribed from the log books.

The prime concerns of this preliminary stage of the research were to become familiar with the contents and format of the log books, and more importantly, to select data which would facilitate an optimum use of the log books. This should not imply that once this has been accomplished the potential information contained within the logs will have been exhausted. On the contrary, it is hoped that the decisions made at this stage will serve to open the doors for more in-depth and varied investigations in the future.

CHAPTER III

DATA RETRIEVAL AND ANALYSIS

The retrieval and analysis of the data were undertaken in two phases since the precise nature of the contents of the log books was initially unknown. The first phase centered on the collection and interpretation of the locations and dates of both the westward and eastward voyages through the Strait. The second phase involved a return to the Hudson's Bay Company's Archives in order to collect references to adverse weather conditions, trade, and to the navigational activities undertaken to secure a safe passage in the vicinity of sea ice. This second stage focussed only on the westward-bound voyages, because the first phase of the investigation indicated that sea ice posed a more severe threat to navigation during that portion of the voyage.

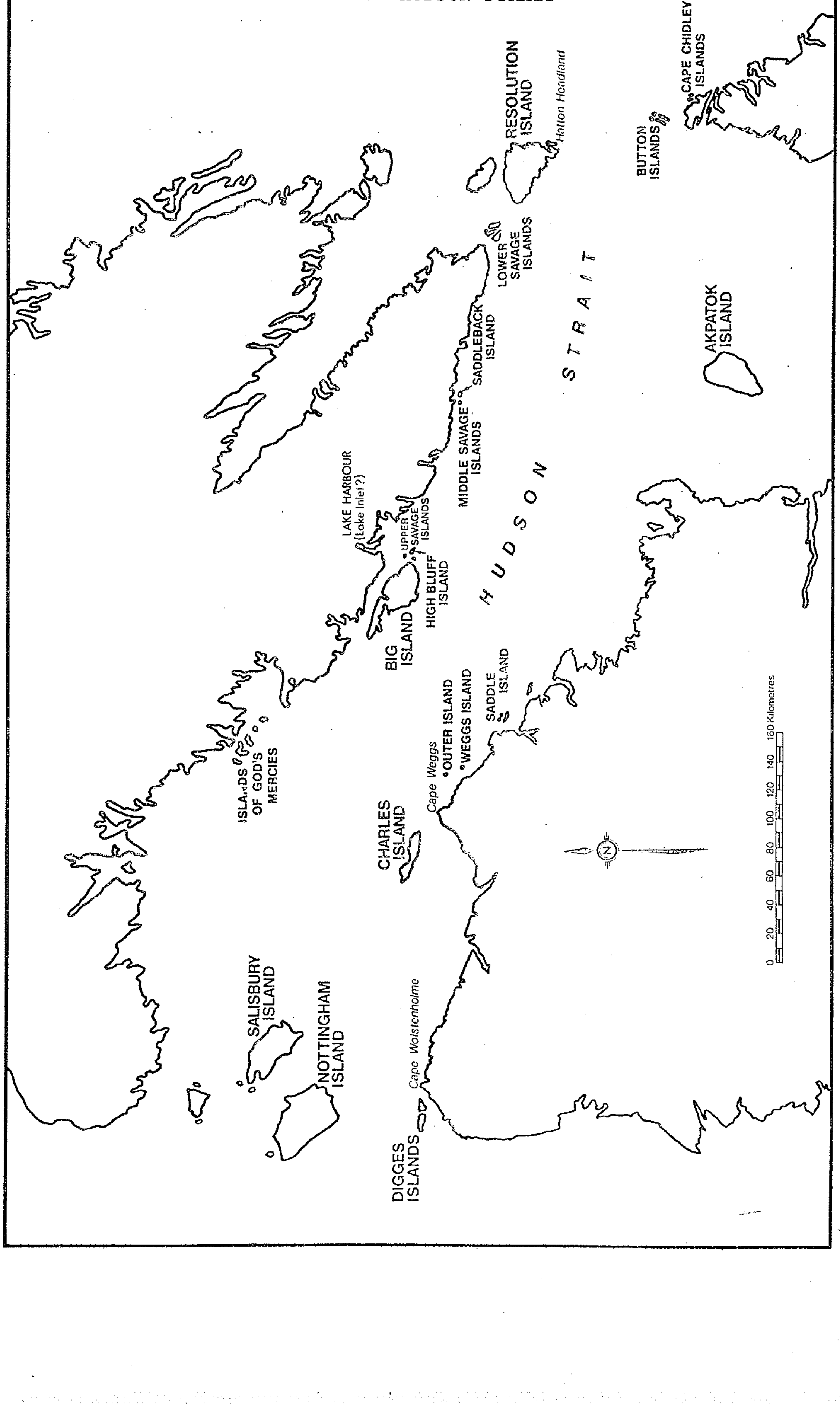
1. DATA RETRIEVAL

In order to select data which pertained to Hudson Strait only, it was necessary first to define its eastern and western limits. The natural limits are roughly located at Resolution and Buttons Islands in the east and at Diggs and Salisbury or Nottingham Islands in the west. The natural tendency for these islands to serve as gateways to and from the Strait is quite apparent in Figure III-1.

Initially, it was not known whether any or all of these islands were referred to in the log books. As it happened, all of the above locations were referred to, and Resolution and Diggs Islands were most often mentioned. Consequently, the eastern and western limits were set at Resolution and Diggs Islands respectively. The remaining three islands were used as limits when a particular log book did not give any references to Resolution and/or Diggs Island(s). As a result of this decision, the first mention of Resolution Island, and the last reference to Diggs Island marked, respectively, the entrance to, and departure from, Hudson Strait on the westward journey, (vice versa for the eastward voyage).

As stated in Chapter II, it was hoped that by plotting the locations of the ships as they passed through Hudson Strait, evidence of ice conditions or severity might be revealed. The initial stage of data collection involved the transcribing of daily noon locations and dates of each voyage through Hudson Strait from the log books. At this stage, the decision

FIGURE III-1 MAP OF HUDSON STRAIT



to focus on the westward portion of the voyages had not been made, and therefore dates and locations cited during both passages were collected. Figure III-2 contains an example of the data cards used to facilitate transcription.

Section (a) of Figure III-2 identifies the particular voyage in terms of the year in which the voyage was made, the name of the ship, the archival reference number (all of the Hudson's Bay Company's log books are catalogued as C1 followed by a piece number), the officer or person who was responsible for keeping the log book, and whether the card represented the eastward or westward voyage. Below this, in section (b), transcriptions from the log books were made based upon the noon observations. When a locational reference was not available at noon, the entry closest to it was taken, and the time of that reference was noted in the 'Remarks' column. The selection of the noon observation was based on the following factors. Since the time scale of the entire record spanned 120 years, it was felt that more than one observation per day would be too sensitive for the requirements of this study. By choosing to use the same time each day, two objectives were met: i) a degree of standardization was preserved, and

YEAR 1751 SHIP King George I PIECE #360
OFFICER William Coats (Master)

DAY	PLACE NAME	DIRECTION/ DISTANCE	REMARKS
July 5	Saw Buttons	4 leags	(10:00 P.M.)
8	Nearest land	NE 6 miles	
9	Nearest land on N Shore	E by N 4 miles	(8:00 P.M.)
10	Savage Isle	N¼ W 4 leags	(8:00 P.M.)
13	W. end of Charles	SSE 2 miles	(10:00 A.M.)
14	Cape Diggs	SSE½E 6 miles	(4:00 P.M.)
	Nearest part Mansfield	W 5 leags	(6:00 P.M.)

FIGURE III-2 SAMPLE DATA CARD

ii) the interval between observations was fixed at 24 hours. Furthermore, the noon entry usually provided other information regarding sailing conditions, weather, grid locations, and also often served as a summary of the day's activities.

Once the ships had entered Hudson Strait, locational references were primarily given in terms of landmarks, and their distances and directions from the ship. These two elements were listed under the headings of the Place Name and Distance. A total of 15 landmarks were consistently referred to, and are listed in the order of their location from east to west:

Resolution Island (and portions of the island)
East Bluff of the North Shore
Buttons Island
Lower Savage Island
Saddleback Island
Middle Savage Island
Upper Savage Island
Laker's Inlet
Islands of God's Mercies
Cape Weggs
Charles Island
Cape Wolstenholm

Salisbury Island

Nottingham Island

Diggs Island

These locations are shown in Figure III-1. It should be noted that all but the last six locations are on the north shore, and only Cape Weggs, Charles Island, Cape Wolstenholm, and Diggs Island are on or near the south shore.

The distances from these landmarks to the ships were usually given in leagues (1 league = 3 miles), and the directions were based on the 32-point compass.

The Remarks column was provided for the purpose of noting the time on those occasions when the recording was not made at noon, and for transcribing comments which referred to exceptional conditions. An example of this type of exceptional condition is:

> "We have passed the greatest quantity [of ice] I ever saw in Hudson's Straits before."
>
> (Log of the Ship King George, Ausugt 9, 1778. Hudson's Bay Company Archives, C1/382)

As was explained in Chapter II, more than one log book was often available in a given year. However, only one log book per year was used. This decision was made as a result of the fact that when two or more ships sailed, they usually sailed in convoy and their log books tended to duplicate information. The value of the additional log books was to provide a source by which exceptional conditions reported in one log book could be verified by another. When more than one book was available, the log which appeared to contain the most complete and legible account was selected for analysis.

2. DATA ANALYSIS

a) Temporal analysis

The dates on which the ships arrived at the western and eastern limits of the Strait are shown graphically in Figure III.3(a) Both the westward and eastward voyages exhibited a high degree of variability. Table IV.1 presents the mean dates of arrival at Resolution and Diggs Islands, and the ranges within which the dates fluctuated.

To facilitate their statistical manipulation, the dates were expressed as numbers of days after May 2. Thus, 3 May, the earliest date on which an entry was made in a log book is day 1 and 25 December (the last date on which a log book entry was made) is day 237. By using this system of numbering, the mean dates in Table III.1 were calculated from the following equation:

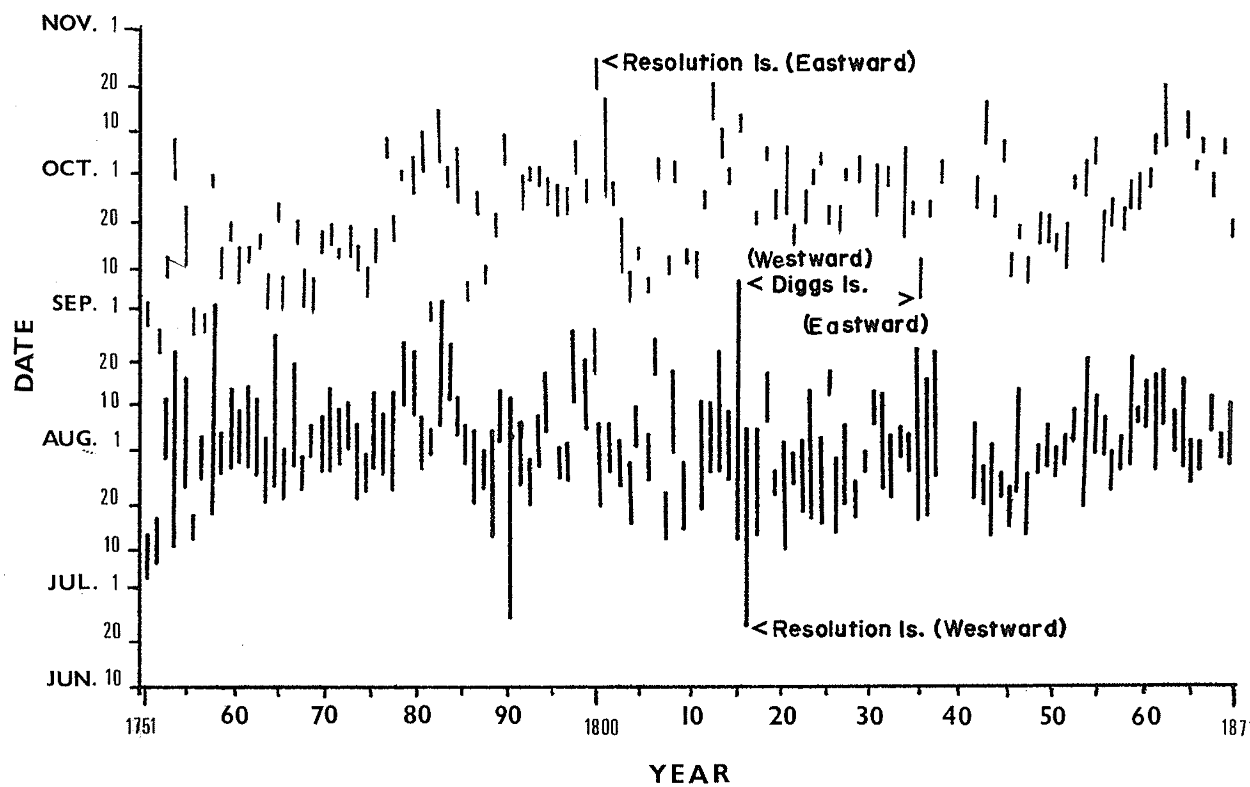


FIGURE III-3 (a) DATES OF ARRIVAL AT RESOLUTION AND DIGGS ISLANDS

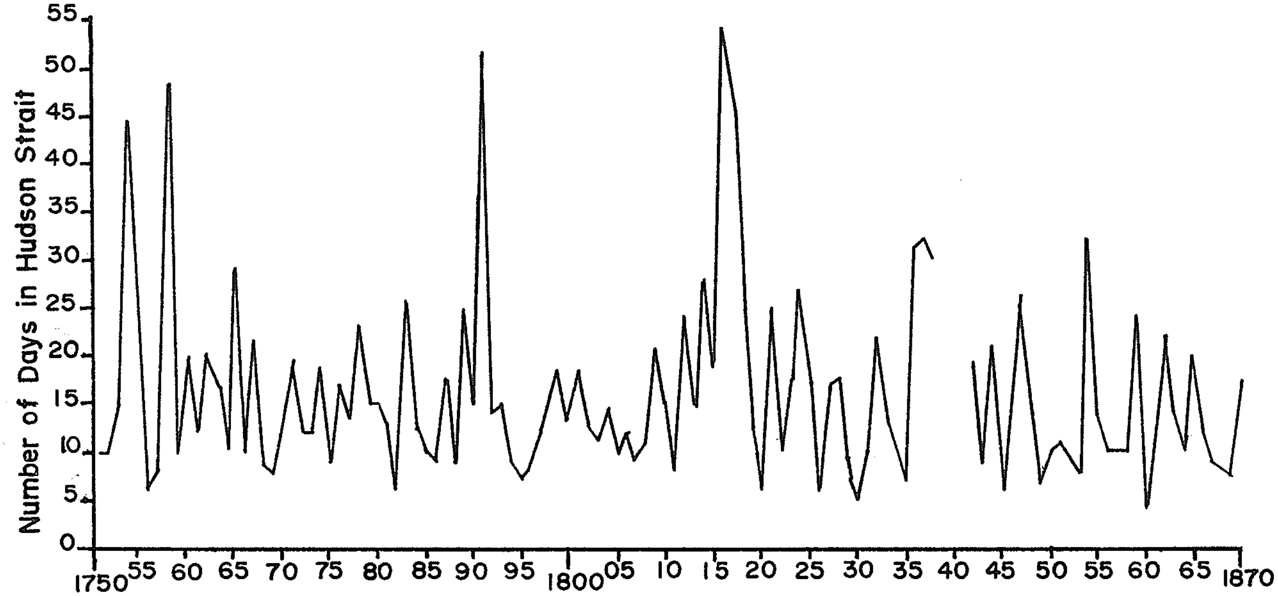


FIGURE III-3 (b) (i) WESTWARD DURATIONS

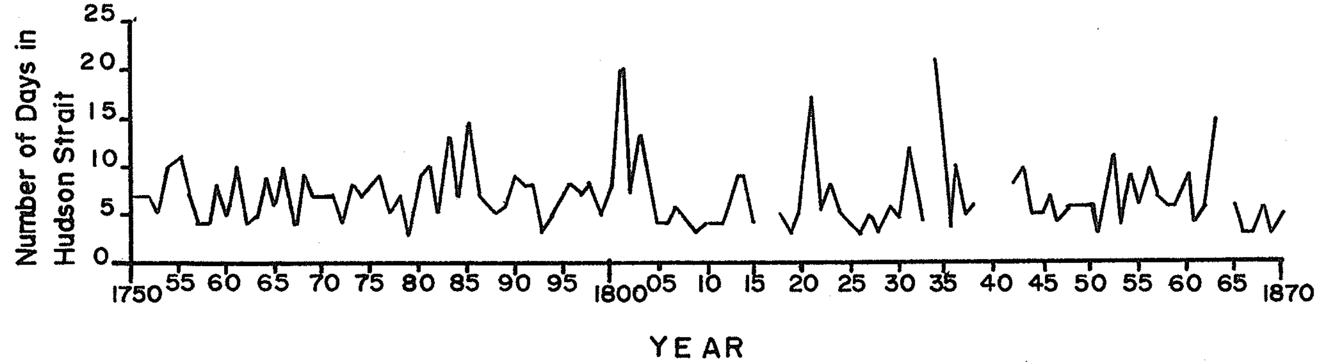


FIGURE III-3 (b) (ii) EASTWARD DURATIONS

TABLE III.1: SUMMARY OF DATES OF ARRIVAL AT RESOLUTION AND DIGGS ISLANDS

	WESTWARD VOYAGES		EASTWARD VOYAGES	
	RESOLUTION ISLAND	DIGGS ISLAND	DIGGS ISLAND	RESOLUTION ISLAND
Mean date	27 July	11 August	20 Sept.	25 Sept.
Earliest date	24 June	14 July	22 August	26 August
Latest date	8 Sept.	15 Sept.	19 October	26 October
Range	77 days	64 days	59 days	62 days

$$\overline{X} = \frac{\sum_{i=1}^{237} x_i}{N}, \quad i = 1, 2, 3 \ldots 237 \qquad (1)$$

where: $\overline{X}$ = mean date

N = total number of observations

Figure III.4 gives a comprehensive overview of the temporal variations between the annual voyages. This illustrates when the ships were situated at particular locations, and it also placed in perspective the relative length of time that the ships were in Hudson Strait as compared with the durations of the remainders of the voyages. The dots running along the bottom portion of the graph represent the dates on which the ships left the Thames estuary. The space between these dots and the lower limit of the thick vertical lines above them is representative of the westward Atlantic crossing. These lines illustrate the durations of the westward voyages through Hudson Strait. Above these lines is another gap which depicts the interval spent in Hudson Bay; followed by thin vertical lines which depict the eastward voyages through the Strait. Likewise are shown the return Atlantic crossings, and the dates of return to the

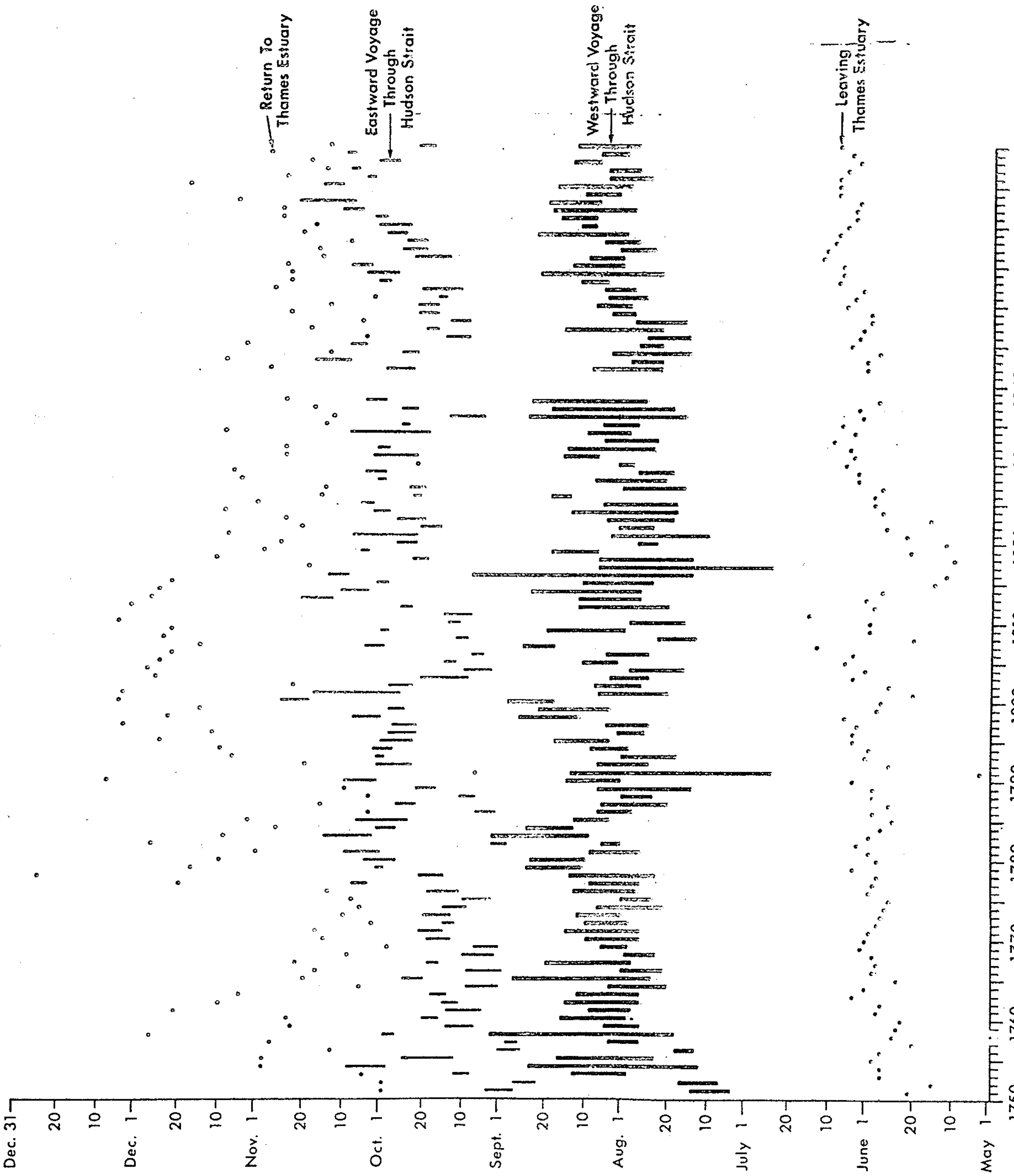


FIGURE III-4 DATES OF POSITIONS OF SHIPS FOR ENTIRE VOYAGES

Thames estuary.

The principal relevance of this information became evident when considered in relation to the second pair of graphs in Figures III. 3(b)(i)and 3(b)(ii)These graphs illustrate the durations, in numbers of days, of each passage through the Strait on the westward (III.3b i)and eastward (III.3bii)voyages. Table III.2 summarizes the most basic statistics concerning the durations.

The mean durations were calculated by the application of equation (1), and the standard deviation by equation (2) below:

$$S = \frac{\sum_{j=1}^{N} (x_j - \bar{X})^2}{N} \qquad (2)$$

Clearly, there are large variations in the durations of voyages through the Strait. This is exhibited in Table III.2 by the ranges of 3-21 days and 5-54 days, and by the standard deviations of 3.31 and 9.25 for the eastward and westward portions respectively. A second feature shown by these graphs

TABLE III.2: DURATIONS OF VOYAGES THROUGH HUDSON STRAIT IN DAYS

	WESTWARD VOYAGES	EASTWARD VOYAGES
Mean duration	16	7
Standard deviation	9.25	3.31
Minimum duration	5	3
Maximum duration	54	21

is that the westward voyages were of a considerably longer duration than the eastward voyages. Based upon the mean durations in Table III.2, the westward mean (16 days) was slightly more than twice that of the eastward voyages (7 days). It was hypothesized that perhaps this disparity was caused by:

i) more ice in Hudson Strait which posed an obstacle to the westward journey;

ii) more favourable winds on the return voyage.

It was primarily as a result of the extended westward durations that this portion of the voyages through the Strait was chosen as the central focus of this study. It was anticipated that these longer durations could have been reflective (at least in part) of difficulties in navigation which were not present on the return voyages. In posing this theory, it was necessary to assume that there was a motivation to complete the trip in as quickly a period of time as possible.

A third, perhaps less obvious characteristic which was observed from the graphs of duration (III.4a and b) was that there were three periods of extremely long durations, in the westward voyages. These are identified in Table III.3.

Although each of these periods had durations

TABLE III.3: PERIODS OF PEAK DURATIONS OF WESTWARD VOYAGES

PERIOD	YEAR	DURATION (Days)
I	1754	43
	1755	35
	1758	36
II	1791	52
III	1816	54
	1817	46

that were twice to three times greater than the mean duration, they generally experienced faster eastward voyages. Of the above six years, only two exhibited extended eastward durations. These two years were: 1755 (eastward duration of 11 days - 3 times the mean), and 1816 in which no return voyage was possible, apparently due to severe ice conditions (log of the ship Emerald, 1816, Hudson's Bay Company Archives, C1/324).

As a result of the high degree of variability displayed in Figures III.3b (i) and (ii), it is difficult to determine visually whether eastward and westward durations are directly related. By way of comparing the durations for each year, a correlation coefficient was therefore calculated using equation (3) below:

$$r = \frac{\Sigma xy}{(\Sigma x^2)(\Sigma y^2)} \qquad (3)$$

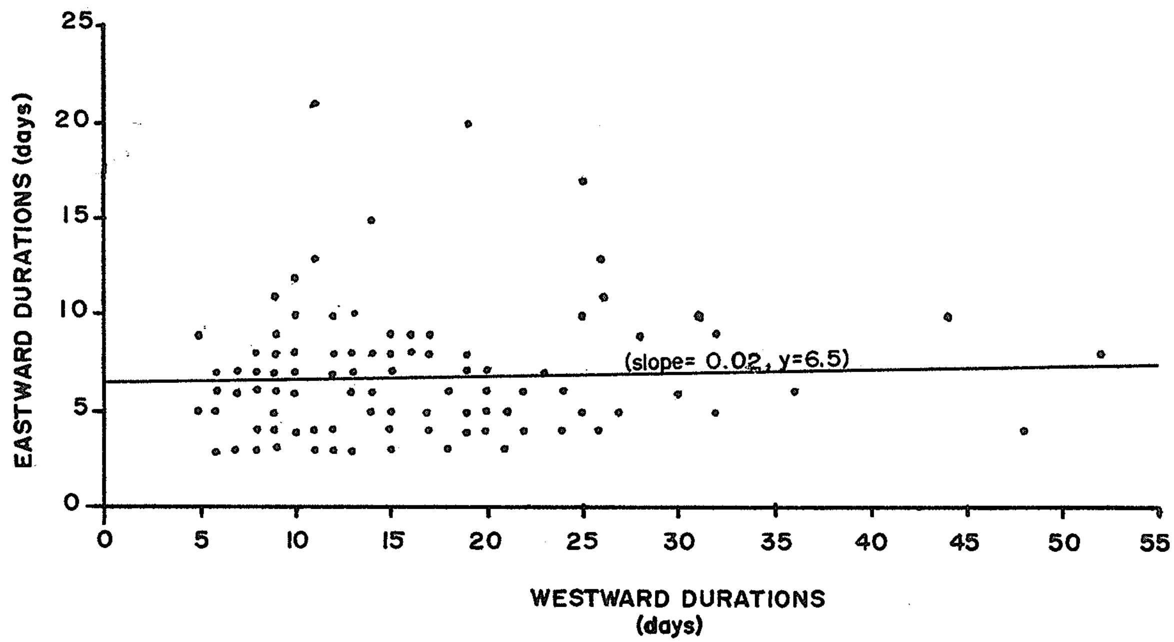
where: r = correlation coefficient
$x = X - \bar{X}$
$y = Y - \bar{Y}$

The value of the correlation coefficient is + 0.06.

The scatter diagram, with a superimposed regression line is shown in Figure III.5. This low correlation demonstrates that the factors which led to delays were seasonal rather than characteristic of a particular year as a whole. Therefore, delays may have been due to the presence of ice in Hudson Strait which was no longer there by the time that the ships were engaged in their return voyages. It is also possible however, that this disparity in durations was the result of other factors such as prevailing westerly winds which could delay the westward voyages but favour the eastward voyages.

The analysis of the spatial and temporal locations of the ships also involved a study of the relationships between i. durations and ii. dates of arrival at Hudson Strait. Since ice conditions in Hudson Strait vary seasonally, it would seem reasonable for one to anticipate the existence of a relationship between dates of entry and durations of the westward voyages. By using equation (3) a correlation coefficient of - 0.4 (significant to 99.9%) was calculated, with the date of entry as the x - variable and the westward duration as the y - variable. This correlation coefficient indicates that only 16% of the variations in duration can be explained by the date of entry

FIGURE III-5 SCATTER GRAPH FOR EASTWARD : WESTWARD DURATIONS



($r^2 = 0.16$). Figure III.6 shows the distribution and regression line for this relationship.

b) Analysis of ships' locations

As discussed in Chapter II, dates and locational data were collected in order to allow the voyages through the Strait to be plotted cartographically. It was anticipated that this information might reflect a change in ice conditions by identifying an alteration in routes. The application of this procedure was met with several difficulties.

One problem which arose at the onset was that quite often the locational references were too vague to facilitate plotting. References were frequently made in the log books to the north and south shores without specifying as to which point on the shoreline the comment referred. Similarly, problems occurred when distances and/or directions from landmarks were not given. The extent to which these limitations existed has been illustrated in Figure III.7.

There were two possible solutions to this problem:

i) the gaps resulting from inadequate information could be bridged by interpolation;

ii) other log books could be examined for

FIGURE III-6 SCATTER GRAPH FOR DURATION:
DATE OF ENTRY

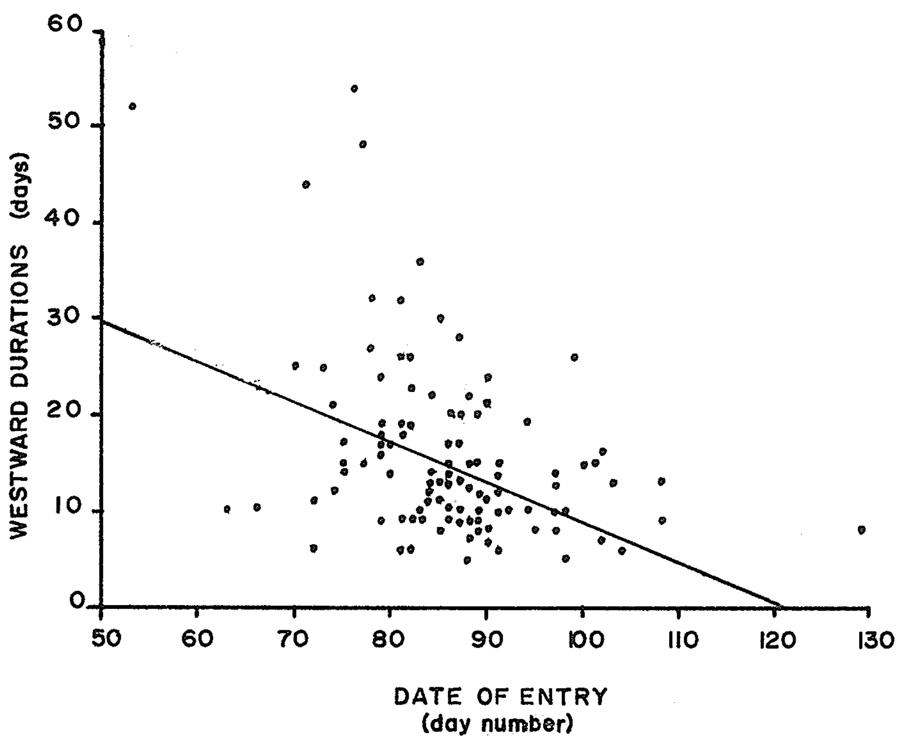
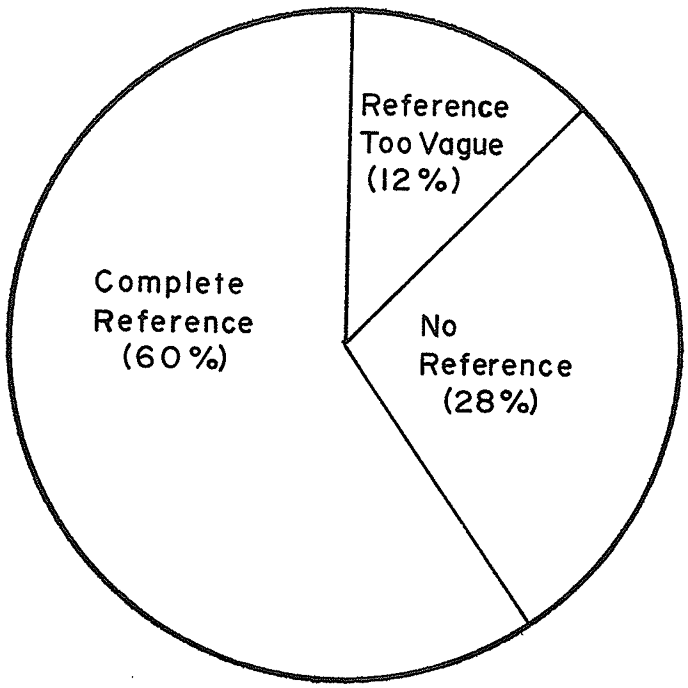


FIGURE III-7 PLOTTING LIMITATIONS



REFERENCES

	Complete	Vague	None
Enclosed & Fast	70	25	57
Grappling	338	55	175
Tacking	141	31	27
Total	549	111	259

the appropriate years to fill the gaps. The first possibility presented the obvious problems of inaccuracies, particularly at the western end of the Strait where the channel widens considerably. Although the second possibility was not explored completely, some difficulties may be expected in relation to finding log books of other ships which were at the same place at the same time as the log containing the gap. This avenue of filling these gaps should, however, be considered, and will be discussed in Appendix C., Future Research.

Despite these difficulties, an attempt was made to plot a representative proportion of the voyages. It was at this point that further difficulties arose in the plotting process. Because the ships navigated by the use of a magnetic compass, all of the locational references were oriented to the magnetic north pole, whereas the map which was used was based upon the position of the geographic north pole. This factor resulted in a twofold problem. The first difficulty arose due to the fact that the magnetic poles change their locations through time. Secondly, the amount of declination between the geographic and magnetic poles changes spatially, particularly at the higher latitudes. Therefore, within the Strait, more than one isogonic line is encountered. Had the log books made note of this change in declination, the problem would not have existed. This was unfortunately not the case with the majority of the log books. Almost all of the log books gave a daily value for the variation (either in degrees or based upon the 32-point compass), however most of the books ceased recording variations upon entering the Strait. By surveying the earlier log books and comparing their entries with present day isogonic maps, it was found that the magnetic declination had not changed so drastically as to significantly affect the plotting of the voyages. Consequently, the pattern of spatial variations in declination within the Strait in historical times was assumed to be the same as at present. Corrections for declination were then derived from modern maps of magnetic declination.

Once these problems had been overcome, it was possible to begin plotting the voyages. The initial intent was to trace a sample of the voyages for which the most detailed and complete locational references were available. Appendix A outlines the breakdown of the 32-point compass and the method by which the voyages were plotted.

Because this portion of the study was not intended to serve as a prime focus, only a sample of 10 of the voyages was selected to be plotted. Of these examples, three are shown in Figure III.8 to represent: an extremely slow voyage, a rapid voyage, and one of average duration. By comparing the routes plotted in Figure III.8, one major observation is revealed. Although the voyages represent drastically different durations, all three followed almost identical routes until reaching the Islands of God's Mercies. The most probable reason for this lay in the fact that the captains were instructed to follow the north shore as closely as possible in order to avoid the ice as was previously noted in a quotation by Lieutenant E. Chappell (1970, 8-9). This confirmed, at least in part, the hypothesis that ice conditions determined to some degree the routes which were followed. The greater variation in routes at the western end of the Strait could have been due to the increased width of the channel. This afforded more leeway in selecting the route which presented the fewest difficulties.

Since the data collected in this phase were crude, it would have been inappropriate to have

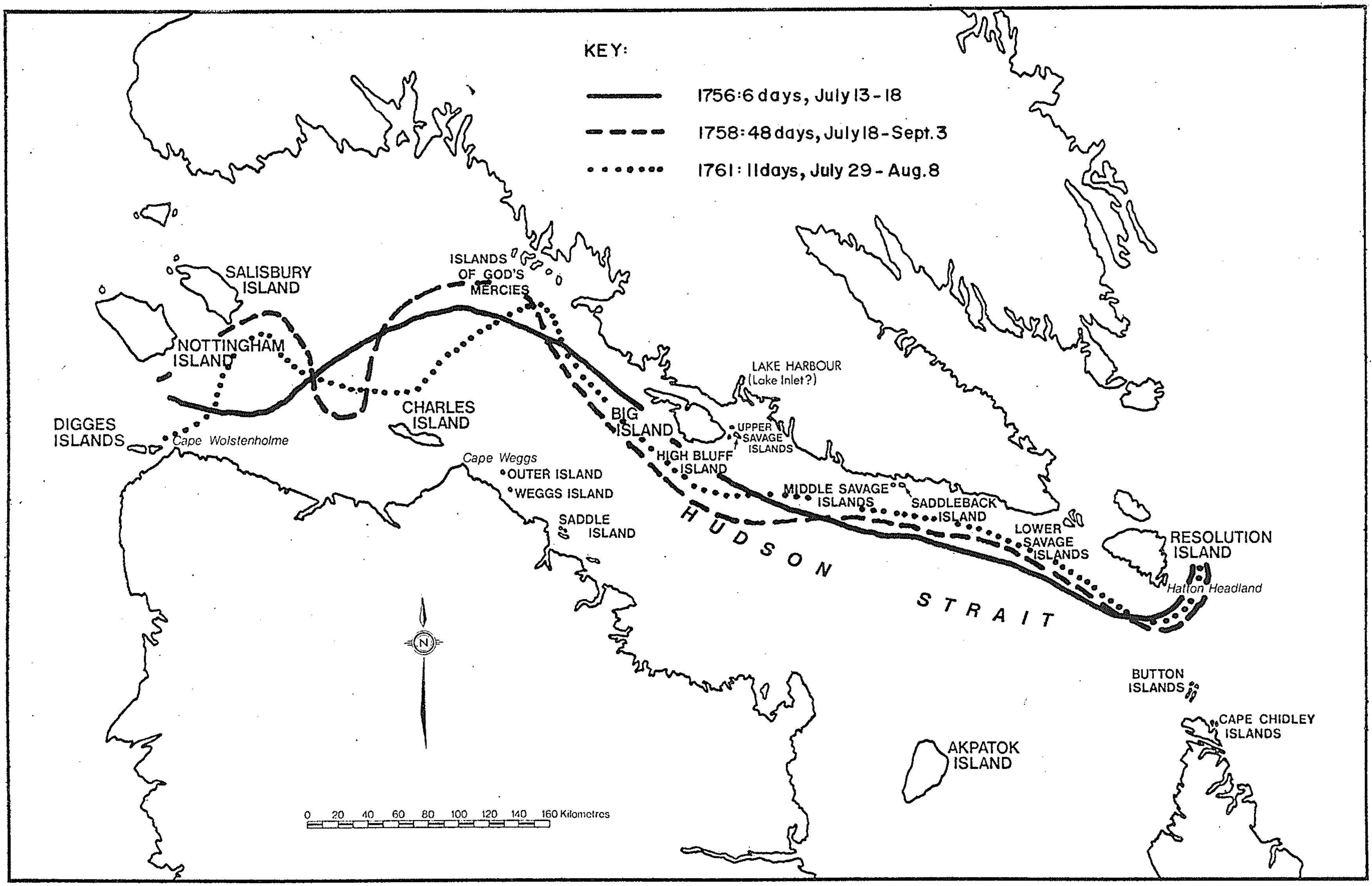


FIGURE III-8 ROUTES OF THREE WESTWARD VOYAGES subjected it to a more detailed statistical analysis. This stage of the research was a pilot study intended to provide a framework for the investigation into sea ice in Hudson Strait. The next section of this Chapter will deal with the second stage of the investigation which is the main focus of the study.

c) Analysis of navigational activities

i) preliminary analysis

Although this portion of the study was to focus on the formulation of an ice index by the examination of navigational activities, references to meteorological and trade events were also extracted from the log books. As was previously stated, if sufficient amounts of ice were present in the Strait, it would be reasonable to assume that this would have a retarding effect on the progress of the voyage. However, adverse weather conditions, as well as trade activities might also have impeded the advancement of the ships. It was for the purpose of isolating those delays which were due to ice from those due to other causes that additional data were collected.

Four navigational activities associated with the presence of sea ice were consistently recorded in the log books throughout the entire period. These activities were: being enclosed in or beset by ice; being fast in ice; grappling with ice; and tacking to avoid ice (the definitions of these terms may be found in the Glossary in Appendix B). The first two situations seemed to be representative of the most severe ice conditions, however the distinction between being enclosed by ice and being fast in ice was somewhat unclear. It did appear nevertheless, that when a ship was enclosed, it was completely immobile, whereas when it was fast in ice some movement did take place (either voluntarily or by simply drifting with the ice). Even though this conclusion was somewhat conjectural, at this stage in the analysis the two categories were kept distinct since a distinction was made in the log books. A ship which was beset by, or fast in, ice had no recourse but to remain in that state until the ice drifted away. This then, was seen to have the potential for creating major delays.

In the case of the remaining two activities, grappling and tacking, there were occasions on which these activities were conducted for purposes other than dealing with hazardous ice conditions. The following were two such situations in which ships would grapple for reasons other than for protection from ice:

i) to anchor during the night so as to avoid drifting with the currents;

and

ii) to anchor while waiting to resume visual contact with their consorts.

On many occasions, of course, tacking occurred to enable the ship to make headway into the wind or to facilitate a change in course. For the purposes of this study however, only those occasions on which it was specified in the log books that the ships grappled because of dangerous ice conditions ahead, or tacked specifically to avoid ice were transcribed.

One further point to be mentioned regarding the collection of this information relates to the fact that in most cases more than one activity may have been employed in one day. In these situations, the activity which was judged to be diagnostic of the most severe ice conditions was transcribed. The determination of which activity represented the most severe conditions was based upon: the context in which it was written, the length of the delay which it had created, and the amount of physical contact with the ice which was involved. As a result of this decision, the order of priorities was as follows: beset/enclosed (most severe ice), fast, grappling, and tacking (least severe).

With regards to the meteorological data, all references to the state of the weather were transcribed. In total, there were 10 key words which were used on a regular basis in all of the log books. These key words are listed below:

fog
haze
storm/squall (includes thunder and lightning)
gale/strong wind
rain
cloud
frost
snow
sleet
hail

When considered individually, only storms, gales, and fog were expected to create delays in the voyages. It was found however, that unless the gales were of a sufficiently strong force, and from a direction which was contrary to the course which the ships were following, no delay of a significant length of time (at least 12 hours) was experienced. In fact, based upon the comments in the log books, the only meteorological factor capable of significantly prolonging a voyage appeared to be extended periods of calm winds. Few references were actually made regarding unusually long periods of calm conditions, however each voyage recorded fog and/or haze which could have been indicative of a state of very weak winds or calm. Again however, there was no mention of extreme delays created by fog. The fog which is commonly experienced in this region is known as Arctic sea smoke. This forms when colder air overlays the relatively warmer water, thus causing condensation to occur. This fog is not so thick that visibility would be reduced to such a degree that the ships would be unable to move.

Since so little could be inferred with confidence about the relationship which may have existed between fog and duration, the final criteria in this situation was the same as that used for the other meteorological factors. Because the duration of an average westward voyage was 16 days, a delay of less than 12 hours was felt to be too short a period of time. Since there were very few accounts in the log books of extended delays being caused by calm conditions, or other meteorological conditions, these variables were, for the purposes of this study, disregarded. Furthermore, on those occasions in which fog and haze, or calm winds were experienced at the same time as a major delay, ice conditions were generally described as being a prime concern. The following are a few examples of this situation.

> "Turning to the NNW but get Little it being Little Wind and the Ice Very Close".
>
> (Log of the ship Hudson's Bay, August 10, 1753, Hudson's Bay Company Archives C1,348).
>
> "These last two days past have lost 10 leagues which is owing to the closeness of the Ice and Little Wind".
>
> (Log of the ship King George, August 10, 1753, Hudson's Bay Company Archives C1/348).
>
> "Little wind and very calm the Ice Remains very close cannot get the ships under way".
>
> (Log of the ship Hudson's Bay, July 27, 1755, Hudson's Bay Company Archives C1/350).
>
> "We have had one of the thickest fogs, I ever Knew; so that we could think of nothing, but keeping the ships clear of Ice: and therefore stood to the Eastward most of the time".
>
> (Log of the ship King George, August 4, 1776, Hudson's Bay Company Archives C1/380).

Delays due to trade were also not significant in terms of retarding the voyages to any extent. Most trade encounters lasted for only a matter of a couple of hours. The reason for this was explained in Lieutenant E. Chappell's Narrative as follows:

> "It is rather remarkable, that the habitations of the ESQUIMAUX had never before been visited by the officers of the HUDSON'S BAY ships, although they had often landed in the Straits: but this may be explained in two ways. In the first place, the ESQUIMAUX are evidently anxious to conceal their places of abode; secondly, the commanders of the Hudson's Bay ships had directions from the Company not to go on shore amongst the ESQUIMAUX themselves, nor to send their boats...."
>
> (Chappell, 1970: 111-112)

The 'Esquimaux' did however occasionally trade with the ships by meeting them in Hudson Strait in canoes, luggage boats, or on ice floes. The following quotation from one particular log book illustrates the fact that the welfare of the Hudson Bay Company's trade, was a concern to the ships' captains.

> "At 8 a.m. nine canoes and one luggage boat came off but had not any whale bone or hardly a piece of seal skin which makes me very apprehensive of some stranger being in the Straits before us".
>
> (Log of the ship King George, July 23, 1787, Hudson's Bay Company Archives C1/390).

Although trade and weather conditions undoubtedly contributed to some degree to extending the durations of the voyages, it was thought that the impact of such situations was minimal in comparison with that of ice. As a result of this conclusion, the study proceeded to focus entirely on navigational activities related to ice obstruction.

There were two further points which should be discussed before presenting the details of the analysis. These points are concerned with the effects on sailing of:

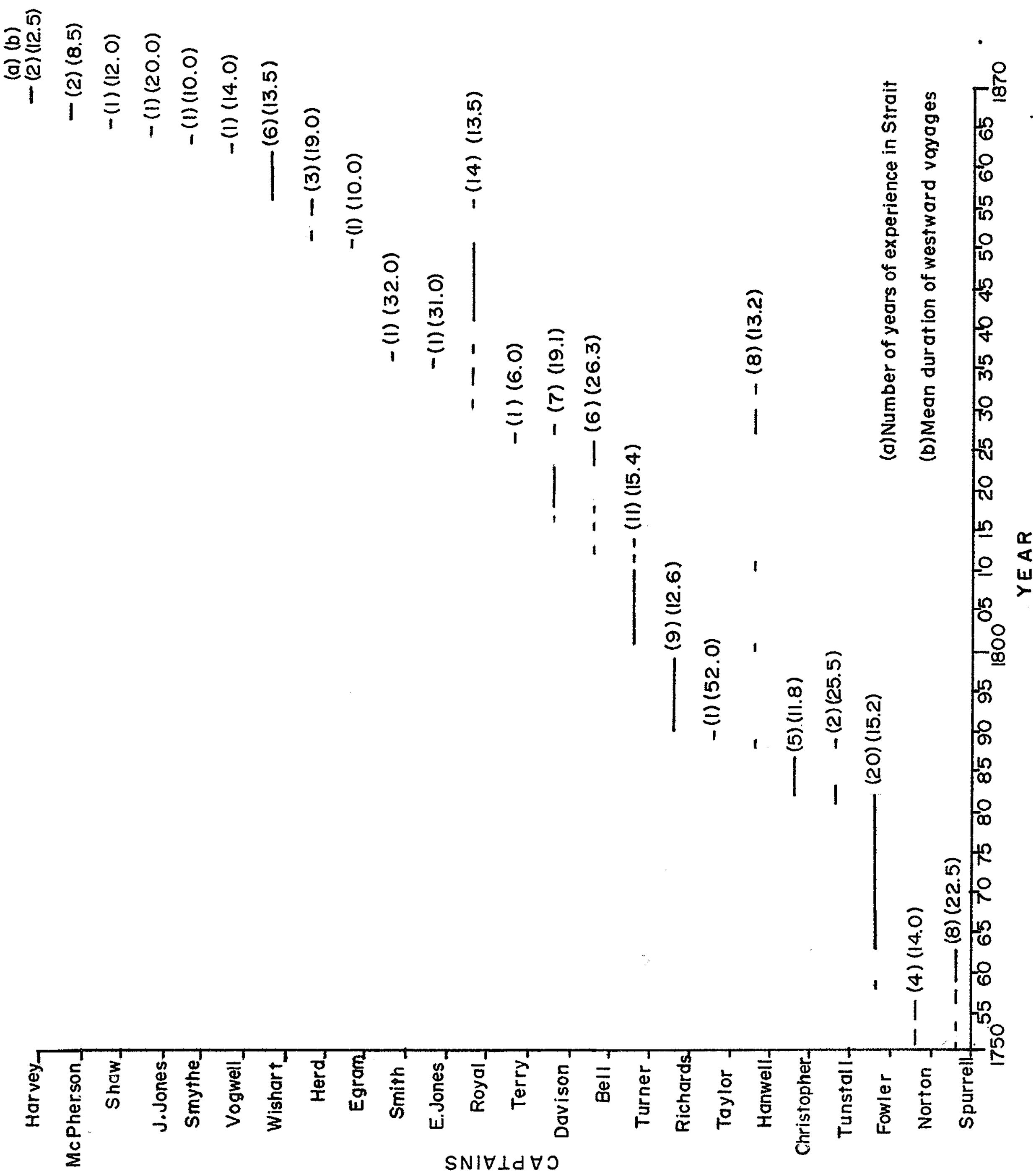
i) improvements in ship design;

ii) the amount of experience of the captains

Over the entire period encompassed by this study, it appeared that only four types of sailing vessels were used: brigs, frigates, pinks, and sloops (definitions of these types of ships may be found in the Glossary of Terms in Appendix B). The main characteristic which these ships had in common was that they were all fairly small. The fact that the durations did not lessen towards the end of the period [see Figure III.3 (b)] was possible evidence that ship designs were probably not drastically altered. This point could be disputed on the grounds that ice severity may have increased through time but that changes in the ships were able to overcome such an obstacle. Had this been the case, it would have been reasonable to assume that some mention would have been made about this situation in the log books. This was not found to be the case, however. It was assumed therefore, that any major improvements in ship designs, were not sufficient to have had a significant effect on the navigability of the ships through the Strait.

The effect of the captains' experience on the durations of the voyages through Hudson Strait was the final factor which was considered prior to the actual analysis of the navigational activities. Figure III.9 depicts the years in which each captain sailed through the Strait. Illustrated in this Figure are: the years in which each captain sailed; the total number of years of sailing experience (in the Strait); and the mean duration of the voyages undertaken by each captain. Captain Fowler had the longest history (20 years - all of them consecutive but one), and 9 captains sailed through the Strait only once. In order to test the effect of these histories on the durations of the voyages, a correlation coefficient

FIGURE III-9 CAPTAINS' HISTORIES



was calculated with the number of years of experience as the x - variable, and the mean duration per man as the y - variable. The coefficient was found to be -0.17, line A in Figure III.10 presents the regression line for this weak, negative relationship. This illustrates that as the number of years of experience increased, the mean durations decreased slightly. The coefficient of determination (r^2) illustrated that only 3% of the variation of the mean durations could be explained by the number of years of experience. Although these figures indicate that no significant relationship exists between these variables, one further examination was undertaken. This last investigation considered the same relationships which were discussed above, but in this case the record of each captain was examined individually. The results of these relationships are provided in Figure III.11. The strongest relationship between years of experience and duration was found in Captain Turner's record ($r = {}^{+}0.71$), however, the positive aspect of the relationship was unexpected. Figure III.11 (G) depicts a situation where, as Captain Turner gained experience, it took him a longer time to sail through the Strait. A similar situation existed in Figure III.11(F) (Captain Richards) to a lesser degree

FIGURE III-10 SCATTER GRAPH FOR MEAN DURATION PER CAPTAIN: NUMBER OF YEARS OF EXPERIENCE

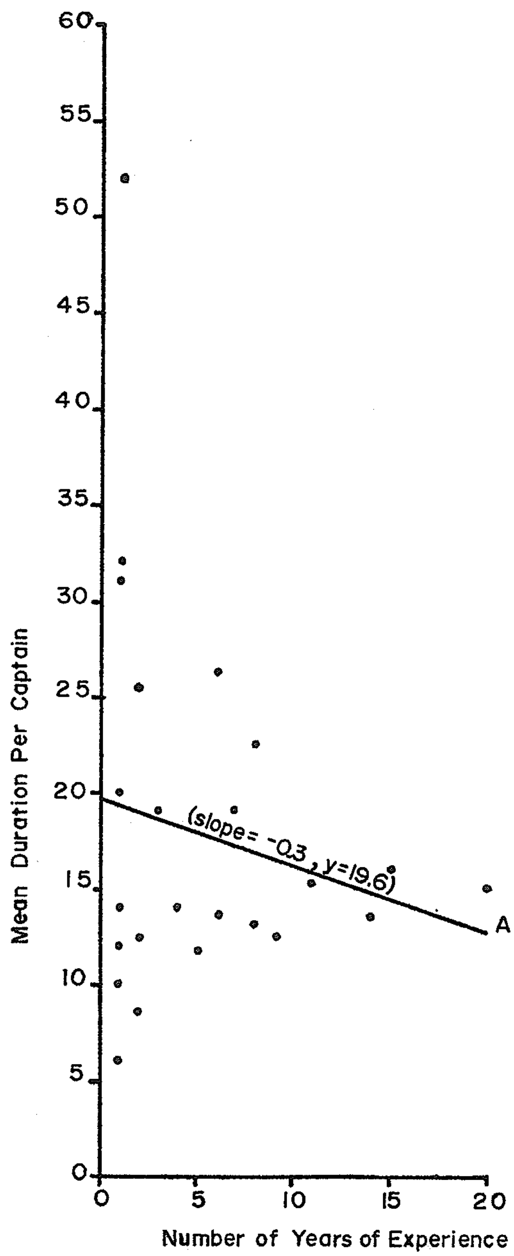


FIGURE III-11 GRAPHS OF DURATIONS PER CAPTAIN (A - G)

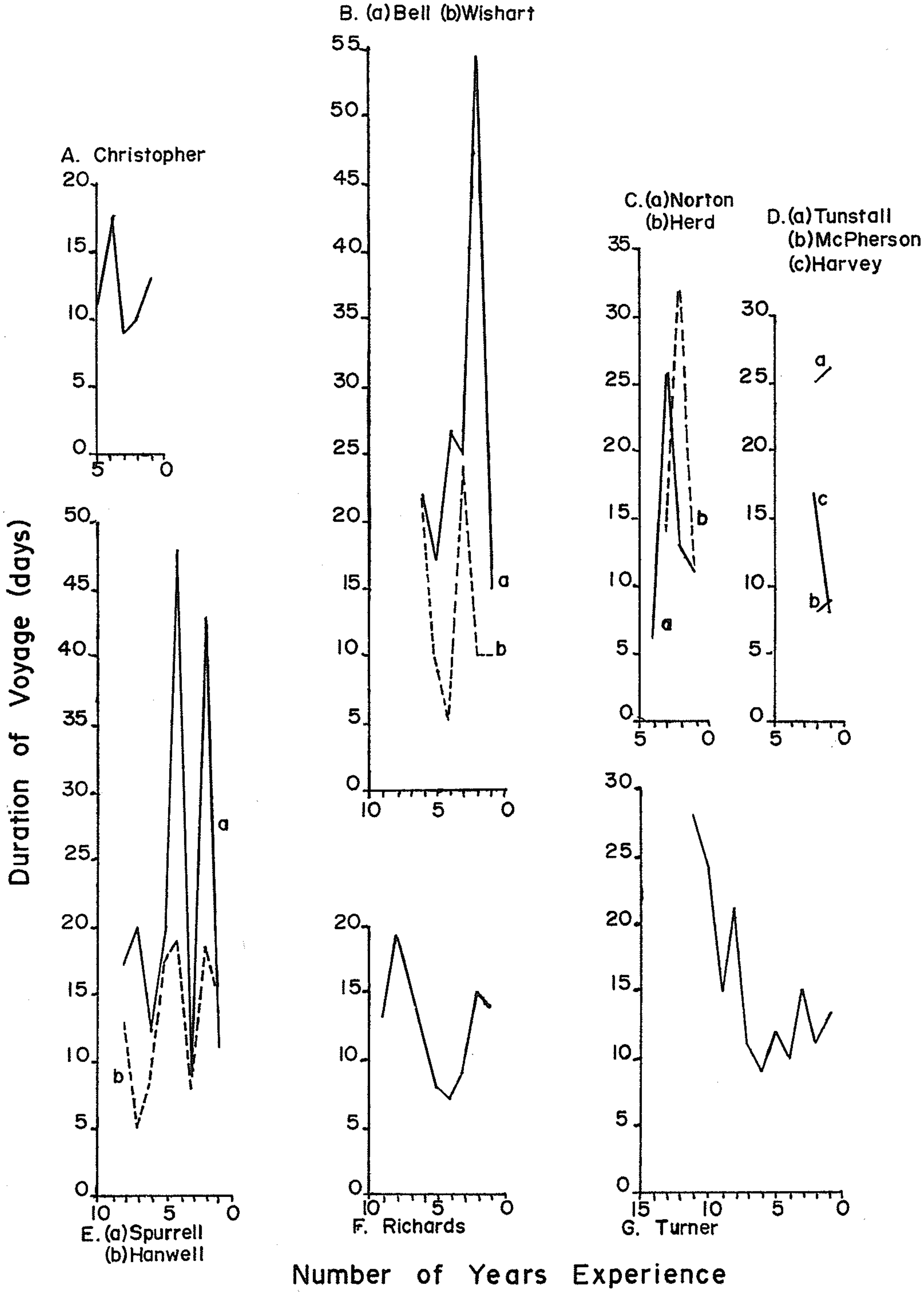
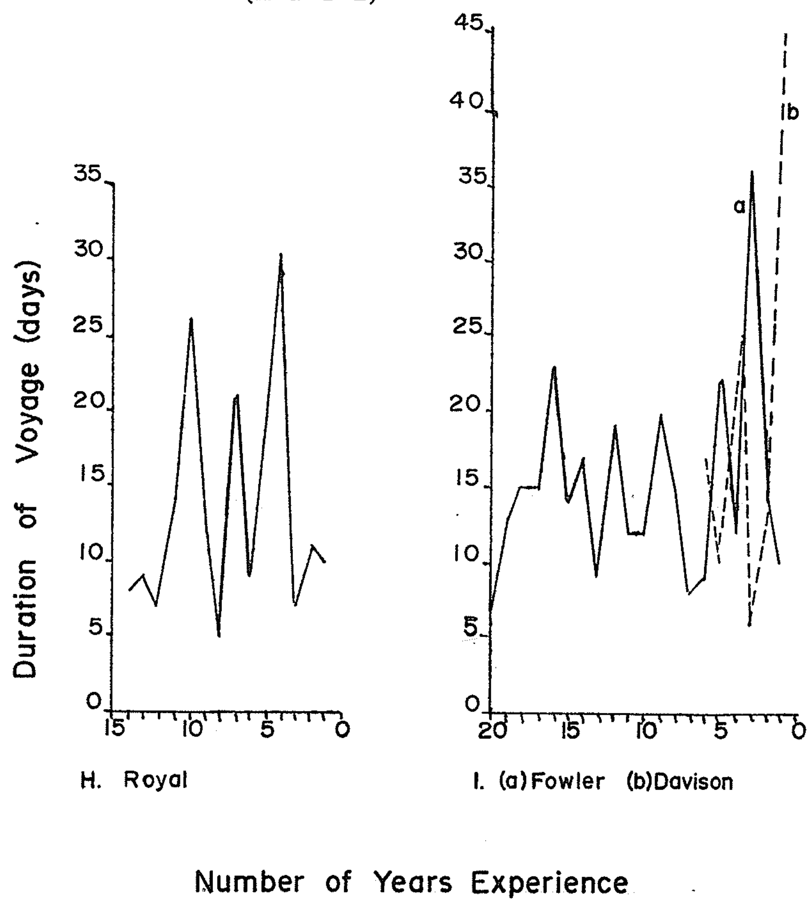


FIGURE III-11 (H and I)



(r = $^{+}$0.31). In all of the other cases, there was a slight tendency for the durations to decrease as the years of experience increased; although the average correlation coefficient (for the negative values) was only -0.2. It should be noted however, that these correlations are based on small samples and therefore, the degree of significance was low. It is also noteworthy in Figure III.11 that the durational fluctuations through time were very erratic for each captain.

The general degree of competency of each of the captains was considered to be mainly dependent upon his background. This 'human' factor no doubt played some part in the ways in which they dealt with the hazards which were encountered in the Strait. An investigation of the background and personality of each captain is beyond the scope of this study. In the light of the findings of the above correlation analyses, it was decided that the effect of experience could be omitted from the investigations of sea ice conditions.

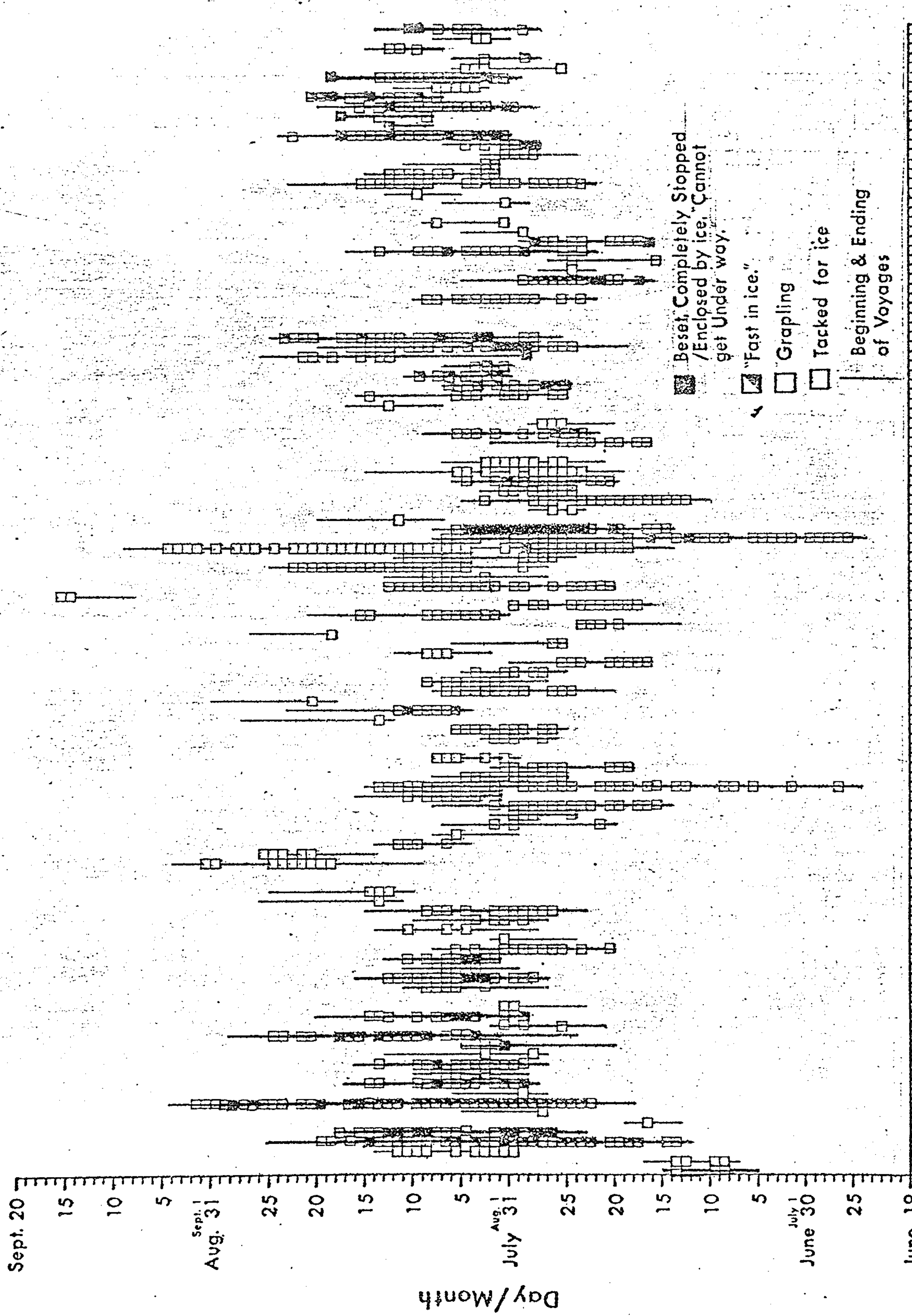
ii) temporal analysis

Due to the qualitative nature of the data the analysis was conducted by relating the frequencies of occurrence of each variable, to voyage durations. The most important characteristic of the durations is that they are 'known' quantities. Since it is not possible to equate each navigational activity with a specific quantity and type of ice, these variables are best studied in terms of their frequencies and relation with the durations, and by a relative, rather than an absolute scale of measurement.

Initially, all of the navigational data were transferred to a 'Navigation Chart' (see Figure III.12). Two factors are apparent in this chart. The first factor is the way in which the occurrences of being 'enclosed' and 'fast' are dispersed through time, and the second is the high frequency of occurrences of 'grappling'. In order to examine these two observations in greater detail, this chart was divided into its three principal components: enclosed and fast (included on one chart because of their similarity), grappling, and tacking [Figures III.13 (a), (b), and (c)].

A striking feature of Figure III.13(a) is the lack of references to being enclosed and fast between 1774 and 1815 (with the exception of

FIGURE III-12 NAVIGATION CHART



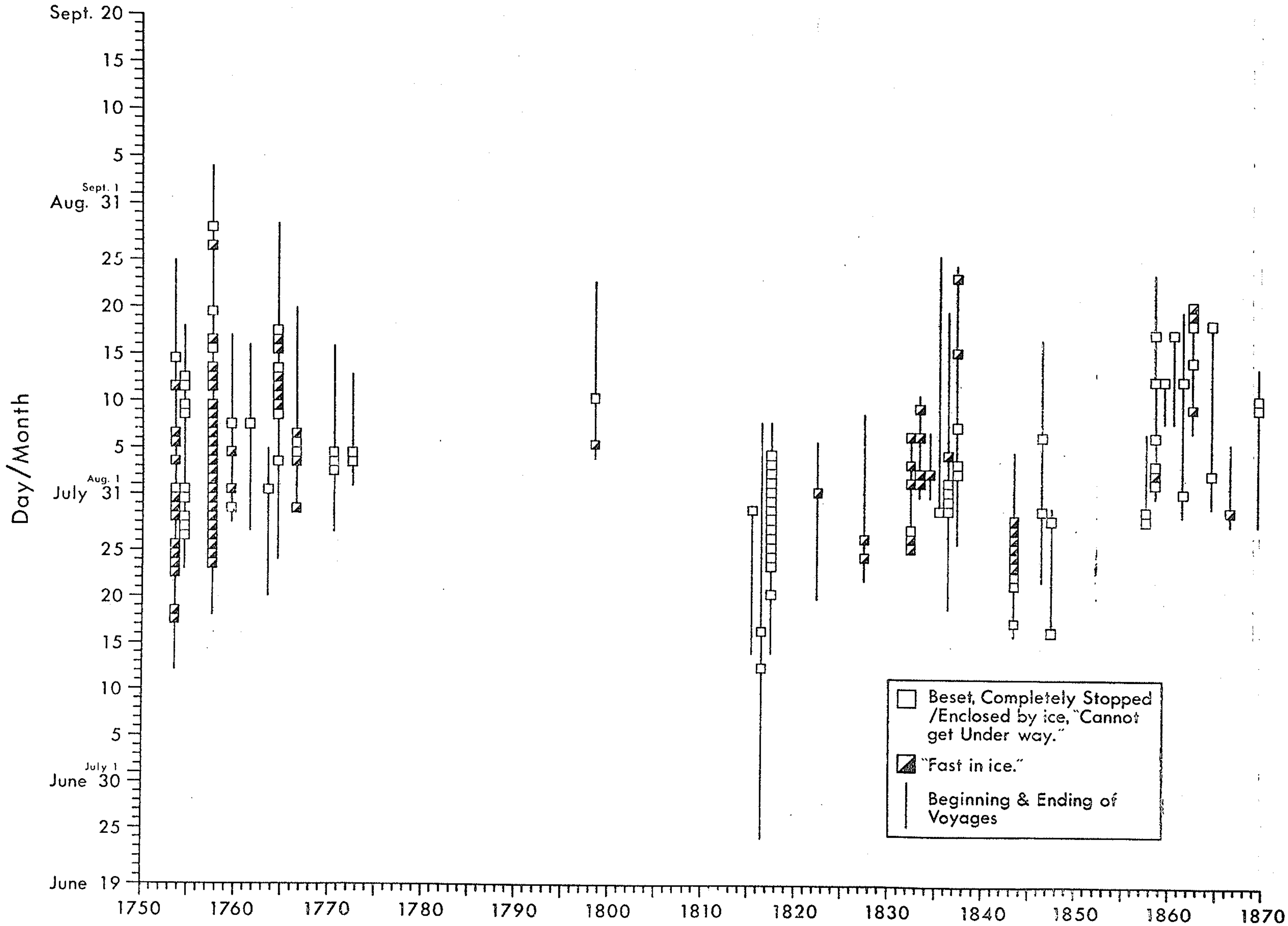


FIGURE III-13 (a) NAVIGATION CHART - ENCLOSED AND FAST

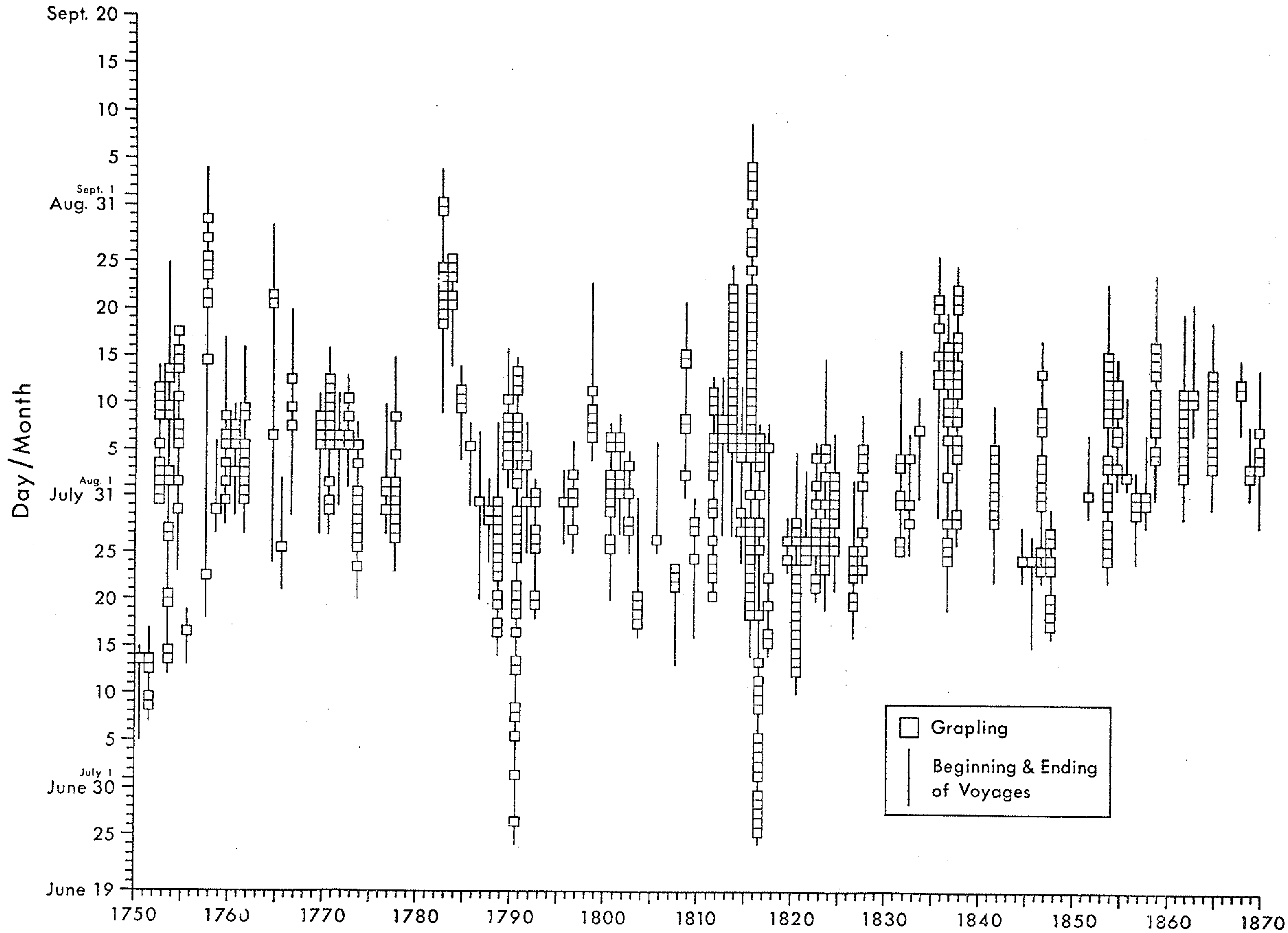


FIGURE III-13(b) NAVIGATION CHART - GRAPPLING

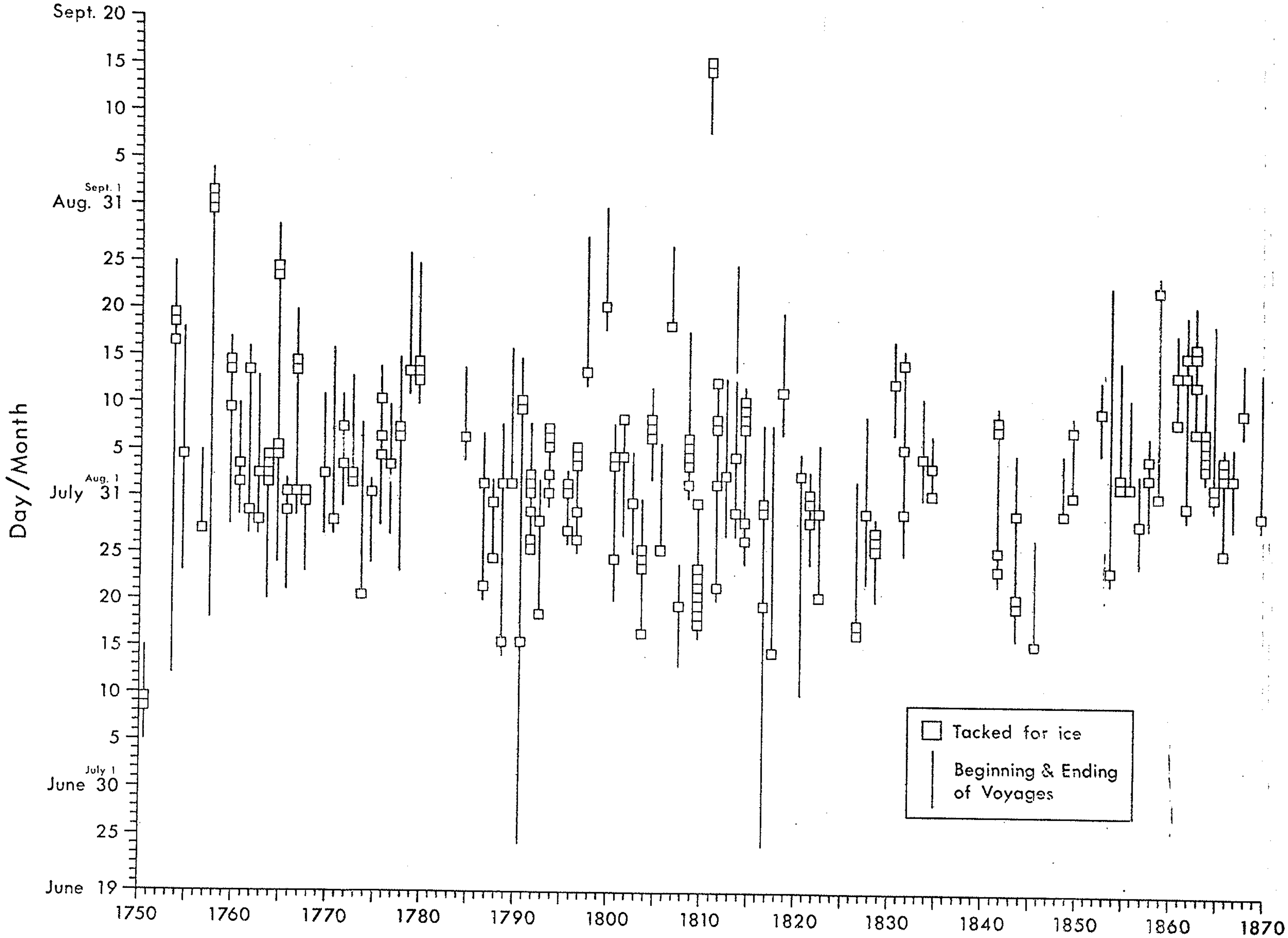


FIGURE III-13 (c) NAVIGATION CHART - TACKING the year 1798). By examining this chart in isolation the impression given is that perhaps this gap represented a period of reduced amounts of sea ice. However, when this period is re-examined in Figure III.12, this is not found to be the case. The mean duration for this period was 15.2 days (the mean for the entire period was 16 days), but included in this segment was the second-longest duration (52 days in 1791). Furthermore, only in 3 years was there no activity at all: 1781 with a duration of 12 days, 1782 - 6 days, and 1795 - 7 days. The average frequency of grappling was 4.4 days, and of tacking, 2.2 days. This was not, therefore, a period of time which was free of ice even though there were no occurrences of ships being either enclosed or fast in ice.

Figure III.13(b) illustrates the occurrences of 'grappling' per voyage. Over the entire period (1751 - 1870 inclusive), there were 560 days on which grappling represented the most severe reaction to ice. This total was more than twice that of 'tacking' (200), and almost four times that of 'enclosed and fast' (155). These figures are also graphically represented in Figures III.14 a-c. This

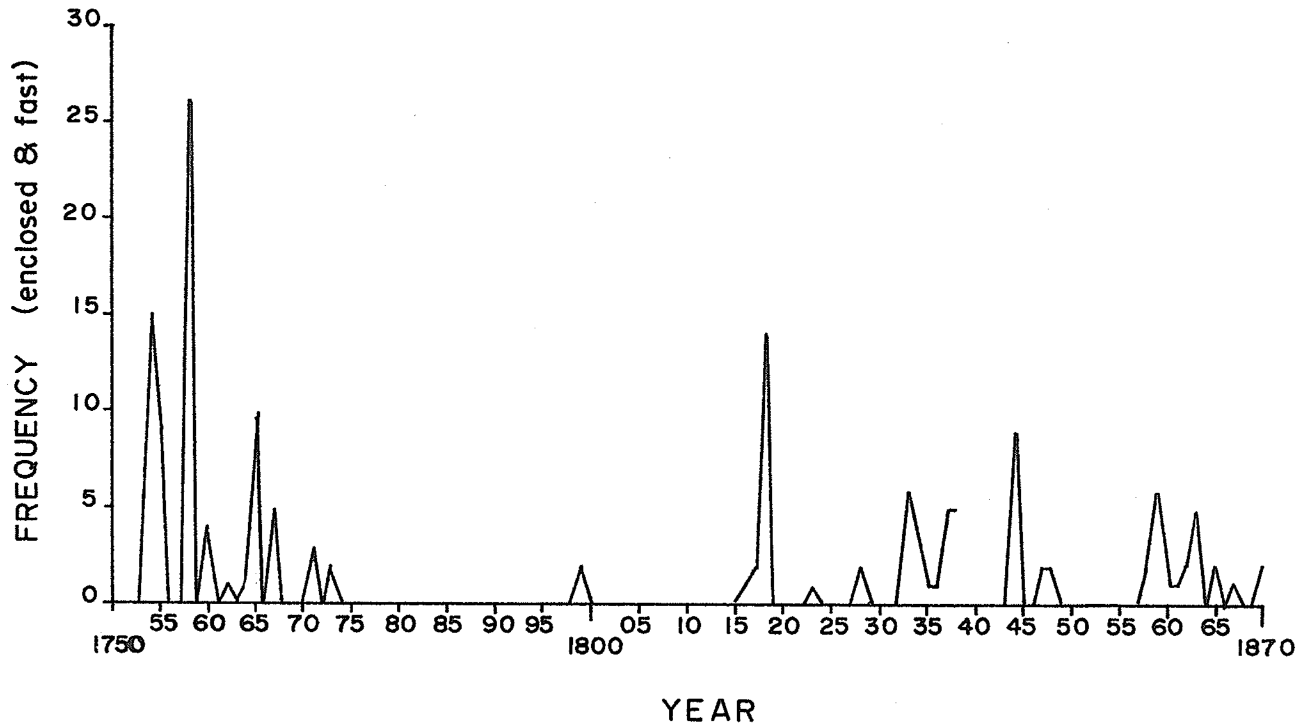


FIGURE III-14 (a) YEARLY FREQUENCY OF ENCLOSED AND FAST

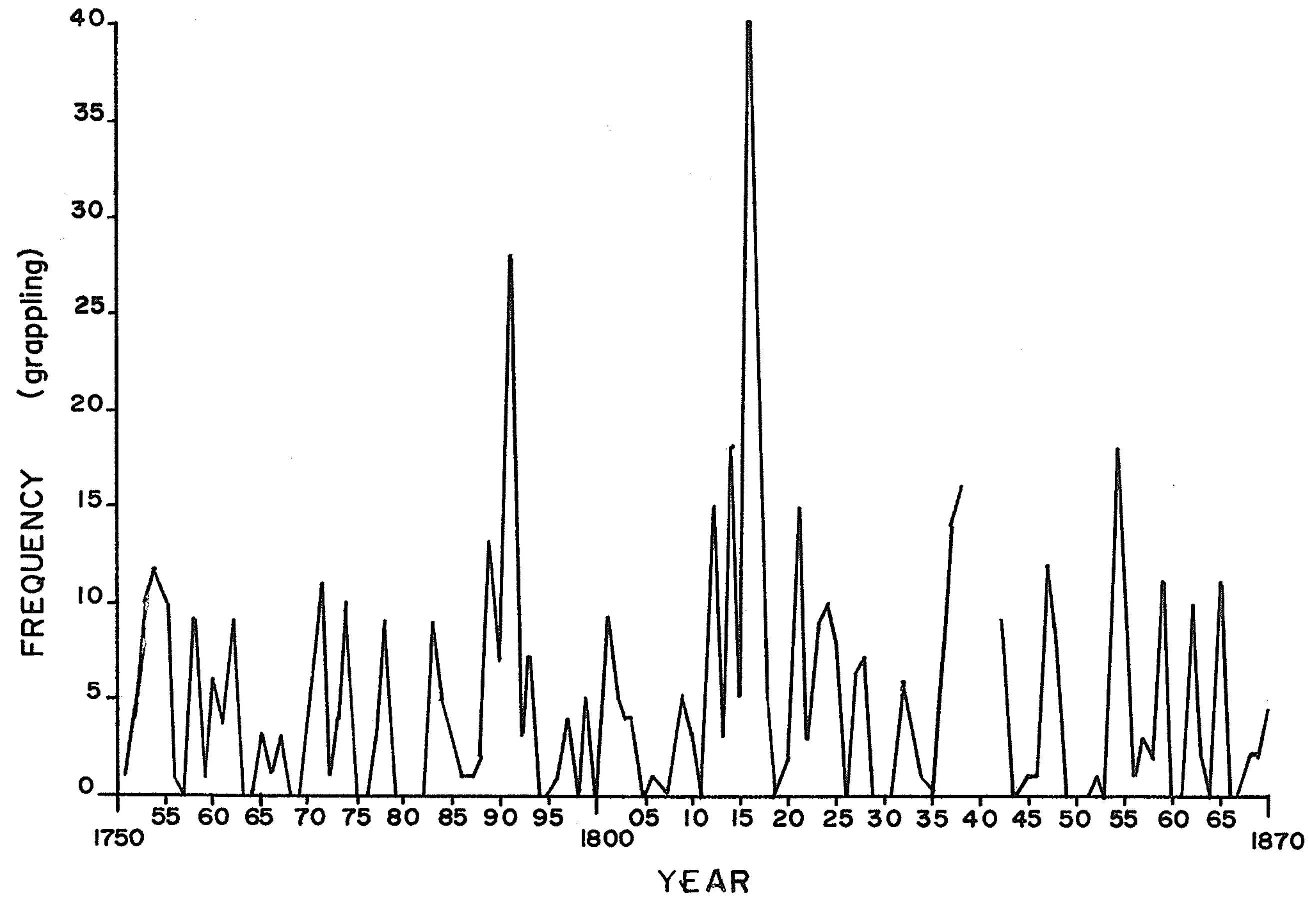


FIGURE III-14(b) YEARLY FREQUENCY OF GRAPPLING

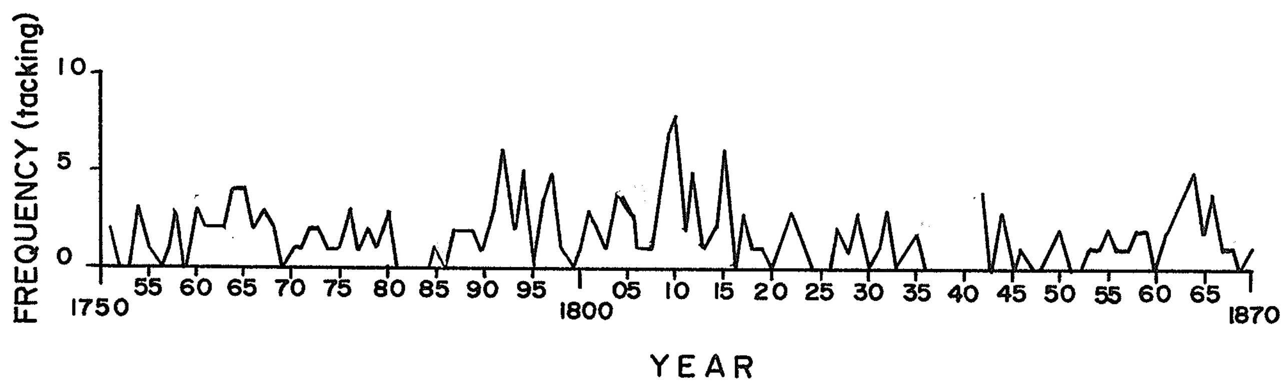


FIGURE III-14(c) YEARLY FREQUENCY OF TACKING high frequency of grappling should not be taken to mean that grappling represented a less severe situation than tacking for two reasons. The first reason being that before the data were transcribed, the decision was made that grappling represented more severe ice conditions than tacking so that in many cases, occurrences of tacking were not transcribed. Furthermore, in order to tack, enough open water had to be available in order to maneuver safely, whereas grappling took place in constricted areas. The Navigation Charts were most useful therefore, in a descriptive and organizational sense.

Using the durations as a foundation for testing the degree to which the navigational activities reflected ice conditions, a series of correlation coefficients was calculated. Table III.4 presents the results of these calculations, and is followed by a discussion of each.

In the first row, the frequencies of navigational activities have been correlated with duration. The regression lines for each of these correlations are shown in Figures III.15 (a) to (d). The strongest relationship is that between duration and enclosed and fast (E+F) plus grappling (G).

TABLE III.4: SUMMARY OF CORRELATION COEFFICIENTS

	NAVIGATIONAL ACTIVITY			
	(E+F)	G	(E+F)+G	T
Duration	+0.5039	+0.8437	+0.9200	+0.1369
Significance Level	99%	99%	99%	*
Adjusted Duration	+0.4917	+0.7268	+0.8181	-0.0458
Significance Level	*	99%	99%	*
Date of Entry	-0.1807	-0.4492	-0.4525	-0.1543
Significance Level	*	*	*	*

*Correlation not climatically significant

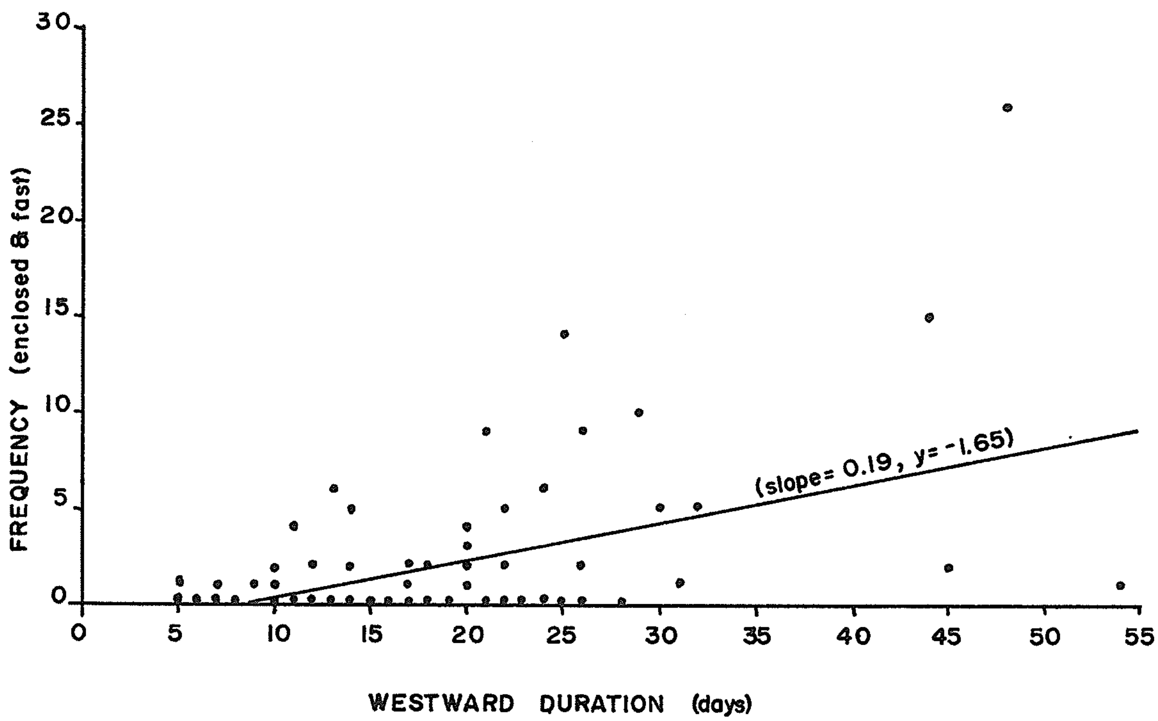
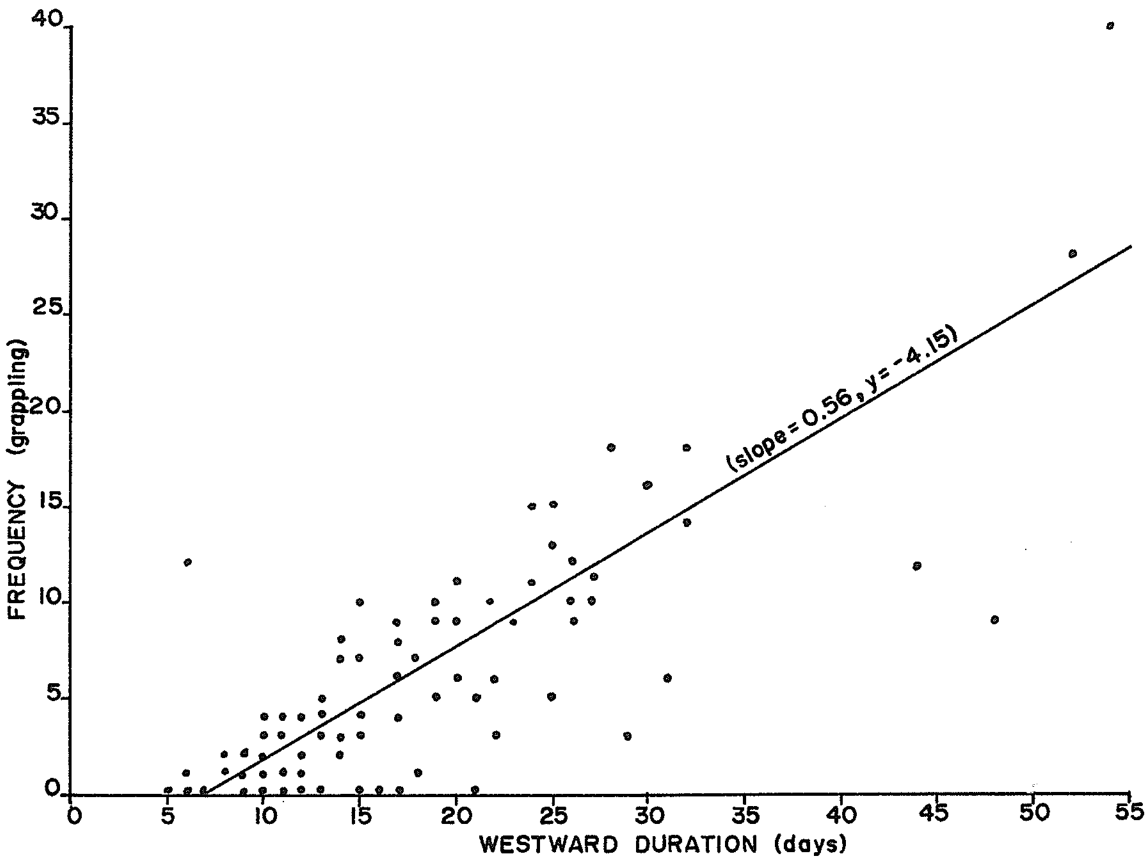


FIGURE III-15(a) SCATTER GRAPH OF FREQUENCY OF ENCLOSED AND FAST : WESTWARD DURATION

FIGURE III-15 (b) SCATTER GRAPH OF GRAPPLING : WESTWARD DURATION



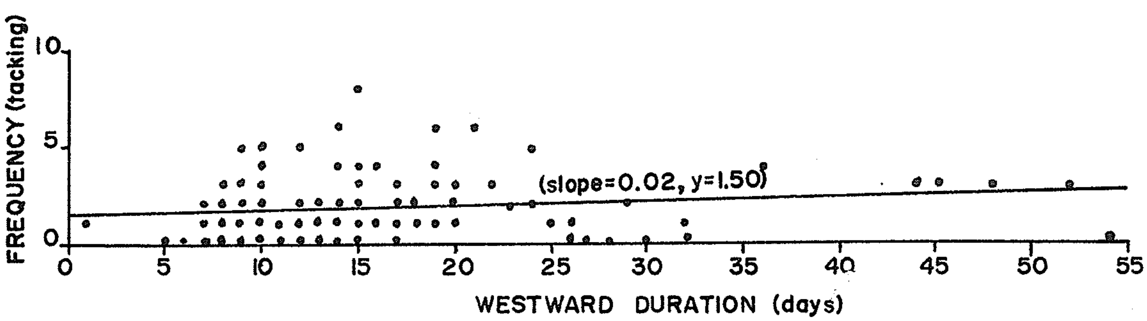


FIGURE III-15 (c) SCATTER GRAPH OF TACKING : WESTWARD DURATION

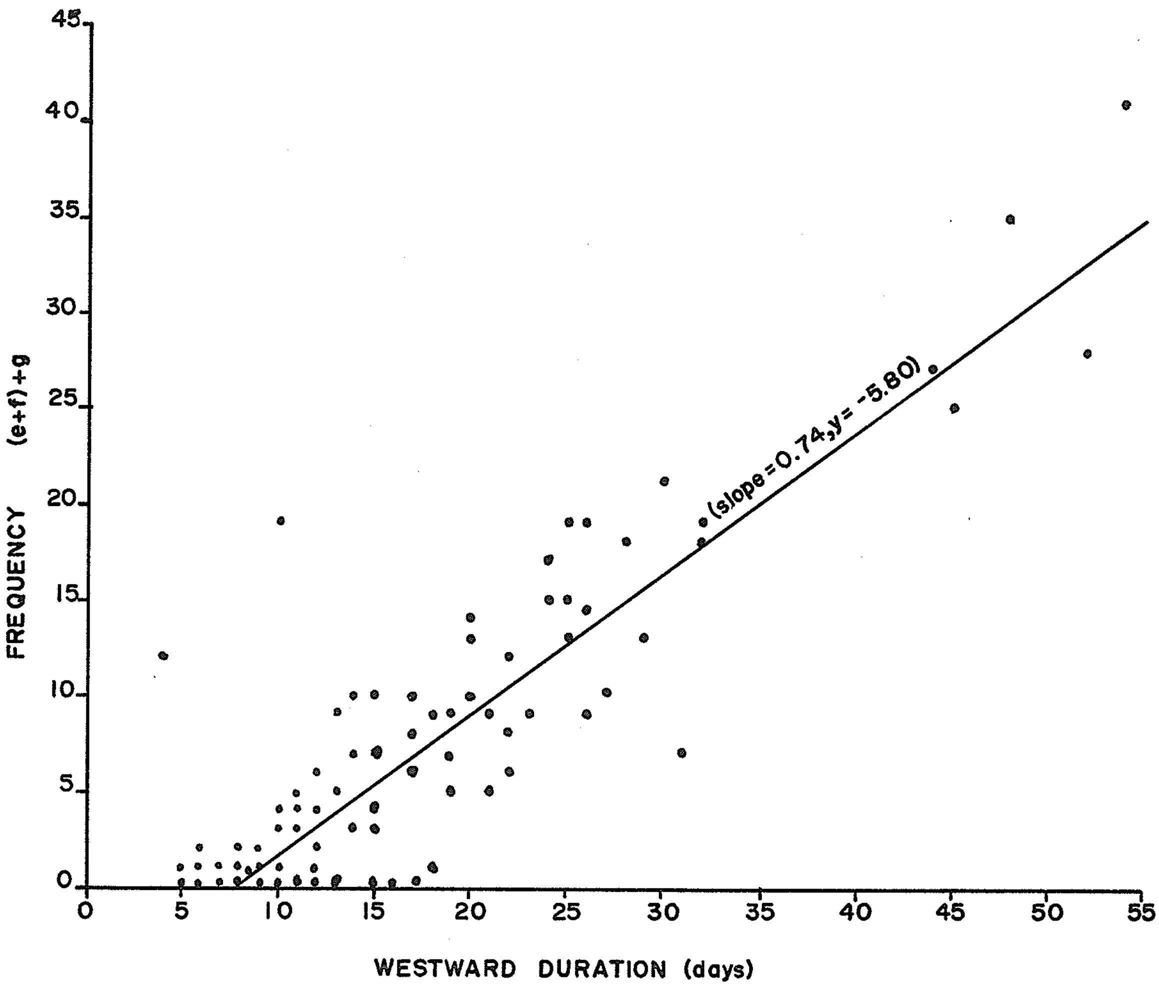


FIGURE III-15 (d) SCATTER GRAPH OF (E+F)+G : WESTWARD DURATION followed by duration and G and duration and (E+F). There is no relationship between duration and (T). A casual relationship may exist here (for the first two cases), but at this stage it would be premature to arrive at a conclusion to this effect. Tacking (T) is the only variable which does not involve ice contact, and it is also the variable which displays the lowest correlation with duration. This may be indicative of the fact that as long as the ship is tacking, it is making headway. In the case of enclosed and grappling the ship is not in motion. Further evidence of this can be seen when (E+F) and (G) are considered together, resulting in a correlation coefficient of +0.92. To more fully illustrate this relationship, 7-year running means of frequencies of (E+F)+G are graphed together with 7-year running means of duration in Figure III.16.

The second row in Table III.4 contains a modification of the previous correlations. It is felt that since the presence of sea ice in Hudson Strait varies seasonally, the date of entry must influence duration. The following equation was

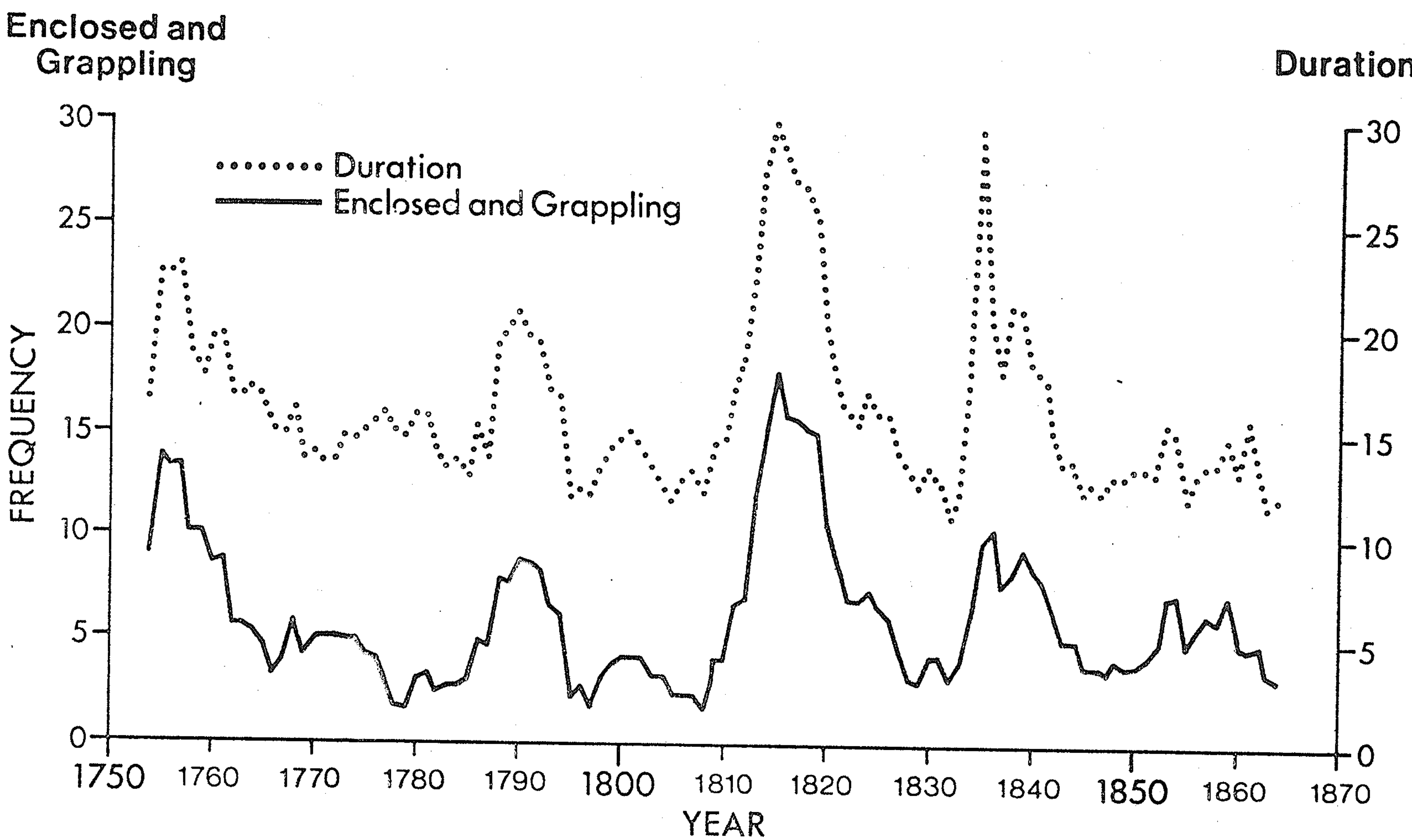


FIGURE III-16 7 YEAR RUNNING-MEANS FOR ENCLOSED AND GRAPPLING, AND DURATION applied to the data in order to correct for date of entry:

$$\text{adj. } Y_i = Y_i - b(X_i - \bar{X}) \qquad (4)$$

where: adj. Y_i = adjusted duration

Y_i = actual duration

b = slope of the regression line (for X = date of entry: y = duration)

X_i = actual date of entry

$\bar{X}$ = mean date of entry

In Table III.4 the correlation coefficients derived using adjusted durations are generally less than those derived by using actual durations, but the relationship between the values derived with (E+F)+G, G, (E+F), and T remains the same. Although these new correlations exhibit little change from the previous set, it is felt that they are closer to reality since they eliminate the effect of the dates of entry.

The bottom row in Table III.4 presents the direct relationship between the date of entry into the Strait and each of the activities. As expected, all of the correlations are negative values since early dates of entry are generally associated with the longer durations. It is noted that these correlations also diminish from (E+F)+G, to G, to (E+F), to T. This serves to reinforce the relationship between duration and date of entry, and between duration and each activity.

In general, Table III.4 makes apparant the fact that tacking is the one factor which is least indicative of the prevailing ice conditions since while tacking the ships were still in motion. Therefore, tacking was excluded from the navigational activities.

iii) spatial analysis

One characteristic which is unique to the log books, as opposed to the Hudson's Bay Company post journals and diaries, is that they recorded observations not only at temporal intervals, but also at spatial intervals. Because the ships were in motion, it is necessary to know where the observations were made as well as when they were made. Therefore, an attempt was made to determine the locations of the observations. The plotting limitations of the locational data has already been discussed, and as a result of those limitations, it is difficult to pinpoint exactly where all of the observations were made. What is required therefore, is a method of determining the general locations of the ships. In order to facilitate this, Hudson Strait is divided into seven sectors as illustrated in Figure III.17. The boundaries of the sectors are determined arbitrarily on the basis of the relative frequencies of references to specific locations. Table III.5 lists those landmarks which are used to identify the presence of a ship in each sector and to define the boundaries.

This method of tracing the routes through the Strait by sectors facilitates the utilization of much of the vague and missing data. Thus on occasions when the precise location of a ship cannot be determined, it is often possible to assign its location to a particular sector.

Before proceeding to count the number of occurrences of each activity in each sector, the area of each sector was calculated. This is necessary due to the fact that the sectors vary in size, and therefore the larger sectors have a higher probability of being occupied by a ship than do the smaller sectors. As a result of this, it is felt that the frequencies of the activities must be presented as frequencies per square kilometer. The area of each

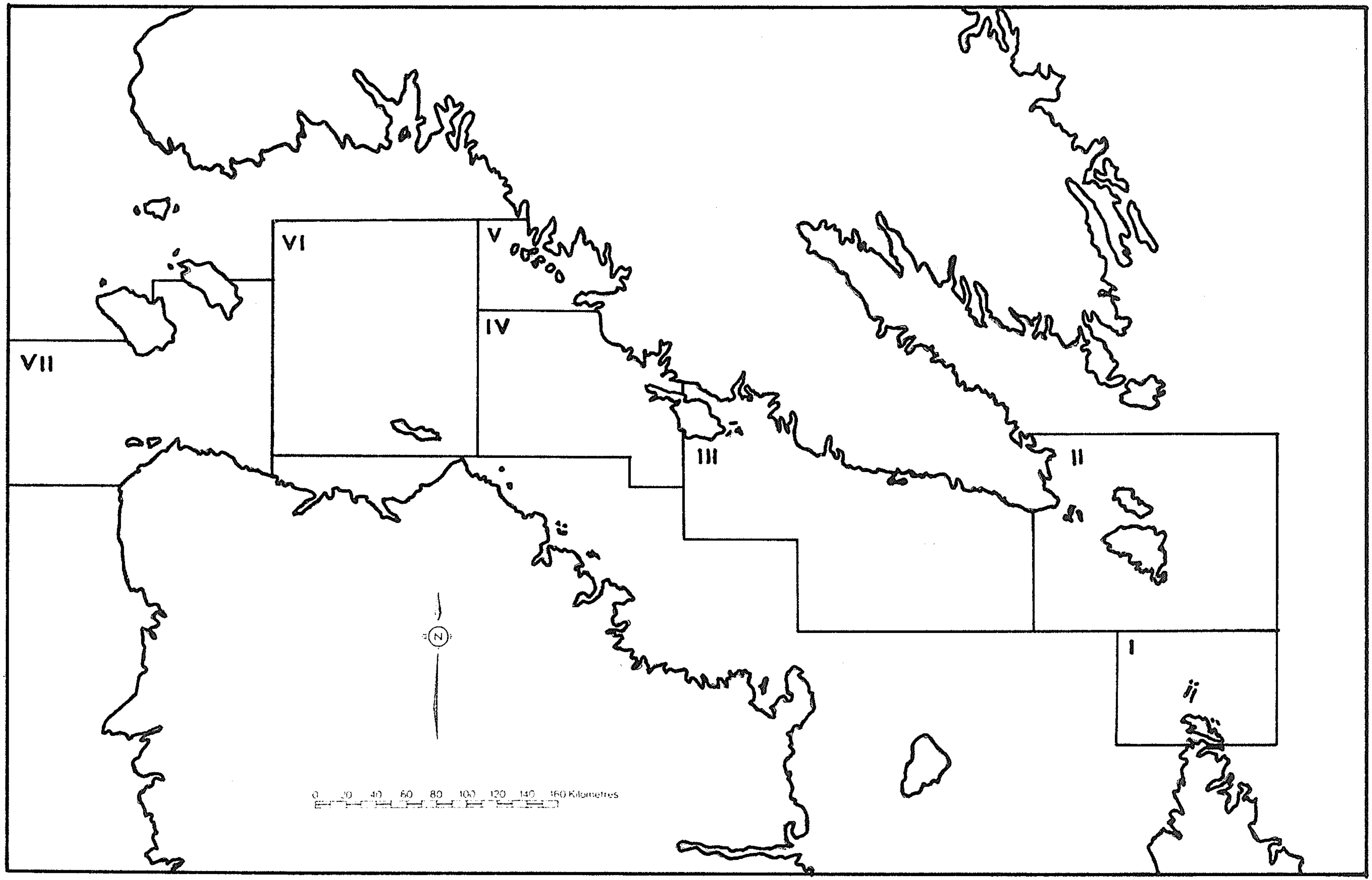


FIGURE III-17 MAP OF SECTORS

TABLE III.5: LANDMARKS FOR SECTOR SELECTION

SECTOR	LANDMARKS AND GENERAL REFERENCES
I	Buttons Island Cape Chidley Islands
II	Resolution Island East Bluff of the North Shore Lower Savage Island
III	Saddleback Island Middle Savage Island Upper Savage Island Lakes Inlet
IV	North Shore Weggs Island] when located to Cape Weggs] the S.W.
V	Islands of God's Mercies
VI	North Shore South Shore Charles Island Weggs Island] when located to Cape Weggs] the S.E. Salisbury Island - when located to the North and N.W. and by distance
VII	Salisbury Island - when located to the North and N.E. and by distance Nottingham Island Cape Wolstenholme Diggs Island

sector was determined by using a planimeter, and these areas are presented in Table III.6.

The occurrences of each activity in each sector were then counted and expressed as a frequency per square kilometer as given in Table III.7.

From this Table, it is apparant that the frequencies varied from sector to sector. Thus, Sector V experienced the highest frequency of (E+F) and Sector II the highest frequency of G. However, when (E+F)+G is considered, Sector III shows the greatest amount of activity. The last column (Rank) in Table III.7 gives the order of each activity for each sector from 1 (most frequent) to 7 (least frequent). Figures III.18(a) to (c) depict these ranks cartographically in order to illustrate where each activity was least, to most often employed.

Following this sectorial analysis a more specific examination was conducted. Even though 40% of the locational references were not sufficient to plot as point locations the remaining 60% were plotted according to the exact reference. Figures III.19(a) and (b) show the spatial distributions of these references to (E+F) and G. When these two

TABLE III.6 SECTOR AREAS

SECTOR	km^2 (ooo's)
I	8
II	21
III	23
IV	12
V	4
VI	21
VII	17

TABLE III.7: FREQUENCIES OF NAVIGATIONAL ACTIVITIES PER SECTOR

	SECTOR	FREQUENCY (f)	f/km^2 (x100)	RANK
A. (E+F)	I	2	.025	7
	II	36	.175	4
	III	62	.274	2
	IV	26	.222	3
	V	12	.339	1
	VI	7	.034	6
	VII	7	.041	5
B. GRAPPLING	I	6	.076	7
	II	156	.758	1
	III	159	.703	2
	IV	77	.657	3
	V	12	.339	5
	VI	78	.376	4
	VII	36	.212	6
C. (E+F)+G	I	8	.101	7
	II	192	.933	2
	III	221	.977	1
	IV	103	.878	3
	V	24	.677	4
	VI	85	.409	5
	VII	43	.254	6

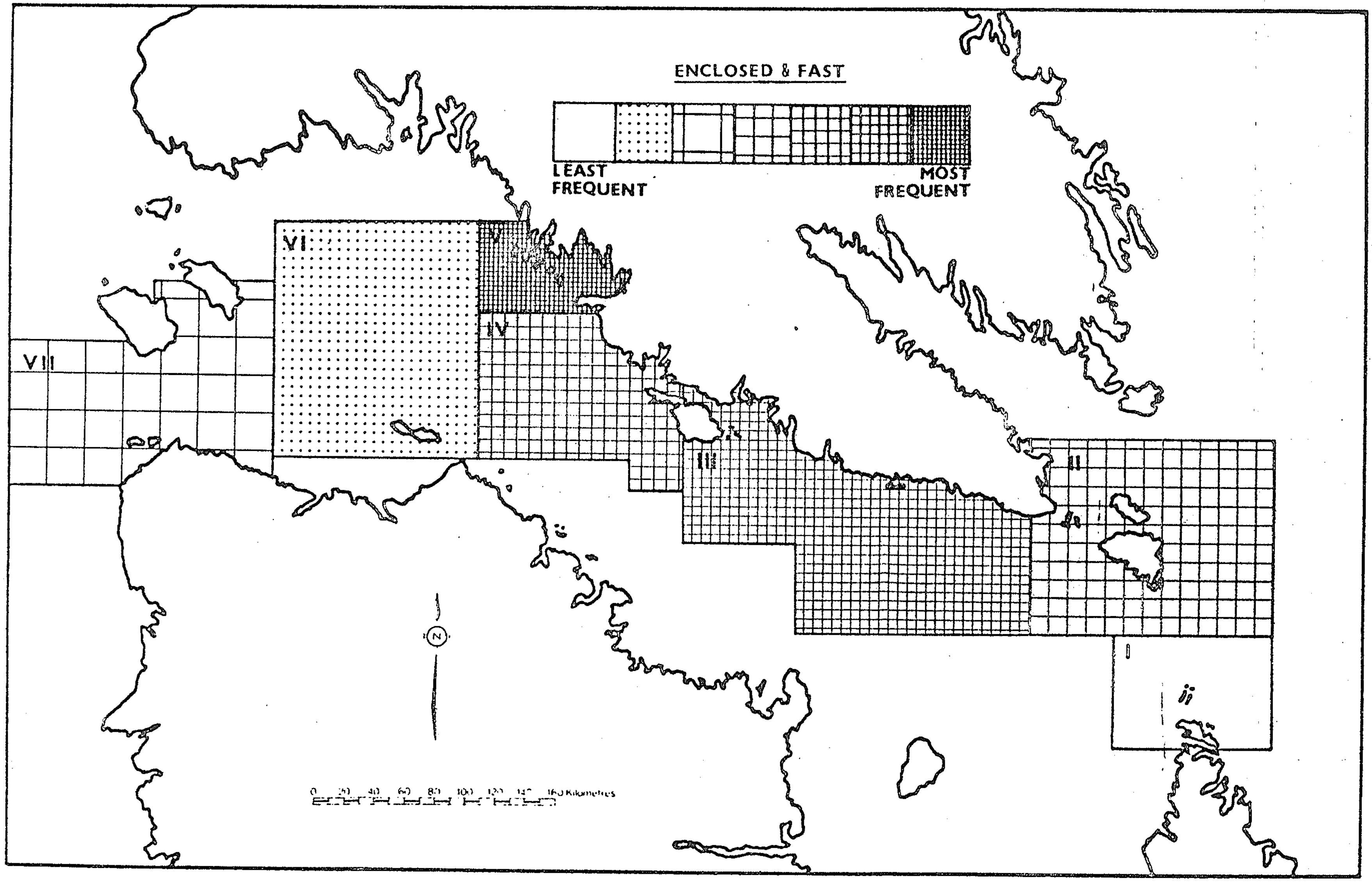


FIGURE III-18 (a) RELATIVE FREQUENCY PER AREA, PER SECTOR - ENCLOSED AND FAST

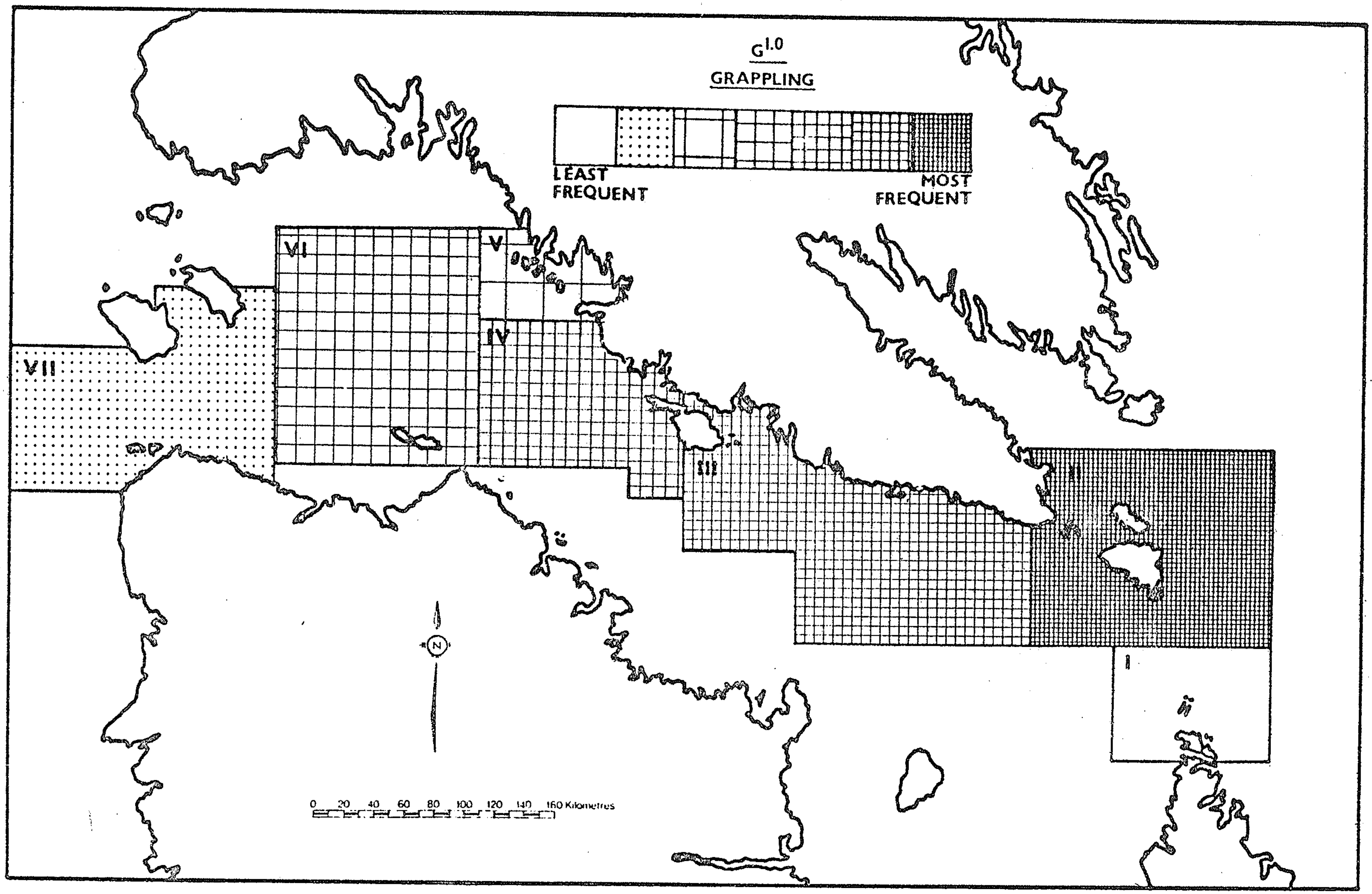


FIGURE III - 18 (b) RELATIVE FREQUENCY PER AREA, PER SECTOR - GRAPPLING

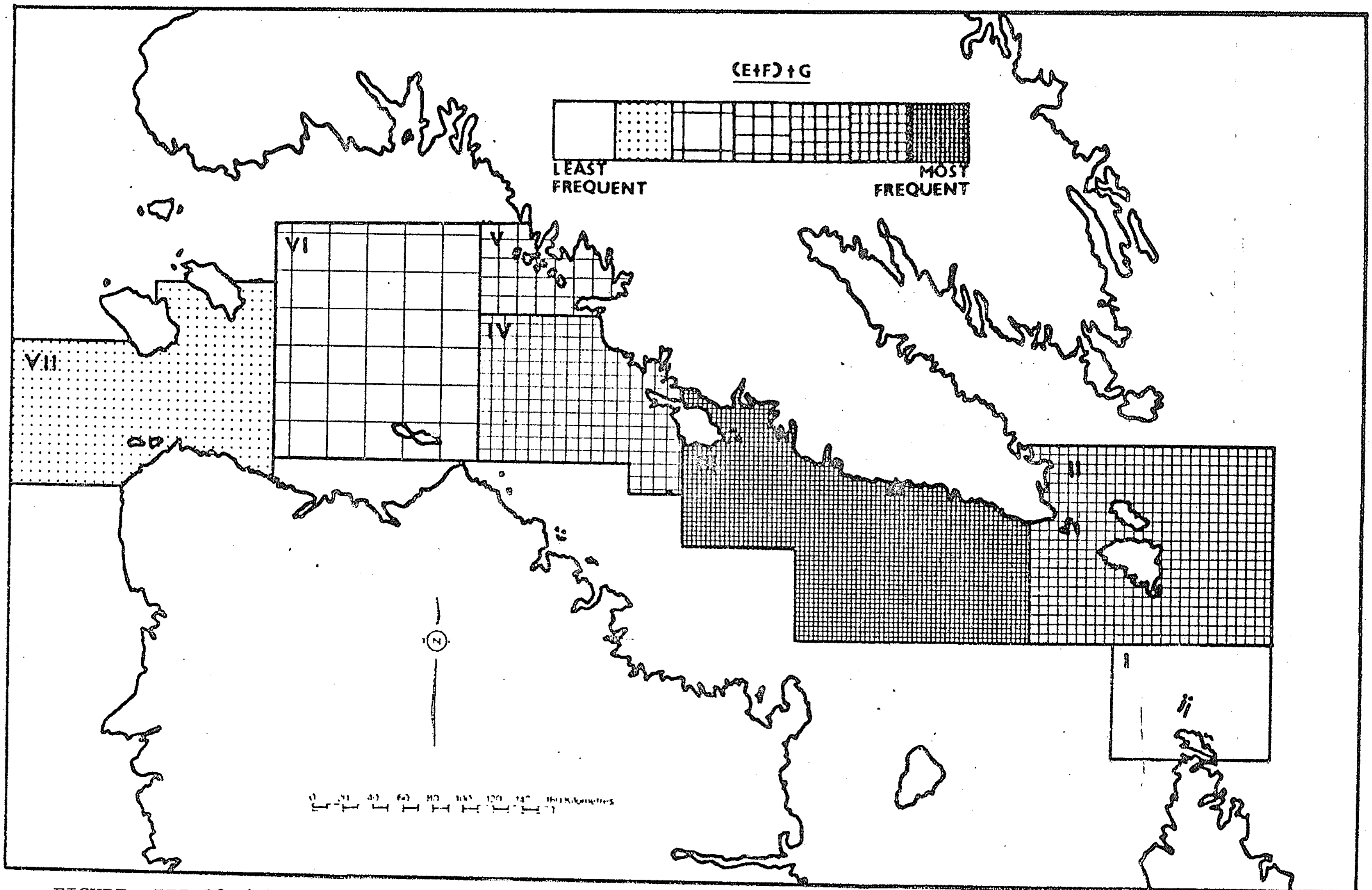


FIGURE III-18 (c) RELATIVE FREQUENCY PER AREA, PER SECTOR - (E+F)+G

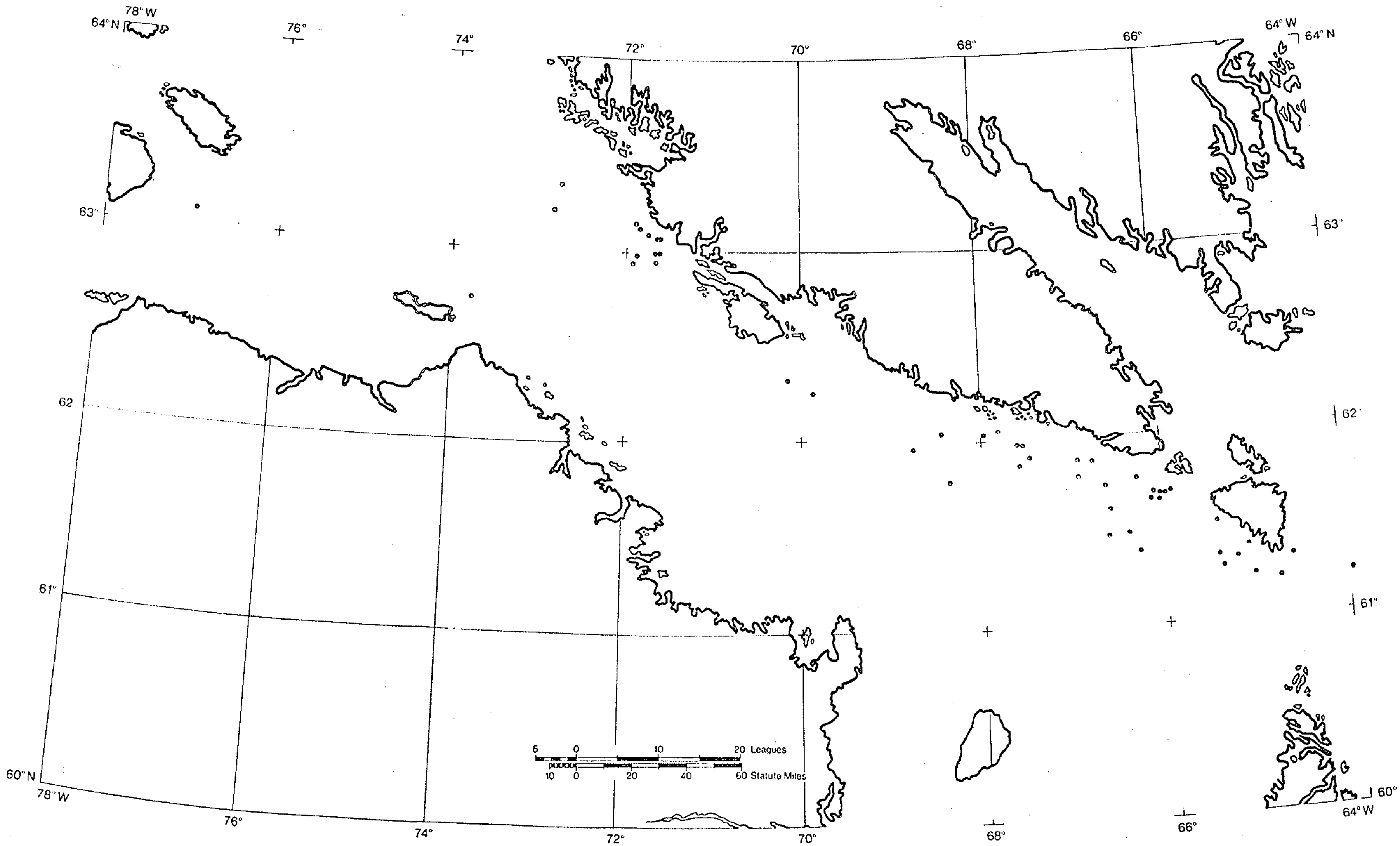


FIGURE III-19 (a)DISTRIBUTION MAP - ENCLOSED AND FAST

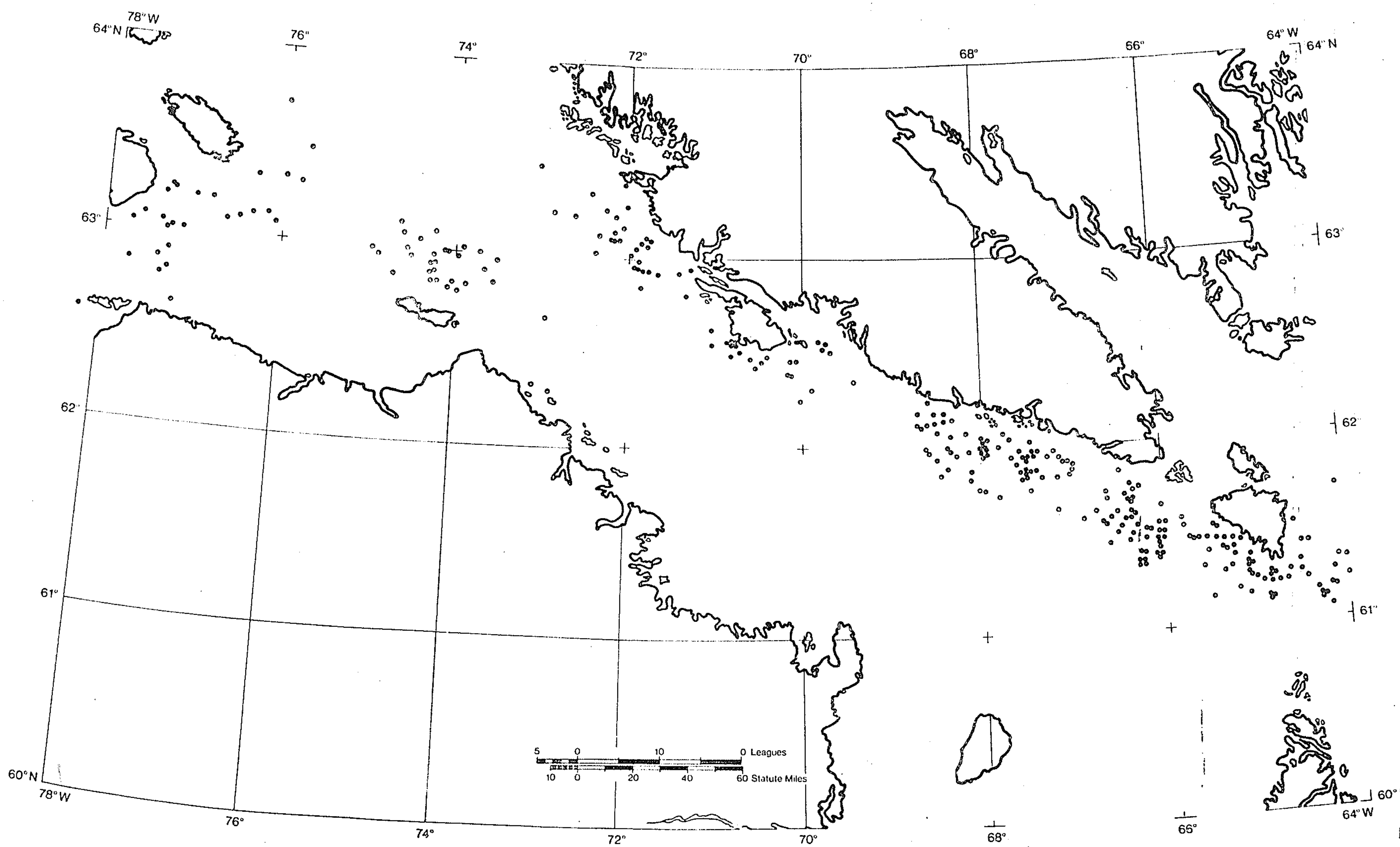


FIGURE III-19(b) DISTRIBUTION MAP - GRAPPLING maps are compared individually with Figures III.18 (a) and (b) only a weak relationship exists owing to the fact that they are based upon frequencies per square kilometer rather than absolute frequencies (as in Figures III.19(a) and (b). However, there is a much closer relationship between the two pairs of maps when (E+F)+G is considered.

3. CONCLUSION

In conclusion, this chapter has served to present the manner by which the data were collected and analyzed in attempting to devise a methodology whereby navigational data might yield some information about sea ice conditions. No attempt was made to evaluate the significance of the procedures or to analyze any of the results arising from the processes described in this chapter. An examination of the prcesses and interpretation of the results will be the prime concern of Chapter IV, Conclusion.

CHAPTER IV

SUMMARY AND DISCUSSION

Prior to the completion of this study, no comparably uniform and continuous historical source had been utilized in a study of sea ice in Arctic waters for a period of time as long as that provided by the Hudson's Bay Company's log books. In this study, those log books have been used to develop an indirect record of sea ice severity for Hudson Strait in the 18th and 19th centuries.

1. SUMMARY

a) Data

A summary regarding the data used in this study would be remiss in failing to restate their many strengths. This data source has limitations. It does not provide actual measurements of the ice, but measurements of this nature cannot be derived in the pre-instrumental period. These log books are, however, not only the sole source of sea ice data for Hudson Strait in the 18th and 19th centuries, but they probably also provide the best source that can realistically be expected.

The most significant strength of this source of data is that it is highly systematic, a quality which makes it feasible to apply the methods of analysis used in this thesis. Three characteristics contribute to the systematic nature of this record.

The first characteristic is the high degree of regularity with which the ships arrived at Hudson Strait. For 120 years Hudson's Bay Company ships sailing from England arrived at the Strait on July 27, on the average, with a standard deviation of only 10 days. The importance of this temporal regularity is that it facilitated a systematic interpretation of the log books through time.

Secondly, the ships followed approximately the same route through Hudson Strait each year. Consequently, all results derived in this study refer not only to the same time of year, but also to approximately the same routes through the Strait. It is also noteworthy that the determination of the routes is made possible by the fact that the ships often maintained visual contact with landmarks, and the resultant locational information permits the frequent identification of the ships' positions.

The final characteristic which facilitates the systematic interpretation of the log books is that their format and contents maintain an extremely high degree of homogeneity. This arises from the fact that their authors received the same general instructions regarding the format and contents of their logs since they were all in the employ of the Hudson's Bay Company.

Besides the highly systematic nature of the data source, it gains added strength from the frequent existence of multiple annual log books within the collection. Each year the Hudson's Bay Company dispatched a convoy of up to four ships destined for Hudson Bay, and at least one log book was kept per ship. Threfore, more than one log book is available for each year. A second source of multiplication arises from the fact that frequently more than one crew member kept a log book on each ship. This multiplication allows cross-checks to be made, and also permits the selection of the most complete log book to be made for each year.

b) Analysis

The original expectation was that the information examined in this study would have provided a numerical index of sea ice severity directly from the navigational activities, but each navigational activity is not associated on a one to one basis, with a specific ice condition. It is, however, possible to deduce general conclusions about the severity of ice from a knowledge of navigational activities.

The condition of being enclosed or fast in ice implies a situation where the ice cover in the vicinity of the ship is so complete that the vessel is entirely surrounded, thereby retarding or even stopping the movement of the ship and placing it in an extremely hazardous situation. It was, therefore, decided that when references to being enclosed and/or fast (E+F) were made, ice conditions were most severe.

Of the remaining two activities, grappling (G), and tacking (T), the former was regarded as being representative of the next most severe condition. Although the log books referred to 'grappling' in the sense of attaching a grappling hook to the ice, the word "grapple" has since been incorporated into modern English as meaning: "a hand-to-hand fight....to wrestle....to try to cope" (Webster's New World Dictionary, 1977). These definitions, as well as the original definition (see Appendix B) imply that grappling was an extreme measure to take and involved considerable risk. This leads to the conclusion that unless the ice conditions were of a severe and dangerous nature, this operation would not be performed.

The final activity which was related to the presence of ice was 'tacking'. This was simply an avoidance measure which involved turning out of the way of ice. Two conclusions can be drawn from this: i) the ice was sparse enough to leave room for the ship to change its course; ii) while tacking, the ship was still in motion, therefore, creating a minimal delay in the voyage.

The durations of the voyages were incorporated in this study since they also provide quantifiable measures. In order to incorporate this element, one fundamental premise must be accepted, and that is that there was a motivation on the part of the ships' captains to execute the voyages through the hazardous waters of Hudson Strait as quickly as possible with the least amount of risk. On no less than three occasions did Lieutenant E. Chappell, in his <u>Narrative</u>, note that the crew were not happily anticipating the voyage through Hudson Strait.

> "Nothing could exceed the consternation and astonishment of every person on board, to find we were directed to proceed, almost immediately, for HUDSON'S BAY! - Had we been ordered to the NORTH POLE, there could not have been more long faces among us. Down fell, at once, the aerial castles which had been so long building; and nothing remained but the dismal prospect of a tedious voyage, amidst icy seas, and shores covered with eternal snows."
>
> (1970: 5)

> "The boat returned in the morning, with the purser in sad distress; eight men having deserted from the boat, from an antipathy to the voyage."
>
> (1970: 10)

> "We had been long wishing to get into the STRAITS; and now that objective was accomplished, we as sincerely wished ourselves back again into the ocean."
>
> (1970: 49)

Prolonged periods of adverse weather were found to occur rarely and, therefore, keeping in mind the desire to pass through the Strait quickly, sea ice was determined to be the prime cause of delay to the voyages. In order to ascertain a more distinct connection between sea ice and the navigational activities, these activities were correlated against the durations of the westward voyages (the results of which are to be found in Table III.4). These calculations were conducted to ascertain whether variations in duration were significantly determined by the frequency of occurrence of navigational maneuvers required to avoid ice. This was shown to be so in the case of E+F (r=+0.50) and G (r=+0.84), and was particularly evident when the two [(E+F)+G] were considered together (r=+0.92). The insignificance of T as a delaying factor was also shown when correlated against duration (r=+0.14).

Another factor illustrated in Table III.4 is the comparative unimportance of dates of entry into Hudson Strait. As stated in Chapter III, one would tend to assume that since sea ice is a seasonal phenomenon, the time of year at which the ships were in the Strait would have a major effect upon the amount of ice which was encountered. It was found, however, that the relationships between the dates of entry and durations, and between the dates of entry and the frequency of the navigational activities, were weak. The correlation coefficient for the relationship between the date of entry and duration was -0.40. Therefore there was a slight tendency for the durations of the voyages to decrease as the dates of entry increased. However, with a correlation of -0.40, only 16 percent of the variation in the duration is explained by the date of entry. This might be attributable to the fact that the variation in the dates of entry was small (standard deviation = 10 days), and therefore, the ships did not generally enter the Strait at widely different times of the year. The effect of the dates of entry was, nevertheless, taken into account, and the durations were adjusted accordingly [equation (4)]. The result of this adjustment was to reduce the correlation coefficients slightly, but not to alter the order of ranking of the activities in terms of their correlation with duration (see Table III.4).

2. DISCUSSION

a) Temporal variations

By accepting (E+F)+G and the durations as indicators of general sea ice conditions, one may obtain an impression of how ice conditions fluctuated through time. Figures IV.1(a) and (b) show yearly fluctuations of durations and of (E+F)+G respectively. From these graphs, two important points should be noted: i) the high degree of correspondence between the durations and (E+F)+G, and ii) the existence of

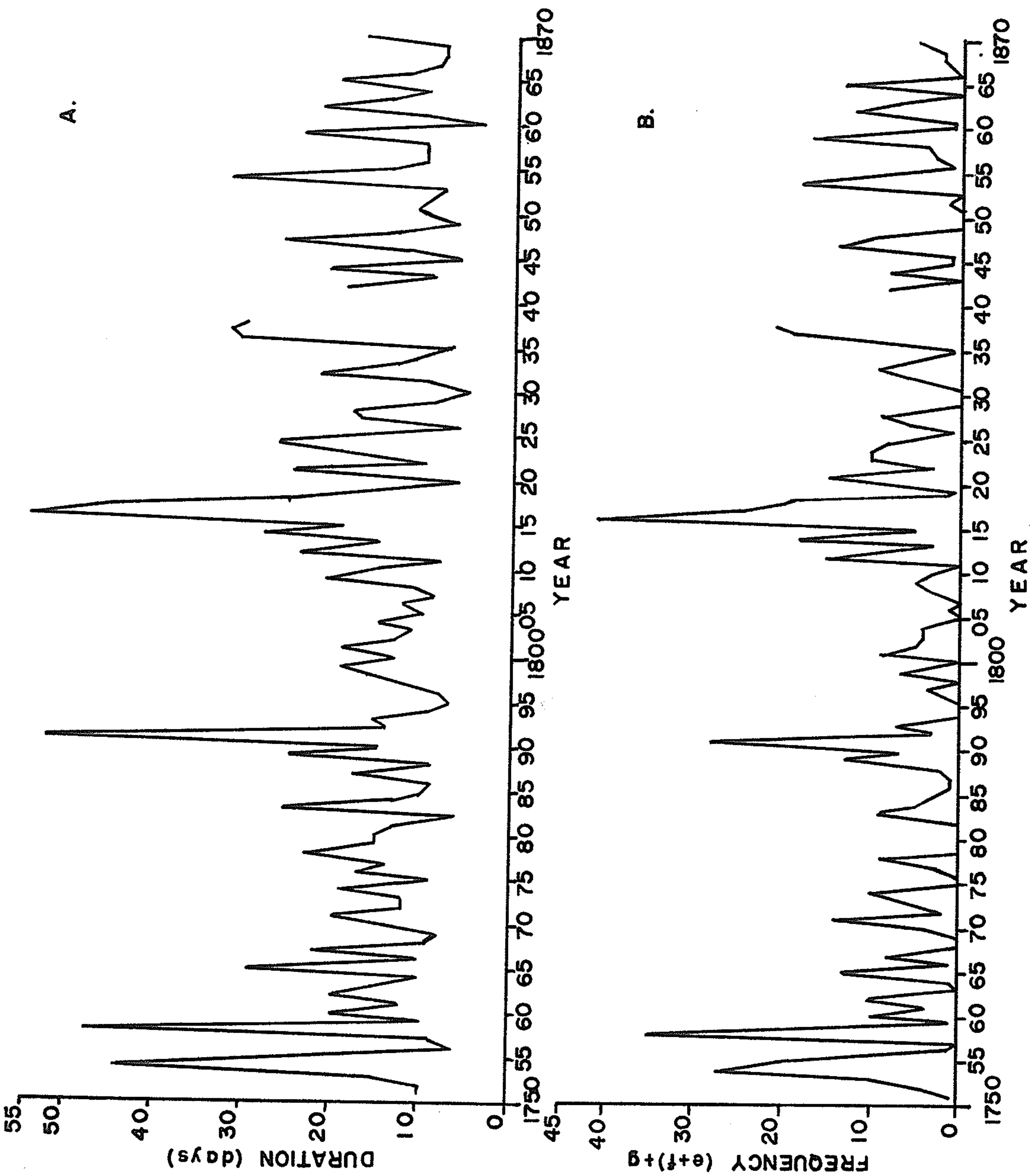


FIGURE IV-1 YEARLY DURATION (A) AND FREQUENCY (B) OF (E+F)+G three peaks indicating years with long westward voyages through the Strait, coupled with frequent occurrences of (E+F)+G. These periods of extended durations have been identified in Table III.3 as being: I - 1754, 1755, 1758; II - 1791; and III - 1815, 1816. When considered in terms of 7-year running means, however 4 periods of long durations and frequent occurrences of (E+F)+G emerge, as can be seen in Figure III.16. These periods are listed in Table IV.1.

Although the fourth period appears as a major peak, it does not exist when the data are considered on a yearly basis, rather than as an average.

The third period is interesting to note, since it includes the time known as 'the year without a summer'.(Hoyt, 1958). This climatic anomaly has been well documented for Europe and the northeastern United States (Hoyt, 1958; Post, 1977; Ladurie, 1971; and Wood, 1965), but not for the more northerly regions of the globe. The fact that the unusual years of 1815-16 are reflected in Figures III.16 and IV.1(a) and (b) is encouraging as it may signify that the durations and frequencies of (E+F)+G do, in fact, reflect the prevailing ice conditions.

TABLE IV.1: PERIODS OF LONG WESTWARD DURATIONS AND FREQUENT ACCOUNTS OF (E+F)+G

(Based on 7-year running means)

PERIOD	YEARS	AVERAGE DURATION FOR PERIOD (days)	AVERAGE FREQUENCY OF (E+F)+G FOR PERIOD
I	1754 - 60	23	13
II	1787 - 93	21	9
III	1814 - 25	24	13
IV	1835 - 42	24	11
MEANS	1751 - 1870	16	6

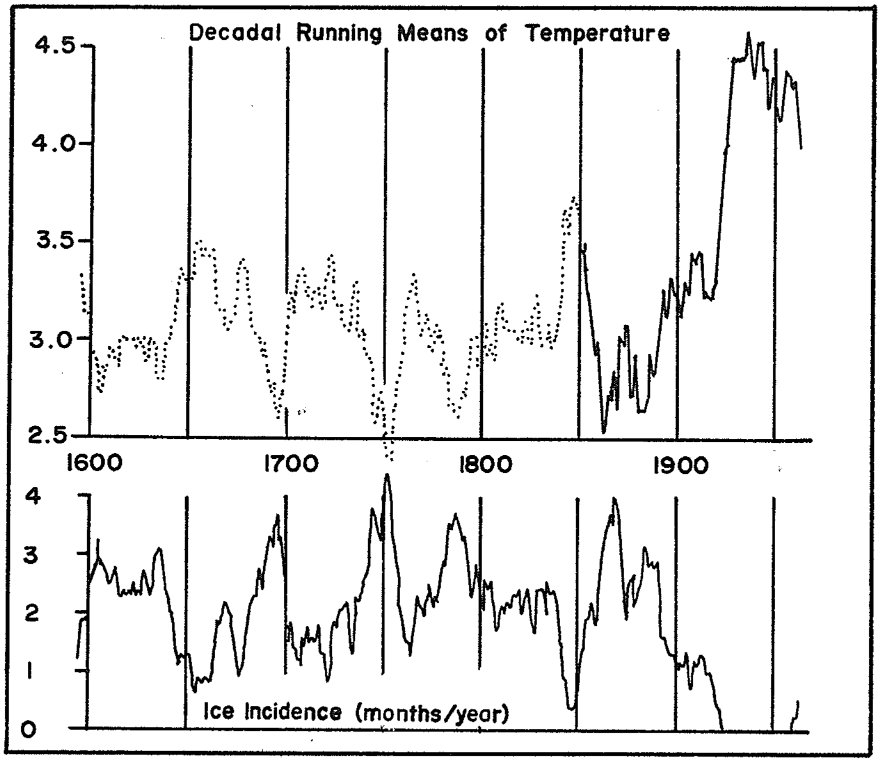
The peaks exhibited in the first and second periods (1754 - 1760 and 1787 - 1793) are also apparent in a study by Bergthorsson (1969) in which he examines Icelandic drift ice and temperature for the past 1000 years. To arrive at his conclusions, Bergthórsson employed three sources of data:

i) annual mean temperatures for two stations (Stykkisholmur and Teigarhorn, Iceland) for the period 1846 - 1873;

ii) annual number of days in which ice occurred on the coast, based on data compiled by Thoroddsen (1915-16) for the period 1781 - 1915, and on "indirect information regarding general weather in Iceland" (Bergthorsson, 1969: 94) for 1591 - 1780;

iii) the number of severe years per decade. This last source includes those years with reports of starvation or of drift ice reaching the SW coast of Iceland, and it completed the record by extending it back to the 10th century. Figure IV.2 presents Bergthorsson's results of temperatures and ice incidence, and these data display quite clearly the periods of low temperatures and frequent occurrences of (E+F)+G for the first and second periods identified in Table IV.1. The remaining two periods (1814 - 1825

FIGURE IV-2 BERGTHORSSON'S GRAPH OF TEMPERATURE AND ICE



(After: Bergthorsson, 1969: 98)

and 1835 - 1842) are not, however, reflected in Figure IV.2.

The second period of peak ice conditions coincides with a period of severe weather in France. This emerges in LeRoy Ladurie's study of grape harvests in France since the year 1000. The following quotation gives a clear description of the years 1787 - 1789.

> "The grapes were over a month late and rotted before they could ripen ...'So unfavorable meteorological conditions produced in Champagne in 1786 and 1787 wine wine which was late, scarce and sour. Burgundy too was affected in 1787 by frosts, cold rain, a dull summer, and late harvests' ...'the final catastrophe came in 1789, for which the thermometric curves show a very cold May to September.'"
>
> (LeRoy Ladurie, 1971: 72)

These independent indications that the first three periods given in Table IV.1 were marked by severe weather support the view that this study has yielded valid measures of ice severity, but this view is not confirmed conclusively. Furthermore, since the durations increased with the increases in (E+F)+G, it is reasonable to assume that the peak periods are representative of severe ice conditions.

b) Spatial distribution of sea ice - 1751 to 1870

In order to more easily examine sea ice locations, Hudson Strait was divided into seven sectors as discussed in Chapter III, and depicted in Figure III.17. Frequencies of E+F, G, and (E+F)+G per square kilometer were calculated for each sector and mapped [Figures III.18 (a to c)]. When these maps are compared, the sector displaying the highest frequency changes from sector V for E+F, to sector II for G, and sector III for (E+F)+G. However sector I exhibits the lowest frequency in all three cases. Because sector III had the second-highest frequencies for E+F and G, it therefore exhibited the highest frequency when these two factors were combined.

In general, it appears that encounters with ice became less frequent as the ships moved toward the western end of the Strait. Whether this is due to the increasing width of the channel in that direction, or to an actual decline in ice amounts, or both may possibly be revealed when the data are compared with modern observations.

The maps shown in Figures III.19(a) and (b) were based upon those locational references which provided both the distance and direction from a given point. Therefore, although only specific references were used, these locations are more precise than those used in Figures III.18 (a) to (c). These two maps [II.19(a) and (b)], also show a higher occurrence of E+F and G in the areas of sectors II, and particularly sector III, as well as a general decline in frequency west of sector III.

The rather high incidence of encounters with ice to the south of Resolution Island (sector II), as indicated in Figures III.19(a) and (b), is in keeping with the fact that the current carrying ice out of Hudson Strait meets the current carrying ice southward from Davis Strait at Resolution Island. This situation is described below by E. Chappell.

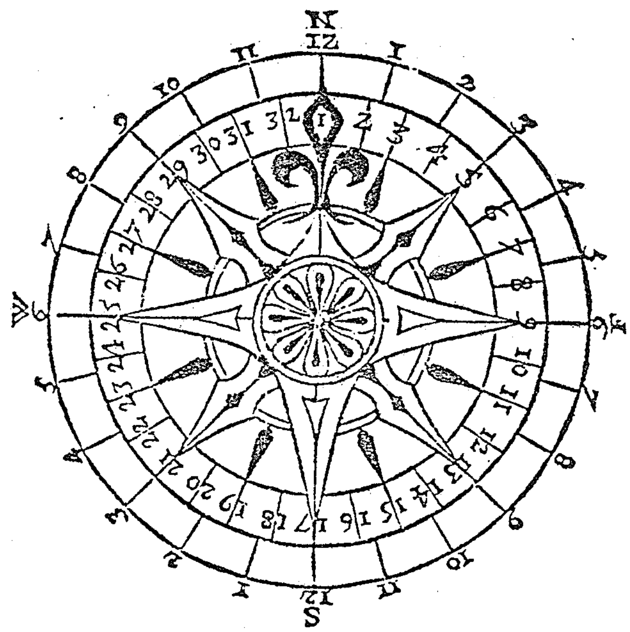
> "...it requires strong winds to carry the drift ice out of the STRAITS, which is very likely otherwise to choke the passage. Entering HUDSON'S STRAIT, it is a necessary precaution to keep close in with the northern shore; as the currents of HUDSON'S and DAVIS' STRAITS meet on the south side of the entrance, and carry the ice with great velocity to the southward, along the coast of LABRADOR."
>
> (1970: 40-41)

In relation to the hypothesis presented in the introduction, certain navigational activities do reflect sea ice conditions. Whereas exact amounts of ice cannot be determined by the data and methods described in this study, relative degrees of ice severity for each year, and fairly precise locations of those conditions of severity can be deduced.

APPENDIX A

METHOD OF PLOTTING VOYAGES

The 32-Point Compass:

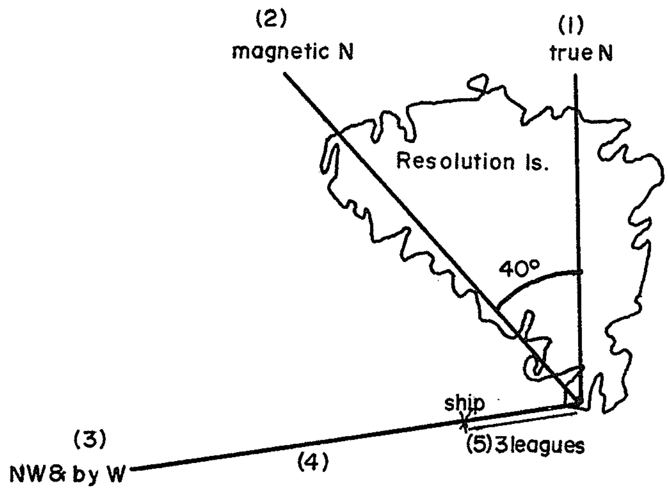


(1 point = 11¼ degrees)

Names of compass points (by number):

1. N	9. E	17. S	25. W
2. N&byE	10. E&byS	18. S&byW	26. W&byN
3. NNE	11. ESE	19. SSW	27. WNW
4. NE&byN	12. SE&byE	20. SW&byS	28. NW&bW
5. NE	13. SE	21. SW	29. NW
6. NE&byE	14. SE&bS	22. SW&byW	30. NW&byN
7. ENE	15. SSE	23. WSW	31. NNW
8. E&byN	16. S&byE	24. W&byS	32. N&byW

Example: "Southmost part of Resolution - SE&byE 3 leagues." (From the log of the ship Hudson Bay Pink, C1/346, July 6, 1751, noon, westward bound).



1. True north line is drawn through southern tip of Resolution Island (from grid reference).

2. Using a protractor, magnetic north is determined approximately 40°W of true north.

3. By aligning the N-point of a transparent template of the 32-point compass with magnetic north, a mark is made at NW&byW (so that the observed point is to the SE&byE).

4. A line is drawn from the point (#3) to the "southmost part of Resolution" Island.

5. Using the linear scale, 3 leagues (9 miles) are measured along the line drawn in #4.

APPENDIX B

GLOSSARY OF TERMS*

LOG BOOK: A book ruled in columns like a log-board, onto which the account of the log board is transcribed every day at noon, together with every circumstance deserving notice, that may happen to the ship, or within her cognizance, either at sea or in a harbour, etc. from which, after it is corrected etc. it is entered into the journal.

Navigational Terms:

GRAPPLE: A sort of small anchor fitted with four or five flooks or claws....commonly used to fasten boats or other small vessels.

TACK: To change course from one board to another, or to turn the ship from the starboard to the Carboard tack or vice versa, in a contrary wind.

Types of Ships:

BRIG: A small merchant-ship with two masts. Amongst English seamen this vessel is distringuished by having her main-sail set nearly in the plane of her keel... in a brig, the foremost edge of the main-sail is fastened, in different places, to hoops, which encircle the main-mast, and slide up and down it as the sail is hoisted or lowered; it is extended by a gaff above, and a boom below.

---

* All definitions are from William Falconer, New Universal Dictionary of the Marine. (1815)

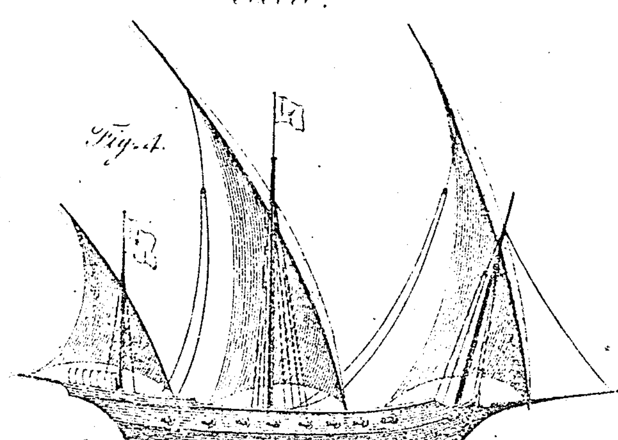
BRIG cont. — This term is not universally confined to vessels of a particular construction, or which are masted and rigged in a method different from all others. It is variously applied, by mariners of different European nations, to a peculiar sort of vessel of their own marine.

FRIGATE: — In the navy, a light nimble ship, built for the purpose of sailing swiftly. These vessels mount from 20 to 50 guns, and are esteemed excellent cruisers.

PINK: — A name given to a ship with a very narrow stern. ...they are vessels of burden, have three masts, and carry lateen [triangular] sails.

All vessels, however small, whose sterns are very narrow, are called pink-sterned.

Xebec.



SLOOP: — A small vessel furnished with one mast, the main-sail of which is attached to a gaff above, to the mast on its foremost edge, and to a boom below; by which it is occasionally shifted to either quarter.

APPENDIX C

DIRECTIONS FOR FUTURE RESEARCH

Although this study has provided some conclusions regarding sea ice in Hudson's Strait for the period 1751 to 1870 inclusive, it is by no means exhaustive in regards to the potential wealth of information contained within the Hudson's Bay Company's log books. The data, analyses, and conclusions of this research represent only the 'tip of the iceberg' which emerged at the onset of this study.

This Appendix provides some suggestions for further research using the Hudson's Bay Company's log books and this study as a foundation. The suggestions presented here will be discussed under the following headings:

1. direct descriptions of sea ice,
2. applications of sea ice data,
3. other environmental information,
4. extension of the historical record.

1. Direct descriptions of sea ice

Prior to the retrieval of the data for this thesis, a decision was made to attempt to reconstruct sea ice conditions by using the accounts of the navigational activities which were employed to cope with the hazard of sea ice. This decision was partly based on the fact that descriptions generally tend to be quite subjective if no instrumentation is used in the observations. Each observer has a personal bias in his perception and description of an object or event. Associated with this difficulty is the problem of terminology. Difficulties were foreseen in attempting to quantify such phrases as 'thick ice' and 'straggling ice'. It was hoped that reports of specific and consistently used navigational activities would not be as encumbered with semantic uncertainties. It would, however, have been naive to assume that no difficulties would arise in the interpretation of the navigational activities, and these problems have been discussed in Chapter III.

The original intent of the research was, therefore, to first interpret the navigational maneuvers and later to develop a content analysis for the interpretations of the direct descriptions of the appearance and behavior of sea ice.

As was previously stated, the major

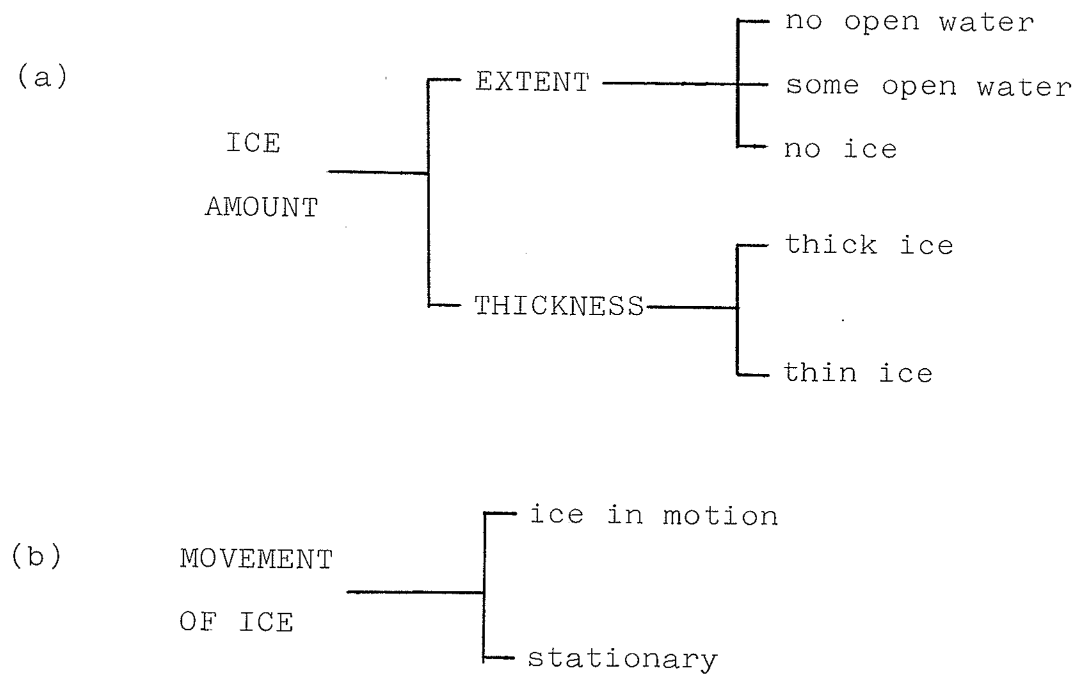
foreseeable difficulty in the interpretation of ice descriptions is in the definition of the terms used to describe the ice. This problem may be negotiated by the careful construction of appropriate categories. The importance of the categories in content analysis has been emphatically stated as follows:

> "The problem of category construction is widely regarded as the most crucial aspect of content analysis. It is the step in which the data are tied to theory, and it serves as a basis for drawing inferences."
>
> (Stone et.al., 1966: 9)

Thus, the analysis of the ice descriptions must commence with the development of a general classification of categories of descriptive commentary.

A cursory examination of the types of terms used to describe sea ice reveals that ice was described in relation to its amount and movement. Therefore two categories can be provided in order to accommodate these factors, with subgroupings contained in each to refine the data contained under the main headings. Figure C.1 provides a suggested format for the construction of these categories.

FIGURE C.1 - CATEGORIES OF ICE DESCRIPTIONS



In C.1(a), each subgroup (extent and thickness) relates to the other, and therefore may often be combined. Likewise, (a) and (b) may also be combined in some instances where the data allow.

Once completed, an investigation of this nature would be an extremely valuable tool in checking the results found in this thesis. Its value stems from the fact that while the data are not the same, the ice descriptions were retrieved from exactly the same source.

2. Applications of sea ice data

Data relating to historical sea ice

fluctuations are directly relevant to the use of Hudson Strait as a shipping route. However, this information has other, more indirect applications in terms of the study of climatic change. When using the log books of sailing vessels as a source of data, one can be fairly certain that wind directions would be quite well documented, and this was the case in this research. Other factors such as temperature and pressure were rarely noted. Since weather journals do not exist for Hudson Strait for the period encompassed by these log books, information regarding climatic conditions may be obtained indirectly from those sources which are available.

Numerous studies have been conducted to determine relationships between sea ice and various meteorological factors. The most likely factor to be related to sea ice is temperature. Bergthórsson (1969) found a correlation coefficient of -0.68 for the relationship between annual temperature and ice incidence during the period 1846 - 1919, in Iceland. He also calculated a correlation coefficient between temperature and the decadal number of severe years (years with starvation, or drift ice reaching the SW coast of Iceland) to be 0.76 during the period 1591 to 1969. From these results, Bergthorsson concluded that:

> "A fairly good correlation is found between annual temperature and the incidence of drift ice in Iceland."
>
> (Berthórsson, 1969: 94)

Another study, which is somewhat more general in its results, examined seasonal temperature and sea ice conditions in the eastern Canadian Arctic (Jacobs and Newell, 1979). Unlike Bergthorsson, Jacobs and Newell included wind direction as a component in their study. The following statements represent two of their conclusions regarding the relationships between these elements generally, and for Foxe Basin and Baffin Bay.

> "There is a general, but locally complex correspondence between the severity of summer climate (and to a lesser extent that of the preceeding winter) and the extent of late summer sea ice."
>
> (1979: 353-354)

> "In general, Foxe Basin tends to have lighter ice conditions in those summers of more frequent southerly airflow and those summers tend also to be warmer. Baffin Bay rarely experiences persistent southerly winds; northerly and

> north-westerly winds predominate
> and show little variation in
> relation to ice conditions."
>
> (1979: 353)

It should be noted that Bergthorsson's findings were based upon historical data, whereas Jacobs' and Newell's results were founded on modern data (1957-1978).

A third study, by Crane (1978), also using modern data (1964-1974), examined seasonal sea ice variations in relation to synoptic-scale atmospheric circulation. In Table 3(1974:446)are the results of his study, in which atmospheric pressure has been added to temperature and wind direction.

From these three studies, it can be concluded that evidence exists which would enable general historical climatic conditions to be derived for Hudson Strait from the sea ice information derived in this research.

3. Other environmental information

As discussed in Chapter III, certain meteorological elements were noted in the log books. These elements are:

fog

haze

storm/squall

gale/strong wind

rain

cloud

frost

snow

sleet

hail

wind direction

Conspicuous by its absence from this list is temperature. Thermometric readings were not completely missing from the log books, but the high degree of their infrequency renders those that do exist of little use. Those elements listed can however, be of value in an examination of the historical climate of Hudson Strait, and of the general region surrounding the Strait.

Although the quantities of rain and snow are not provided in the log books, the frequencies and general amounts of precipitation can be determined.

Furthermore, when all of these factors are examined in conjunction with each other, conclusions regarding atmospheric circulation patterns can be made.

This type of study has been achieved by Oliver and Kington (1970) who used ships' log books, as well as land station data to reconstruct cartographically the synoptic conditions for Great Britain and north-western Europe in the 18th century. Using the British Navy log books, Oliver and Kington were able to construct the following table of meteorological terms used in the log books.

It should be noted that all of the terms found in the Hudson's Bay Company log books are contained in this list except frost, gale, and wind direction.

With the help of William Falconer's Universal Dictionary of the Marine (1815) the Beaufort scale of windspeed, and land based observations, the terms listed in Table C.1 were used to construct synoptic maps.

The major problem identified by Oliver and Kington was the lack of sufficiently long records for particular locations.

"Whilst at sea, the details shift their location and this defeats their use

TABLE C.1: 18TH CENTURY METEOROLOGICAL TERMS

STATE OF SKY	PRECIPITATION, etc.	VISIBILITY
Serene	Drizzle	Haze
Clear	Snow	Thick haze
Fine	Sleet	Mist
Fair	Hail	Fog
Cloudy	Shower	Thick fog
Overcast	Squalls of rain	
Thick weather	Thunderstorm	
	Lightning	

(after: Oliver and Kington, 1970: 526)

> unless a sufficient number of samples for any one time and for any given area provides a guide to the general prevailing circumstances."
>
> (Oliver and Kington, 1970: 522)

This difficulty does not exist when using the Hudson's Bay Company's log books for Hudson's Strait since the ships followed the same route at the same time of year throughout the record. Therefore land based observations are not necessary.

4. Extension of the historical record

The Hudson's Bay Company received its Charter in 1670, and therefore it can be expected that the Company would have sent ships to Hudson Bay, via the Strait, from the late seventeenth century onwards. Prior to 1670, Hudson Strait was also used as a route in the search for the Northwest Passage. Accounts of these voyages through the Strait are available, although they are not in the original documents as used in this study.

Cooke and Holland have compiled a compendium of the exploration of northern Canada, and list as a first reference to Hudson Strait, a Norwegian expedition which sailed C.1360. There is then a gap in their entries until 1508 when

Cabot went in search of the Northwest Passage. From that year on, the catalogue continues quite consistently until 1668 when it becomes virtually unbroken.

This listing of voyages is referenced to an extensive bibliography whose major entries are:

Davies, K.G., ed. Letters from Hudson Bay 1703-40. London: Hudson's Bay Record Society, 1965 (Volume 25).

Dictionary of Canadian Biography, Volume I: 1000-1700 (1966); Volume II: 1701-1740 (1969); Volume III: 1741-1770 (1974). Toronto: University of Toronto Press.

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Hudson's Bay Company. Ships on Hudson's Bay Company Business Sailing Between England and York Fort 1670-1700. Unpublished typescript, Hudson's Bay Company Archives.

Rich, E.E. The History of the Hudson's Bay Company 1670-1870. Volume I: 1670-1763, London: Hudson's Bay Record Society, 1958 (H.B.R.S. Volume 21). Volume II: 1763-1870, London: Hudson's Bay Record Society, 1959 (H.B.R.S. Volume 22).

A similar extension of the record for Hudson Strait can be constructed for the period from 1870 to the present. Because Cooke and Holland trace northern Canadian exploration to the year

1920, much of this extension can also be based on their book. Furthermore, the Canadian government has kept an excellent record of Hudson Strait, and the surrounding area for the more recent period through the Department of Transport ("Navigation Conditions on the Hudson Bay Route from the Atlantic Seaboard to the Port of Churchill"), and most recently through Environment Canada's Ice Climatology Division ("Ice: Summary and Analysis - Hudson Bay and Approaches").

Although the earlier portion of this record extension may not be as detailed and systematic as the log books used in this study, it would nevertheless be a worthwhile endeavor to examine these references as they might provide some evidence of sea ice in Hudson Strait from 1508 to the present; a period of over 400 years.

This appendix has provided some suggestions regarding possible directions for continued research using the Hudson's Bay Company's log books as well as a means for extending that record. There are no doubt, many more possible applications of this data source. It would be unfortunate not to examine this wealth of information to its fullest extent, as it is rare to find a collection of documents so well suited to the systematic study of historical environmental conditions.

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