Historical record of the incidence of sea ice on the scotian shelf and the Gulf of St. Lawrence

Hill, B.; Ruffman, A.; Drinkwater, K.

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HISTORICAL RECORD OF THE INCIDENCE OF SEA ICE ON THE SCOTIAN SHELF AND THE GULF OF ST. LAWRENCE

Brian T. Hill[1], Alan Ruffman[2] and Ken Drinkwater[3]

ABSTRACT
An historical record of the incidence of sea ice on the Scotian Shelf and the Gulf of St. Lawrence of Atlantic Canada has been compiled on an annual basis from the early 1800's to 1962. A variety of data sources were used in the compilation of ice records including ice patrol and shipping reports, local newspapers, lighthouse records and other holdings in the U.S. and Canadian National Archives. In the order of 25,000 ice records were found and used in the plotting of monthly ice charts for the region. This current work was undertaken to lengthen an existing sea ice database covering the years from 1963 to near present. Natural gas development is well under way in the Sable Island area of the Scotian Shelf and while no ice has visited this island's shores in recent memory, it is clear from the ice record that intrusions that far south are not unusual, historically.

INTRODUCTION
Sea ice typically first forms in the western and northern coastal zones of the Gulf of St. Lawrence during December and by the end of January may start flowing out through the Cabot Strait under the influence of wind and current (see Figure 1 for place names). The ice usually reaches its greatest areal extent during March when it extends over the northeastern Scotian Shelf. In severe years the ice, a mixture of drift as well as local, may extend as far as Halifax to the southwest and south towards Sable Island. Spring break up also normally commences in March and recedes to patches within the Gulf by mid-April, but in severe years ice may linger on the Scotian Shelf until May and even June. The ice charts for these regions have been systematically produced and archived by the Canadian Ice Service from 1963 onwards.

The present study was undertaken to lengthen that sea ice database back into the 1800s using available reports from Canadian and US government records and newspapers. Not only will this provide long-time series for climate change studies but will also be used to

[1] National Research Council, Institute for Marine Dynamics, P.O. Box 12093, St. John's, NF, Canada
[2] Geomarine Associates Limited, P.O. Box 41, Station M, Halifax, Nova Scotia, Canada
[3] Department of Fisheries & Oceans, Bedford Institute of Oceanography, Dartmouth, NS, Canada

test statistical relationships of Scotian Shelf ice coverage with meteorological and oceanographic variables being identified by the Bedford Institute of Oceanography (BIO) from analyses performed on the more recent data set (Drinkwater et al., 1999). An historical record of sea ice and iceberg distribution for the east coast of Newfoundland, including the Grand Banks, from 1810 to near present has already been compiled by Hill (1998) and the methods used applied to this project.

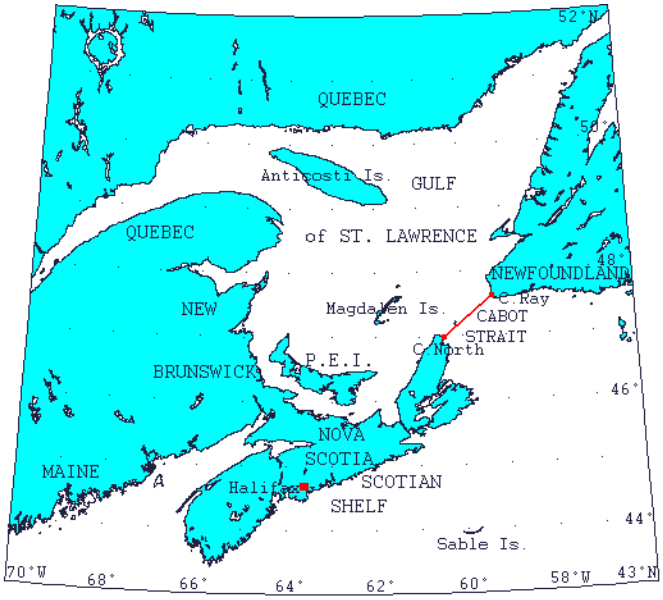

Figure 1. Map of the Gulf of St. Lawrence Area. The ice extent area is calculated east of the line across Cabot Strait.

Data Sources and Methods

Figure 1 shows our area of interest. Using the same coastlines as a background, ice observations were plotted on the chart for every month in which ice occurred. An ice edge boundary line was estimated for any ice seaward of Cabot Strait. A time series of the Gulf of St. Lawrence ice extent on the Scotian Shelf was constructed from calculation of the area east of a line drawn from Cape Ray, Newfoundland, to Cape North, Nova Scotia, basically the narrowest point across Cabot Strait. For the remainder of this paper this area is what is meant by the Gulf ice extent.

Data were derived from a variety of sources, in the order of 25,000 ice records, amounting to over 500 pages of re-typed small print, were found spanning the years 1769 to 1962. Information for early years is sporadic but is continuous from 1817. In addition, annual Canadian government Gulf of St. Lawrence ice survey reports were identified covering the period from the mid-1950s so the emphasis in the search was for ice records prior to that time.

A number of local newspapers from the provinces of Newfoundland, Nova Scotia, and Prince Edward Island were searched for ice reports and a list of those can be found in the Gulf of St. Lawrence web site of the Institute for Marine Dynamics at

http://www.nrc.ca/imd/ (the web site is currently undergoing revision; please contact one of the authors if difficulties are encountered). These newspapers were useful in providing local information but were often limited in information further afield. Two shipping newspapers, Lloyd's List (1741) and the New York Maritime Register (1869) were very helpful in providing wider coverage. The International Ice Patrol (IIP) was inaugurated in 1914 after the sinking of the *RMS Titanic* through a collision with an iceberg off the Grand Banks in 1912. Since then the IIP has published information on annual ice conditions in their bulletins and this remains one of the prime sources of its kind. Initially, information was collected by IIP patrol ships and other commercial ships traversing the area but with the onset of World War II this was supplemented by aerial reconnaissance with a marked improvement in the details of ice observation. Records held by the National Archives of Canada in Ottawa provided much information on ice in the Gulf of St. Lawrence and the St. Lawrence River for the late 1920s and most of the 1930s. This information was collected and disseminated by the then Department of Marine and Fisheries for the protection of shipping of shipping in the area and as part of the Canadian contribution to the International Ice Patrol.

Their information was gathered from Signal Service lighthouse stations and patrolling icebreakers. Reference was found from these records to published bi-weekly ice charts but we have been unable to locate them. In 1956, the Canadian Ice Distribution Survey (CIDS) undertook its first aerial survey of the Gulf and published their findings in a Geographical Paper of the Geographical Branch of the Department of Mines and Technical Surveys (Black and Forward, 1957). Not only did the surveys and reports continue on an annual basis (Black, 1957 through 1962) to the end of the period of our interest but two other reports were prepared from data they had access to summarizing spring ice conditions in the Gulf from 1940 to 1952 (Forward, 1954) and from 1953 to 1957 (Forward, 1957). CIDS was also responsible for assembling a huge collection of index cards detailing historical ice reports. The Canadian Ice Service made these available to the authors on compact disk and the several hundred pertaining to the Gulf area are from a wide variety of sources including newspapers and government agencies, often describing observations from ship and aerial patrols during the 1930s and 1940s. In addition, weekly ice report charts constructed by the Meteorological Branch of the Department of Transport covering the period 1957 to 1962 were also consulted.

Finally, a very valuable document proved to be the weekly Hydrographic Bulletin of the U.S. Navy Hydrographic Office published from 1889 to 1954 and is available from the U.S. National Archives in Washington. In its original format, certainly through 1947, the bulletin was a single-sided page newsprint of varying width and length depending on amount of material. The material is largely accounts of hazards (and aids) to navigation and includes ice and iceberg reports, accounts of hurricanes, waterspouts, seismic activity, tidal waves, and derelicts. Starting in 1922, supplemental charts were published, which could be found appended to the bound volumes of the Pilot Charts of the North Atlantic Ocean (also at the U.S. National Archives).

Plotting of the data

Ice reports and mentions of ice from all the available sources from the earliest reports to 1957 were reentered into a chronological master text document some 500 pages in length. Since published reports and ice charts were already available from 1957 to 1962, these years were treated differently, as described later. In order to plot the data for the earlier years, the geographical co-ordinates of the ice sightings were assembled for each month for each year in a spreadsheet. When the latitudes and longitudes were not given they were calculated whenever possible from the description. The ice observations gave rise to over 22,000 useable data points. Many other ice reports could not be translated into co-ordinates as such but were useful in describing the severity of the year or to provide general information. The co-ordinates were plotted using VERSAMAP available as shareware software on the Internet, the coastline being replaced by the World Vector Shoreline (Soluri and Woodson, 1990) for better resolution, and the images stored electronically.

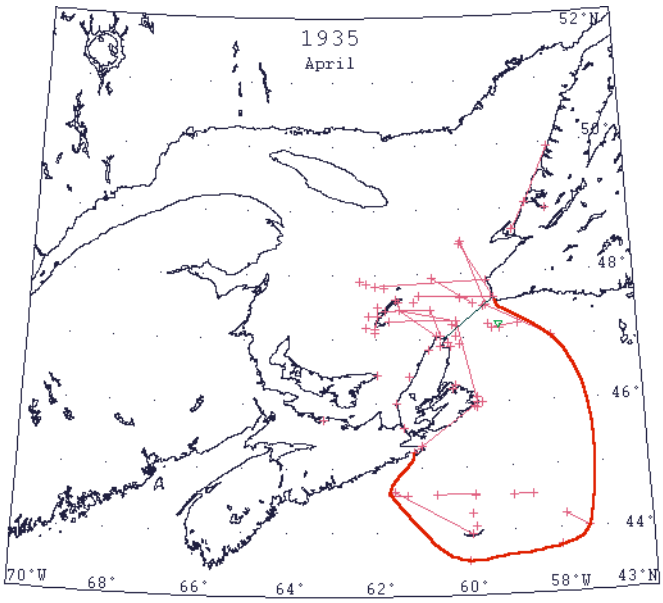

Figure 2. Sample Ice Chart from April 1935 showing Sea Ice and Iceberg sightings (see text) and interpreted sea ice boundary

Figure 2 shows an example from March 1935. Individual sea ice sightings are represented as red crosses. Thin red lines denote observed ice boundaries or traverses through ice from one known position to another. Iceberg sightings, if any, are shown as green triangles and a number of iceberg sightings from one position to another is denoted as a green line. Icebergs observed south of Newfoundland will have drifted west after their journey southward down the east coast of Newfoundland. While a number of icebergs do make their way down from the Labrador coast through the Strait of Belle Isle and into the Gulf of St. Lawrence off the west coast of Newfoundland it is questionable whether all such sightings within the Gulf were actually icebergs of glacial origin. Gulf ice is known to pile high on reefs and coastlines and may reach appreciable size which when floated off may resemble small icebergs from afar. Terminology was not so exact as it is today so icebergs

were often used to describe any unusually high piece of ice. In any case, if an iceberg was the term used then that is how it was plotted.

Once all the information for the month was plotted, an estimated ice boundary line was drawn around the ice sightings seaward of the Cabot Strait. The fewer the sightings then the more uncertain the line so an element of best judgement was necessary, particularly for the more historic data. However, for the years 1958 to 1962, one of the Ice Forecasting Central weekly ice charts towards the middle of the month was selected as being characteristic of the month and the ice boundary line was digitized. The Geographical Branch annual ice reports were also helpful in identifying the ice edge. The digitized line, one for each month, was then re-plotted using VERSAMAP.

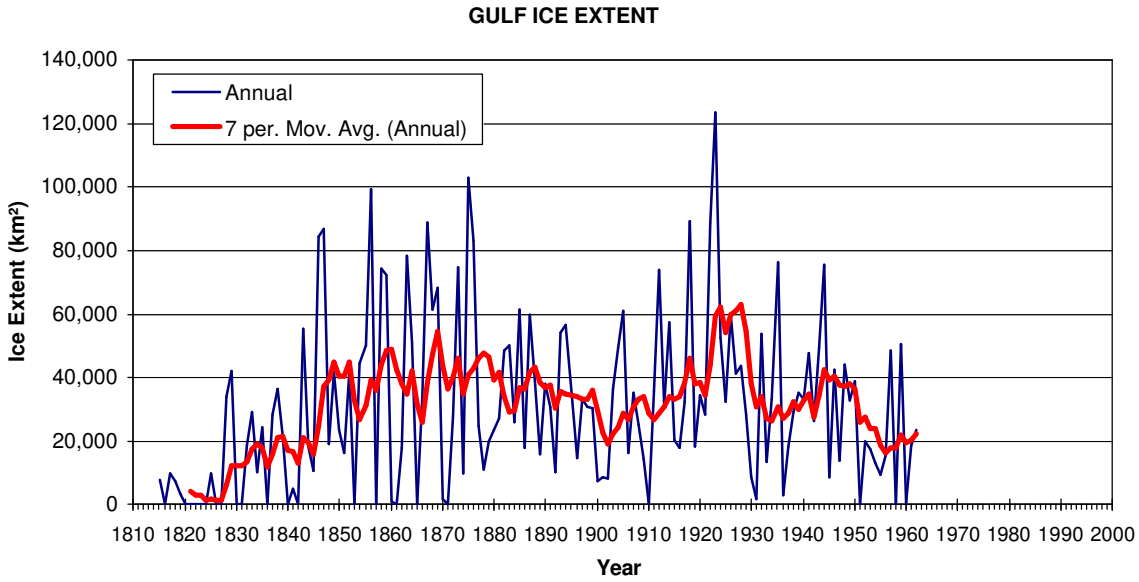

Figure 3. Time Series of Ice Extent east of Cabot Strait showing 7 year moving average

This resulted in some 436 monthly images from which ice areas could be calculated, providing almost continuous yearly data from 1815 to 1962. MATLAB routines were used to perform the ice area calculations from each of the electronic images. All the data, including ice charts, ice reports, ice extent data, latitudes longitudes of ice observations and ice boundary lines can be accessed at the web site mentioned above.

RESULTS AND DISCUSSION

Ice does not necessarily extend seaward past the Cabot Strait every year. From the CIS ice charts, we know that no ice was present in the Strait area or beyond in 1969 and the ice reports for 1951 and 1958 also show no ice during these years. One problem dealing with the earlier historical data is that if there were no ice reports in the Straits or on the Scotian Shelf, is that because there was no ice present or was it because there was no ship present to observe the ice, or, just as likely, was ice present and noted but no record of it has yet been found? Figure 3 shows the time series of ice extent seaward of the Cabot Strait and extending over the Scotian Shelf from 1815 to 1962. The ice extent value for the year is an

average of the months for which there are data, so it may represent just 1 month if that is all that is available, or an average of up to 4 or 5 months.

There are continuous data from 1871 to 1950, an unbroken spell of 80 years (though only a very little ice occurred in 1910), of ice flowing through Cabot Strait, which is in contrast to the span 1951 to present in which there were 3 years in which no ice occurred. The fact that the years surrounding 1871 were very light ice years suggests that there was no ice in Cabot Strait for that year, but it is much harder to prove that ice was not present rather than that it was present. The decades of the 1840s through the 1960s have one year each for which no ice reports are available. The frequency increases for decades prior to 1840 but one also has to consider the ship technology of the time. The ice season in the Gulf in the early 1800s was generally regarded as closed to navigation. The wooden sailing ships of the time were incapable of dealing with the ice conditions and for the month of March, generally the month of greatest ice extent, there are only 2 years in the time series prior to 1845 in which there are ice observations in the Strait. Ships simply did not go there. As technology improved with the advent of paddle steamers and then screw propelled ships the ice barriers of the Gulf were eventually penetrated until the modern era of ice management and year round shipping.

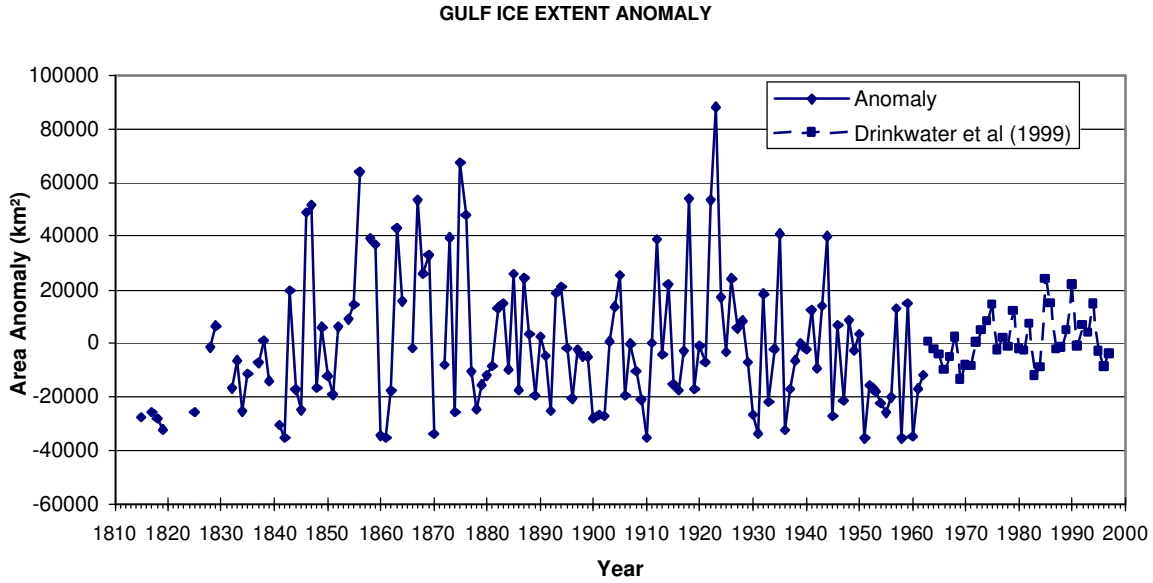

Figure 4. Time Series of Ice Extent Anomaly on East side of Cabot Strait and appended with modern data

Figure 4 shows the anomaly of the annual average values and is appended with data from Drinkwater et al (1999) and also brought up to date. The gaps in the series to 1870 indicate years with insufficient data. Throughout the whole record there is a high degree of interannual variability with sea ice extent changing from near minimum to near maximum values in a matter of two or three years. The most extensive sea ice occurred in 1923 with an extent reaching over a quarter of a million square kilometers and reaching far south of Sable Island. The years 1922 and 1923 appear to have been the most severe for the entire record while the approximate 30 year period around the 1860s also appears to have been severe but not quite so extensive. The early 1990s also saw a crest of increased sea ice severity. No ice has occurred around Sable Island (approximately 44°N 60°W) in recent

times, yet the historical data shows that ice reached the area in 26 of the years between 1846 and 1947 inclusive, or basically 25 % of the time. There were other times, as during the 1890s, when the ice came very close. Figure 5 shows ice occurrence around Sable Island by decade. Again, the era prior to 1840 should be viewed with less confidence. This incursion of ice is relevant to the development of natural gas pipelines and the potential for future oil pipelines to pump offshore gas and oil from the Sable Island region to the coast of Nova Scotia.

Drinkwater et al (1999) remarked that during the month of May ice was observed east of Cabot Strait in only 17 out of 35 years for the period 1963 to 1997, or 48.6 % of the time. The data for the period 1844 to 1962 is remarkably similar with 58 occurrences out of 119 years, or 48.7 %. Prior to the early 1840s the data is a little less clear with 12 years from 1815 to 1841 with no ice reports found for any month in the Cabot Strait and as discussed could mean simply no observed ice rather than no ice at all. Even so, from 1815 to 1962 ice occurred in May 64 times in 148 years or 43.2 % of the time, and thus

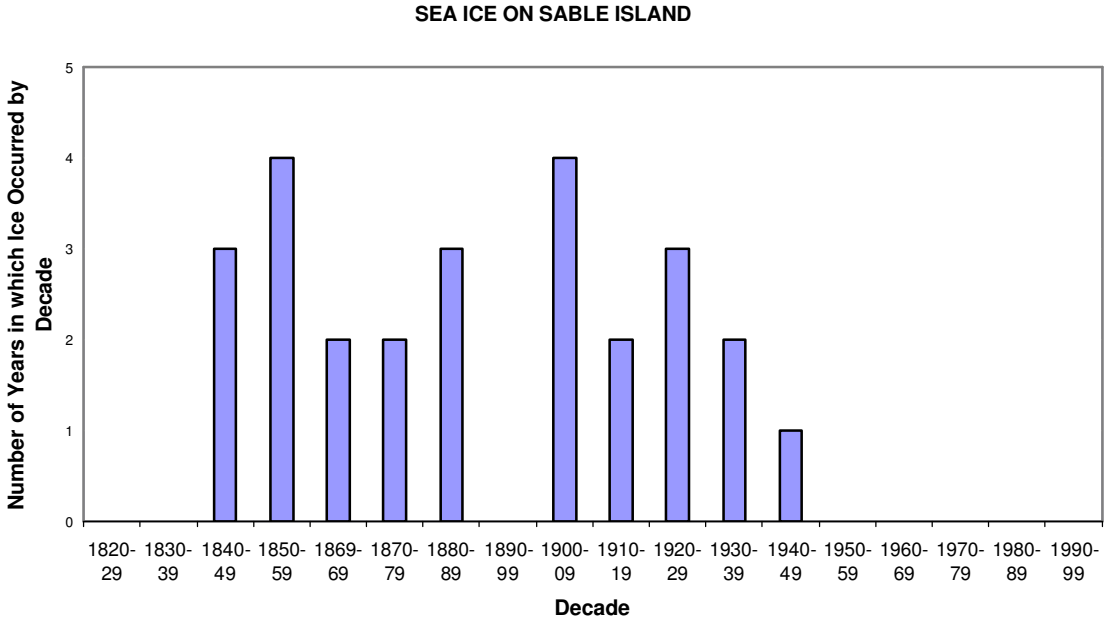

Figure 5. Frequency of Sea Ice Occurring around Sable Island (44°N 60°W) by Decade

overall, there appears little difference in the modern May occurrences when compared to historic data.

Figure 6 compares the 7 year moving averages of the Gulf ice on the Scotian Shelf with the ice extent for the east coast of Newfoundland (Hill, 1998) over the period 1815 to 2001 with both series brought up to date with data from CIS. While there are significant differences in the higher frequency ranges perhaps due to regional climatic differences, there is quite a degree of similarity in the longer-term trends. Both graphs show an increase in ice severity in the mid- to late 19th century with ameliorating conditions at the turn of the century. Both then show a return to more severe conditions in the 1910s and 1920s and since then there has been an unsteady but parallel return to lighter conditions.

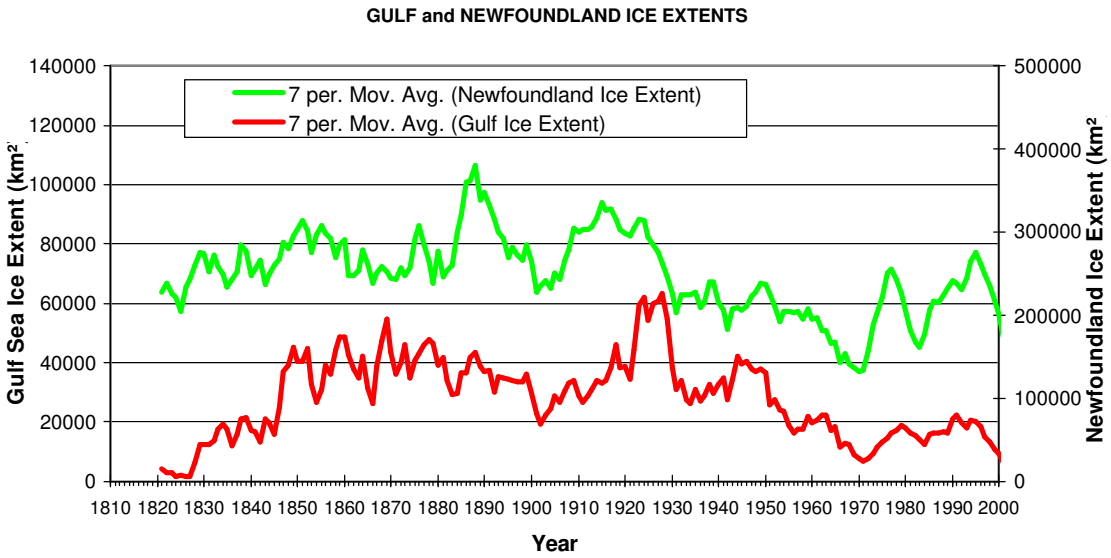

Figure 6. Comparison of the Gulf and East Newfoundland Ice Extents (Moving averages)

CONCLUSION

A time series of ice extent for ice in the Cabot Strait and the Scotian Shelf has been constructed from 1815 to 1962. In comparison with observations since 1962, it appears that the frequency of years with ice during May is similar. However, the trend in the past 50 years has been of decreased ice extent; ice was observed seaward of Cabot Strait every year for 80 years to 1950, but since then there have been three years in which this did not happen; ice around Sable Island last occurred in 1947 [sic 1948], but for a hundred years prior to then it occurred 25 % of the time. Comparison of the historical Gulf data with the sea ice extent off eastern Newfoundland show several similarities in longer term trends with the most severe ice conditions occurring in the late part of the 19th century and the early part of the 20th with milder conditions in between, and an unsteady return to milder conditions, thereafter.

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