ICE CONCENTRATION IN THE EASTERN BEAUFORT SEA

By

William J. Stringer

Assisted By

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NOAA-OCS Contract No. 81-RAC00147

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Introduction and Background

The summertime extent and concentration of sea ice in the eastern Beaufort Sea is a matter of OCSEAP concern from several points of view:

1. An oil spill occurring during summer is generally assumed to encounter open water conditions. Over what. period of time, and for which locations is this assumption valid? Is this assumption valid for all years?

2. Sea ice is often used as a resting platform for birds and sea mammals. Where is this ice located relative to OCS activities?

3. During late spring when migrating birds are first arriving, not a great deal of open water is available for feeding areas. Are there areas statistically free of ice which may contain concentrations of birds each spring?

4. The fall migration of Bowhead whales is assumed to follow the edge of the ice pack. Where is this edge relative to OCS activities and how does it vary from year to year?

This report attempts to provide basic information from which the answers to these questions may be obtained. Clearly, the characterizations described require a statistical analysis of ice conditions over a span of some years. This, in turn, requires the availability of reliable ice data of sufficiently high resolution to provide the required information.

Two main sources of ice data were used for this analysis: Landsat imagery and Navy/NOAA Joint Ice Center Ice Analysis Charts. These two data sources have the following characteristics:

1. LANDSAT IMAGERY. Landsat provides images of the earth's surface in the visible and near infrared portions of the spectrum (and is, therefore, cloud-limited). The satellite orbital characteristics are such that at the latitude of the Beaufort Sea, a given location is imaged for four days in

succession followed by a fourteen day period with no coverage. For considerable portions of the period Landsat imagery has been available, two satellites have been operated with orbital coverage nine days apart, resulting in a possible coverage frequency of four days out of every nine. This frequency of coverage has been sufficient to provide a statistical data base for many OCSEAP analyses. 'However, the work reported here called for observations each half-month during the spring-summer period for each year of study. This condition could not be met in late summer with sufficient data to provide statistical confidence, so an additional data source was used - also based on satellite imagery, but of much lower spatial resolution than the 80-meter Landsat resolution.

2. NOAA/NAVY JOINT ICE CENTER ICE ANALYSIS CHARTS. 'These charts are produced weekly, largely on the basis of NOAA and Defense Meteorological Satellite Program (DMSP) weather satellite imagery (operating in the visible, near infrared and thermal infrared with resolution cells on the order of 500 meters), which is cloud-limited, and Electronically Scanning Microwave Radiometer (ESMR) imagery and Scanning Multichannel Microwave Radiometer (SMMR) imagery, both of which are cloud-limited only in instances of intense rainfall. The ESMR and SMMR resolution elements are on the order of 10^4 meters. Because these two instruments operate in the microwave region, their signals respond-to the product of the source's emissivity and temperature raised to the fourth power. Despite the fourth power temperature dependence, the emissivity of various ice types varies to such a great extent that the measured signal is usually more a function of the source's emissivity rather than temperature. By this means, It is held that various ice types can be identified (see Troy et al., 1981). However, some ambiguities remain, particularly in cases when the ice is sufficiently warm that its surface is wet.

The NOAA and DMSP imagery is obtained on a highly frequent schedule (two to three times per day) while the SMMR and ESMR data is obtained on approximately a three day schedule. As a result, the ice analysis charts are usally based on visual band data during summer, except in cases of extreme cloudiness. In those cases, the lower resolution data is employed.

Data Analysis

Because of the high resolution available from Landsat imagery, it was determined to first analyze this imagery and then employ the data contained on ice analysis charts. The Landsat images were divided into seven bimonthly periods between June 16 when the ice concentration was always above 90% to September 30 when freeze-up was usually initiated. Because of extreme cloudiness in the eastern Beaufort Sea region, the Landsat data density resulted in relatively low statistical significance in some portions of the study area for some of the half-month analysis periods. (See table 1.) The images were analyzed by overlaying therewith a grid containing 5 km square elements. (Thus the study area was represented by approximately 1500 grid elements.) Ice concentration was estimated within each grid square and recorded. When all images for each time period were analyzed, the concentration was averaged and entered into the corresponding grid on the period summary map. Also, maps of dominant concentration were prepared (areas were identified where a particular concentration range [0-10%, 11-50%, 51-90%, 91-100%] dominated the observations. (This latter calculation can be important because it is a measure of the reliability that an average concentration indeed represents average conditions.) These dominant ice condition maps are included for those periods for which they were deemed statistically reliable.

Similarly, the ice analysis charts, taken from a one week period roughly every two weeks were scaled and averaged on a 5 km grid. (Statistical analysis was performed in a manner to be described below.) Because of the frequency of coverage and data source considerations discussed previously, the two averaged data sources were combined in the following way:

The frequency of coverage contained in the ice analysis charts was considered to provide better statistics on ice conditions on a broad scale. However, because of the large size of the resolution elements of the satellite imagery used, it was likely that in the confined nearshore areas, the Landsat-derived data was the more accurate of the two. This would be particularly true in terms of identifying areas of early open water. (Fortunately, the Landsat data was statistically more reliable during this period as well.) Therefore, the data were combined with the Landsat-derived data modifying the nearshore areas of the ice chart derived maps.

Table 1

LANDSAT IMAGERY ANALYZED

Path/Row	June 16-30	July 1-15	July 16-31	Aug. 1-15	Aug. 16-30	Sept. 1-15	Sept. 16-30
76/10				8-1			
77/10	6-27						9-25
78/ 10		7-16	7-16				
80/ 10	6-30				8-23		9-28
1974							
77/10	6-22						
79/10		7-12				9-4.'	
80/ 10	6-25						
1975							
77/10							9-24
79/10	6-28		7-16				
80/ 10						9-9	
1976							
77/10				8-13			
79/10			7-28				
..1977							
76/10			7-20				
77/10				8-14			
79/10	6-17	7-5					
80/10			7-24				
1978							
75-11	6-17						
77/10		7-7			8-30		
78/10		7-8	7-17				
79/10			7-18				
1979							
77/10			7-20				
78/10	6-15	7-3	7-21				
1980							
76/10		7-4					
77/10	6-17						
78/10	6-18	7-6			8-20		9-25
79/10			7-16		8-21	9-8	
1981							
77/10			7-18	8-5			
79/10	6-23	7-11					
80/10	6-24	7-3	7-21				
TOTAL	12	10	12	4	4	3	4

Ice Concentration Analysis

When analyzing maps of average ice conditions, some measure of variation should be taken into account. In order to provide an assessment of variation, the standard deviation from the local average concentration was calculated for 29 locations in the study area. Following each average concentration map is a map showing the average concentration and standard deviation for each of the 29 specific locations. These maps are discussed together for each time period.

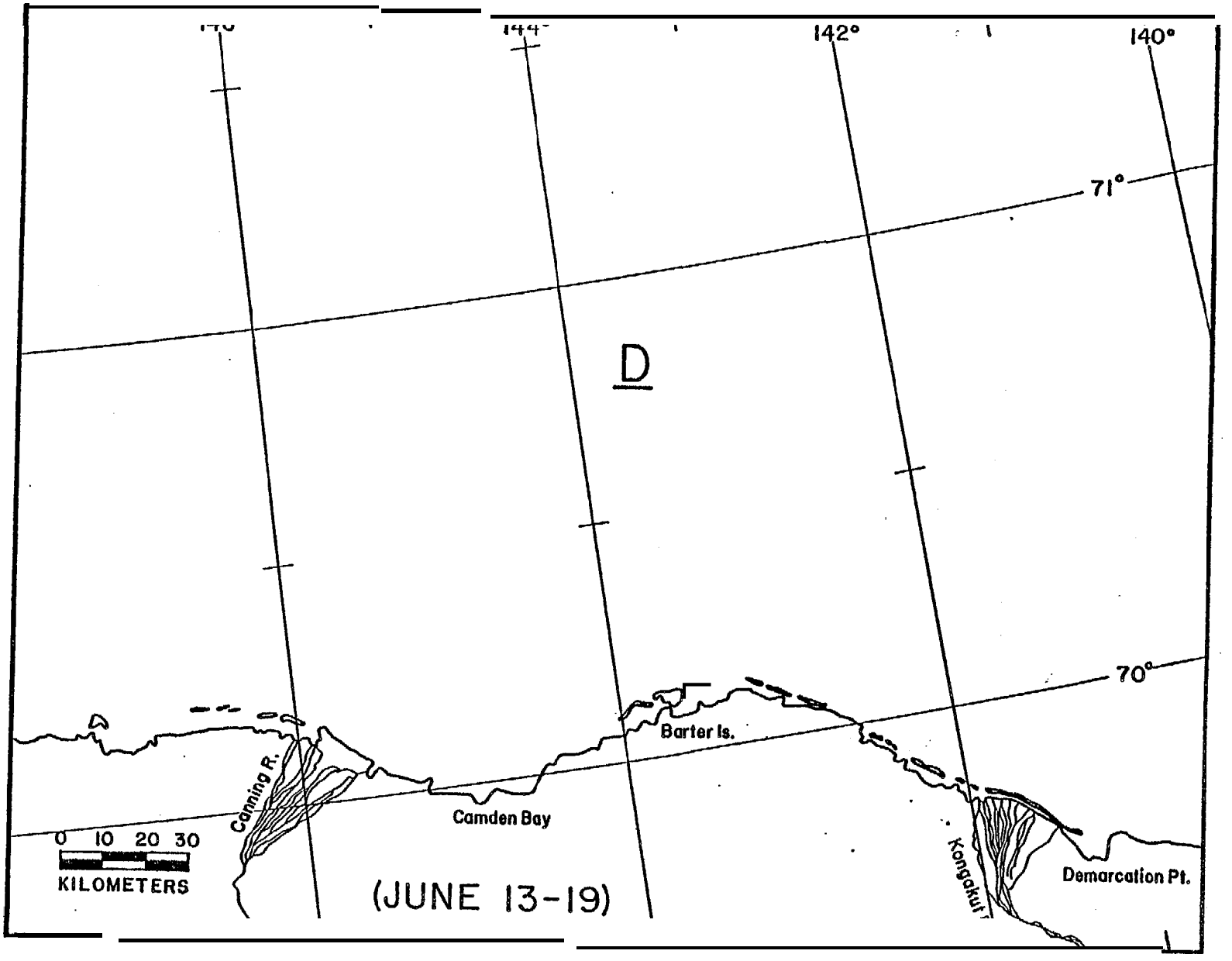
A separate statistical compilation showing the variation of concentration within each observation year at given locations along the coast is included to give some measure of extreme conditions to be encountered.

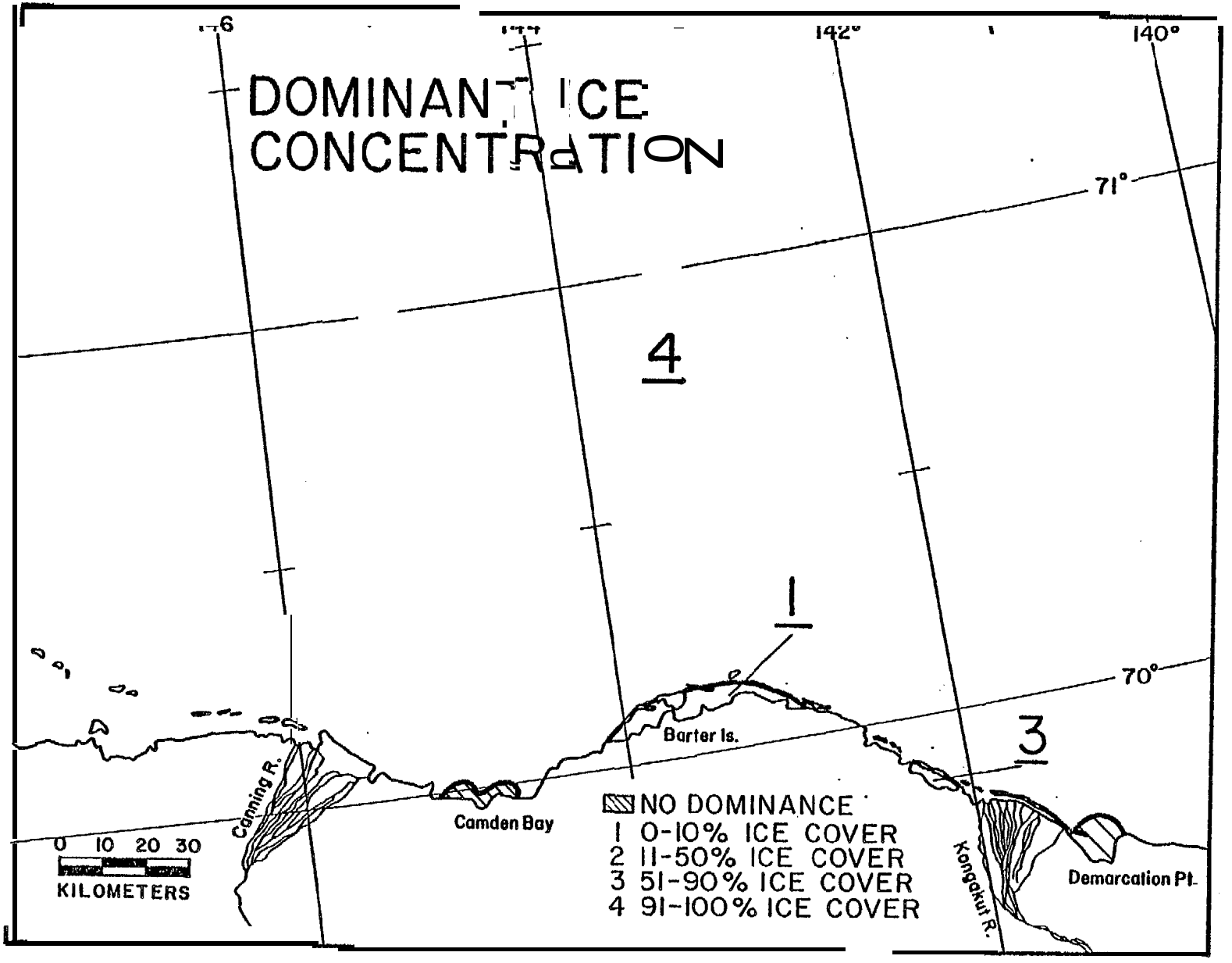
In this section, the results of ice concentration analysis are presented in map format.

Ice Concentration for June 13-19

A= 0-25% average ice concentration
B= 26-50?? average ice concentration
C= 51-75% average ice concentration
D= 76-100% average ice concentration

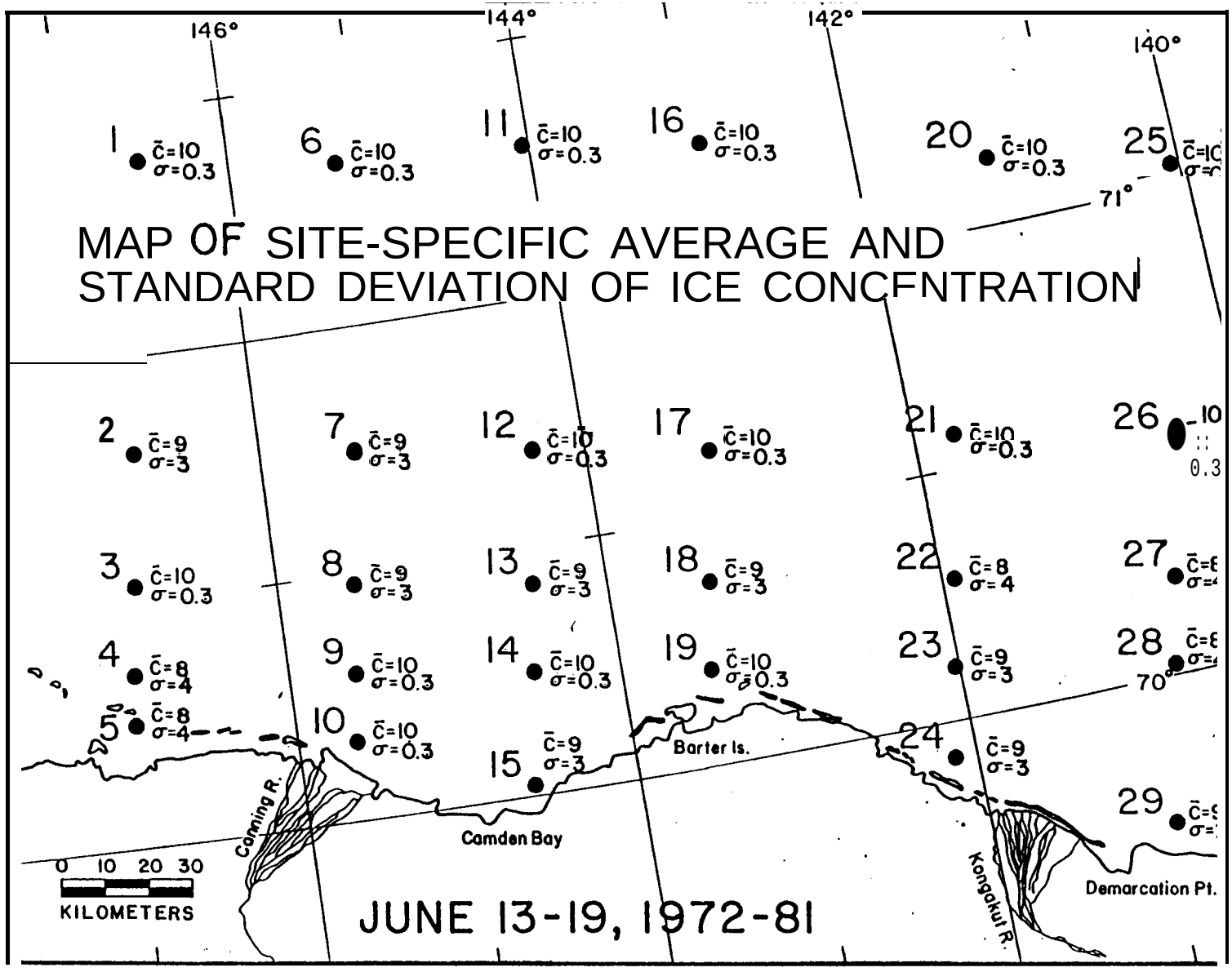
Ice concentration is uniformly greater than 75% throughout the study area. The site-specific map of concentration (following page) shows that there is little variability (low standard deviation values) anywhere within the region except in the extreme eastern portion where average concentrations of 80% and 90% are found. Here standard deviations of 30% and 40% occur. This is very likely a result of the early removal of ice in the Mackenzie Bay area following flooding by the Mackenzie River. Similarly, the dominant ice concentration map shows that for the most part, the entire study area was dominated by greater than 90% ice concentration. Exceptions were found in highly sheltered coastal areas.


142°
140°
71°
D
70°
Barter Is.
Canning R.
Camden Bay
Kongakut
Demarcation Pt.
0 10 20 30
KILOMETERS
(JUNE 13-19)


DOMINANT ICE CONCENTRATION
146°
142°
140°
71°
70°
4
1
3
Barter Is.
Canning R.
Camden Bay
Kongakut R.
Demarcation Pt.
0 10 20 30
KILOMETERS
NO DOMINANCE
1 0-10% ICE COVER
2 11-50% ICE COVER
3 51-90% ICE COVER
4 91-100% ICE COVER

$\bar{c}$ = average ice concentration in tenths of ice cover "

σ = average ice concentration in tenths of ice cover

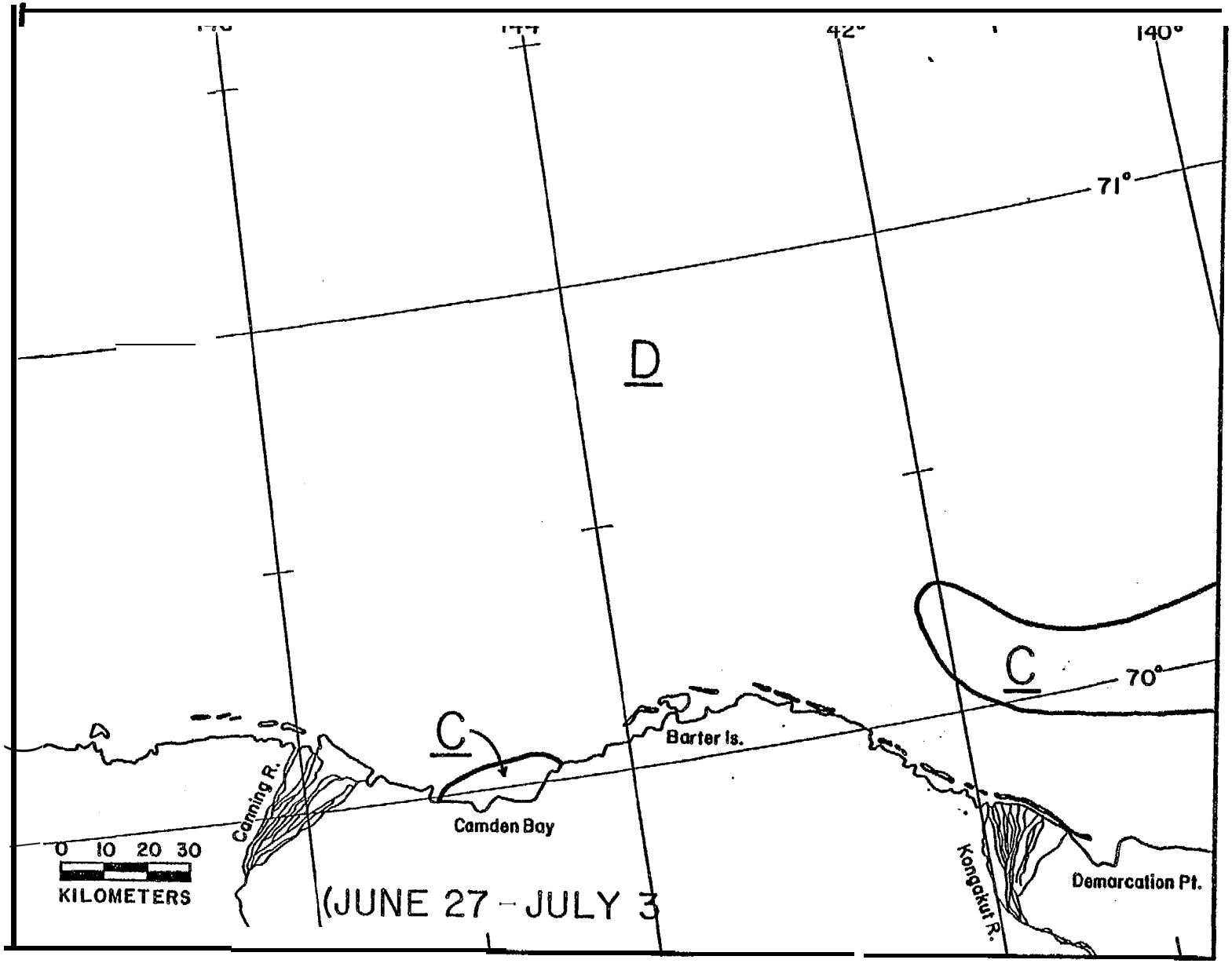


Ice Concentration for June 27-July 3

A= 0-25% average ice concentration
B= 26-50% average ice concentration
C= 51-75% average ice concentration
D= 76-1OCM average ice concentration

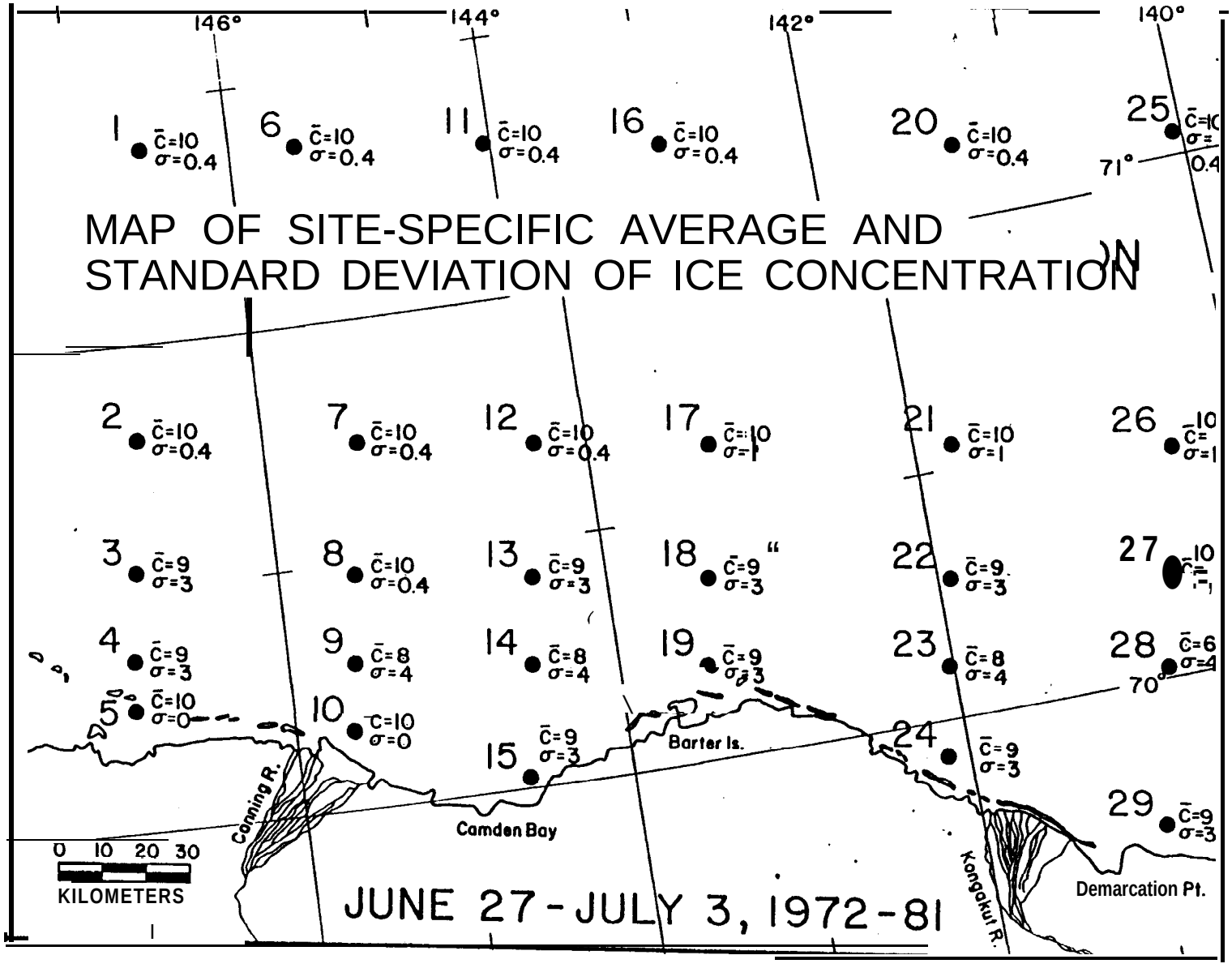
Ice concentration remains for the most part greater than 75% throughout the study area. However, the eastern weakening of the ice shown only in the standard deviation values for the previous period becomes evident now as a tongue of 50-75% concentration enters the study area from the east. Furthermore, the site-specific concentration map shows that all across the study area out to a distance of 25 km, average concentration values are around 80% to 90% and standard deviations range from 30% to 40%. Hence, although the average concentration remains greater than 75%, the probability of open water being found in the region between shore and 25 km offshore is considerably greater than during the previous period.

During this period a large area in Camden Bay has statistically less than 75% ice cover. There is no dominant ice concentration map for this period because the data for the ice analysis maps were in two week units, while the Landsat data were in hi-monthly units.


144
142°
140°
71°
D
C
70°
C
Barter Is.
Canning R.
Camden Bay
Kongakut R.
Demarcation Pt.
0 10 20 30
KILOMETERS
(JUNE 27 – JULY 3

$\bar{c}$ = average ice concentration in tenths of ice cover "

u = average ice concentration in tenths of ice cover

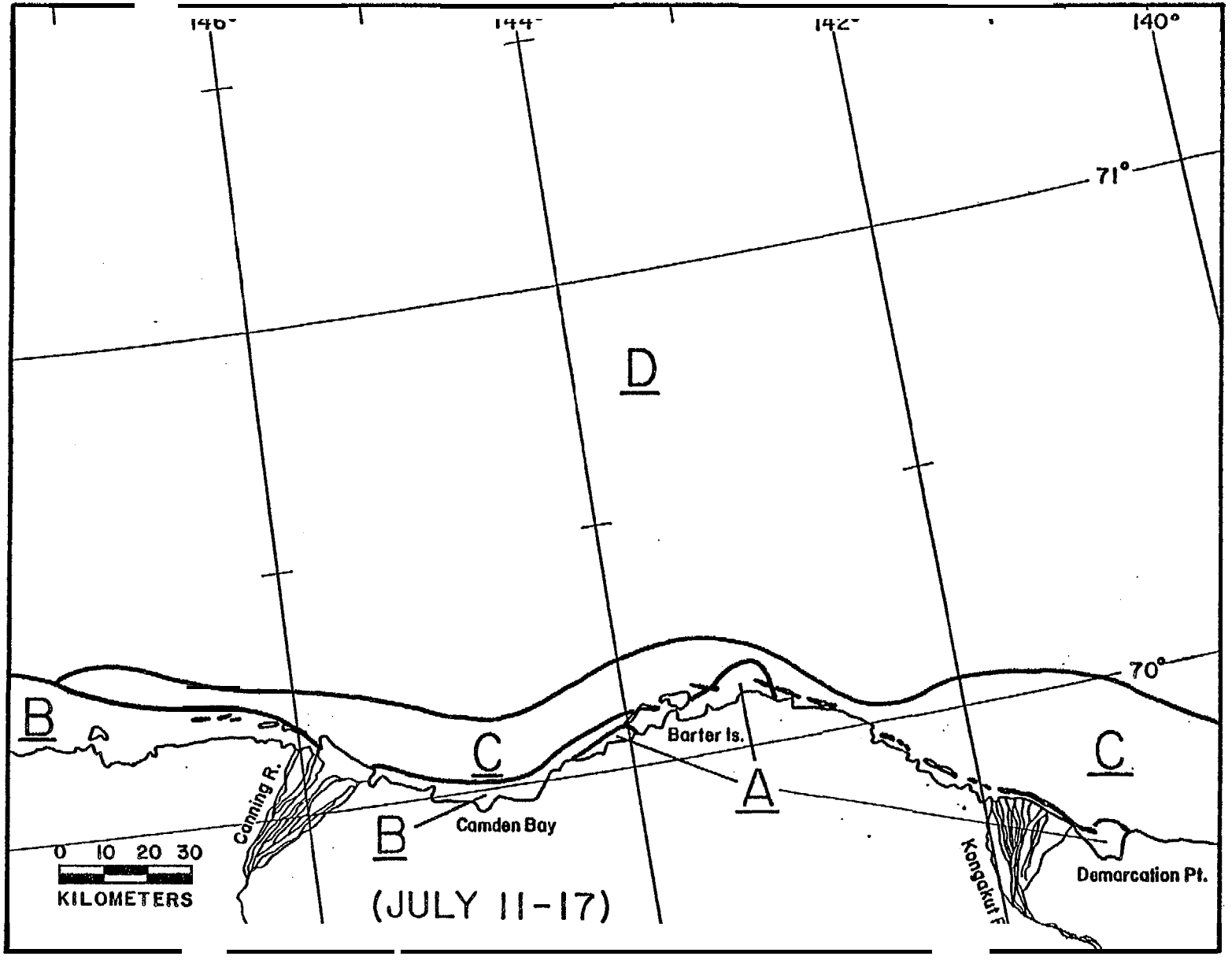


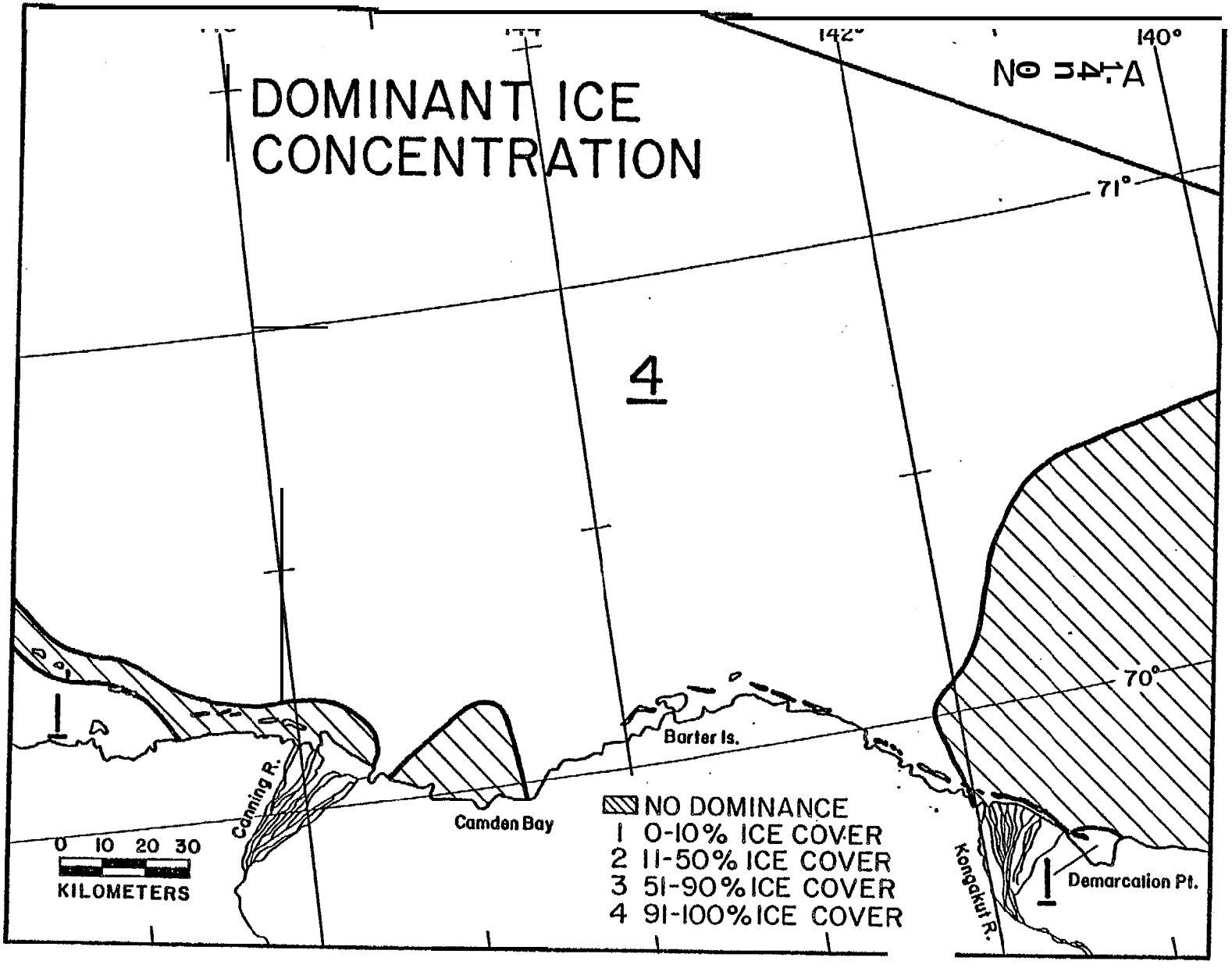
Ice Concentration for July 11-17

A= 0-25% average ice concentration
B= 26-50% average ice concentration
C= 51-75% average ice concentration
D= 76-100% average ice concentration

By this time a considerable change in ice concentration has taken place in the study area. A broad band of 51-75% concentration now stretches nearly all the way across the region extending to distances between 5 and 30 km offshore. Between this zone and shore are areas of even less average concentration. Highly protected areas have the lowest concentration, 0-25%, and the dominance map shows that 0-10% is the dominant condition in these areas. Hence, these areas can be reliably considered to contain largely water at this time.

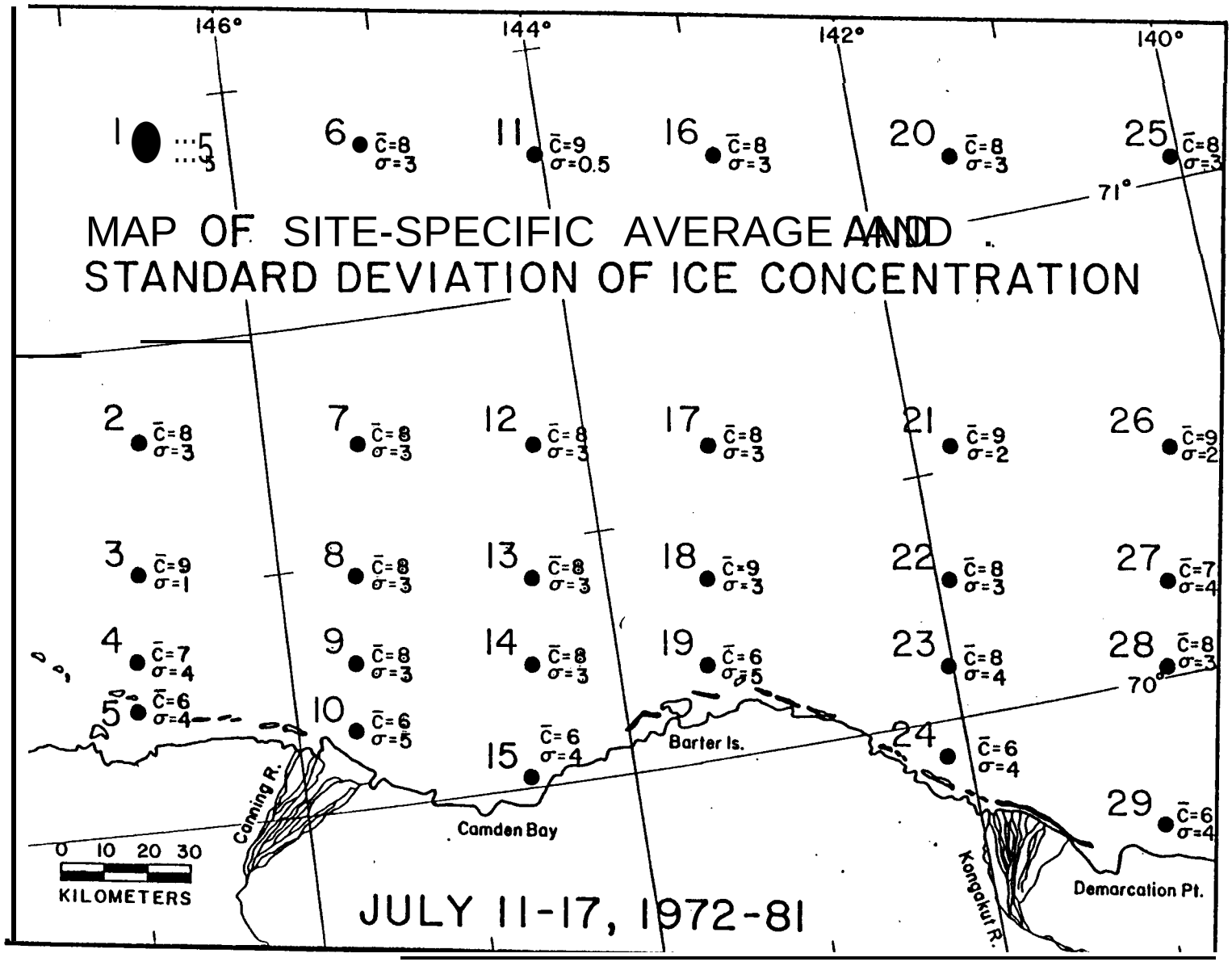
Examining the map containing site-specific average concentrations and standard deviations, it can be seen that variability in concentration decreases from +40% in nearshore areas only to ±30% 40 km offshore. This might seem to imply a large variation in concentration in the 76-100% concentration region. However, the dominance map shows that 91-100% concentration occurs here on more than 50% of observed occasions. Hence, the average concentrations shown on this map are generally representative of the dominant concentrations and, therefore, this map can largely be taken to represent normal ice conditions for this time of year.


146°
144°
142°
140°
71°
70°
D
B
C
A
B
C
Barter Is.
Canning R.
Camden Bay
Kongakut R.
Demarcation Pt.
0 10 20 30
KILOMETERS
(JULY 11-17)


DOMINANT ICE CONCENTRATION
4
NO DATA
142°
140°
71°
70°
Barter Is.
Canning R.
Camden Bay
Kongakut R.
Demarcation Pt.
0 10 20 30
KILOMETERS
NO DOMINANCE
1 0-10% ICE COVER
2 11-50% ICE COVER
3 51-90% ICE COVER
4 91-100% ICE COVER

$\bar{c}$ = average ice concentration in tenths of ice cover

σ = average ice concentration in tenths of ice cover



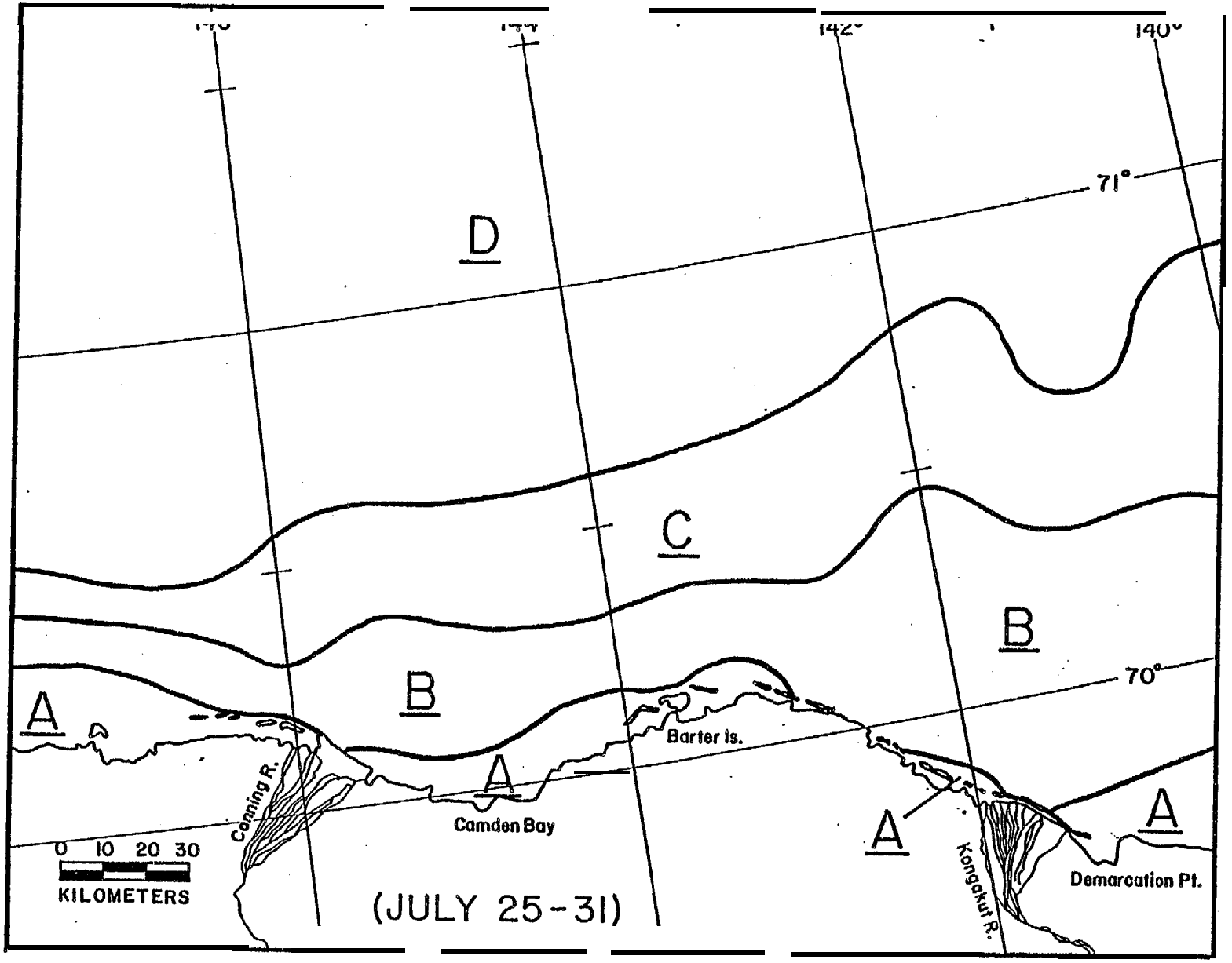
Ice Concentration for July 25-31

A= 0-25% average ice concentration
B= 26-50?? average ice concentration
C= 51-75% average ice concentration
D= 76-100% average ice concentration

Ice concentrations continue to decrease throughout the study area. However, shores exposed to the east show a tendency to have slightly higher ice concentrations. This tendency can also be seen on the previous period's ice concentration map. It is postulated that this occurs because of a general drift of ice from the east, resulting in accumulation of ice on east-facing coasts.

Note that, whereas during the previous period there was a band of 51-75% ice concentration across the study area, just offshore there is now a band of 26-50% ice concentration roughly in its place. Now the band of 51-75% concentration is even farther offshore.

The site-specific ice concentration map shows that throughout the study area the standard deviation of concentration from the average is 30 to 40%. This variability tends to decrease both with very high and very low concentrations. The dominant concentration map shows that despite this variability, the dominant ice condition in the nearshore areas is less than 10% concentration. The dominant concentration map also shows that all of the 51-75% concentration and even part of the 26-50% concentration zone had concentrations greater than 91% on more than 50% of observed occasions. This indicates that normally there is a well defined pack ice edge between the nearshore area and the offshore zone.


142°
140°
71°
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D
C
B
B
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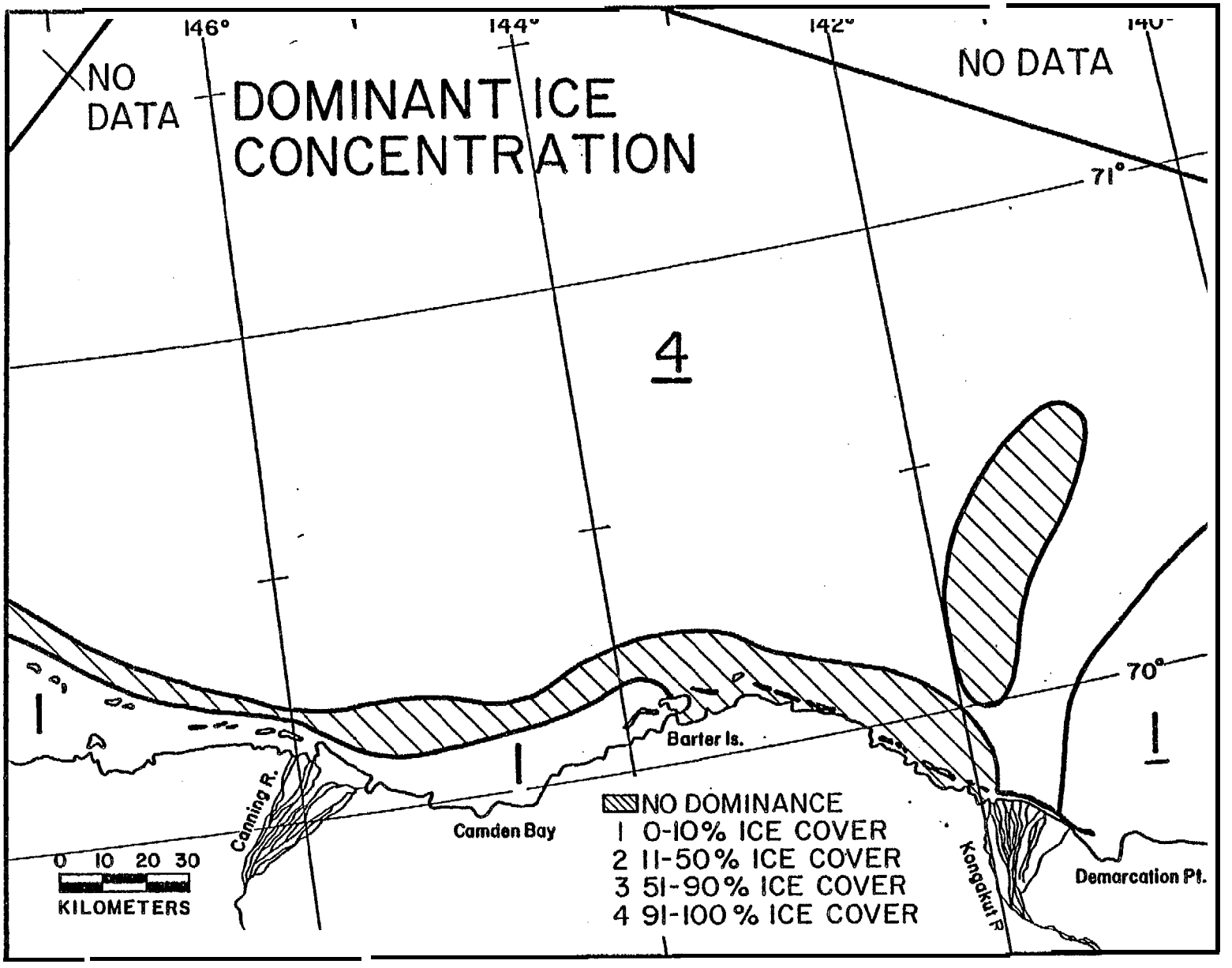
A
A
A
Barter Is.
Canning R.
Camden Bay
Kongakut R.
Demarcation Pt.
0 10 20 30
KILOMETERS
(JULY 25-31)


NO DATA
DOMINANT ICE CONCENTRATION
NO DATA
146°
144°
142°
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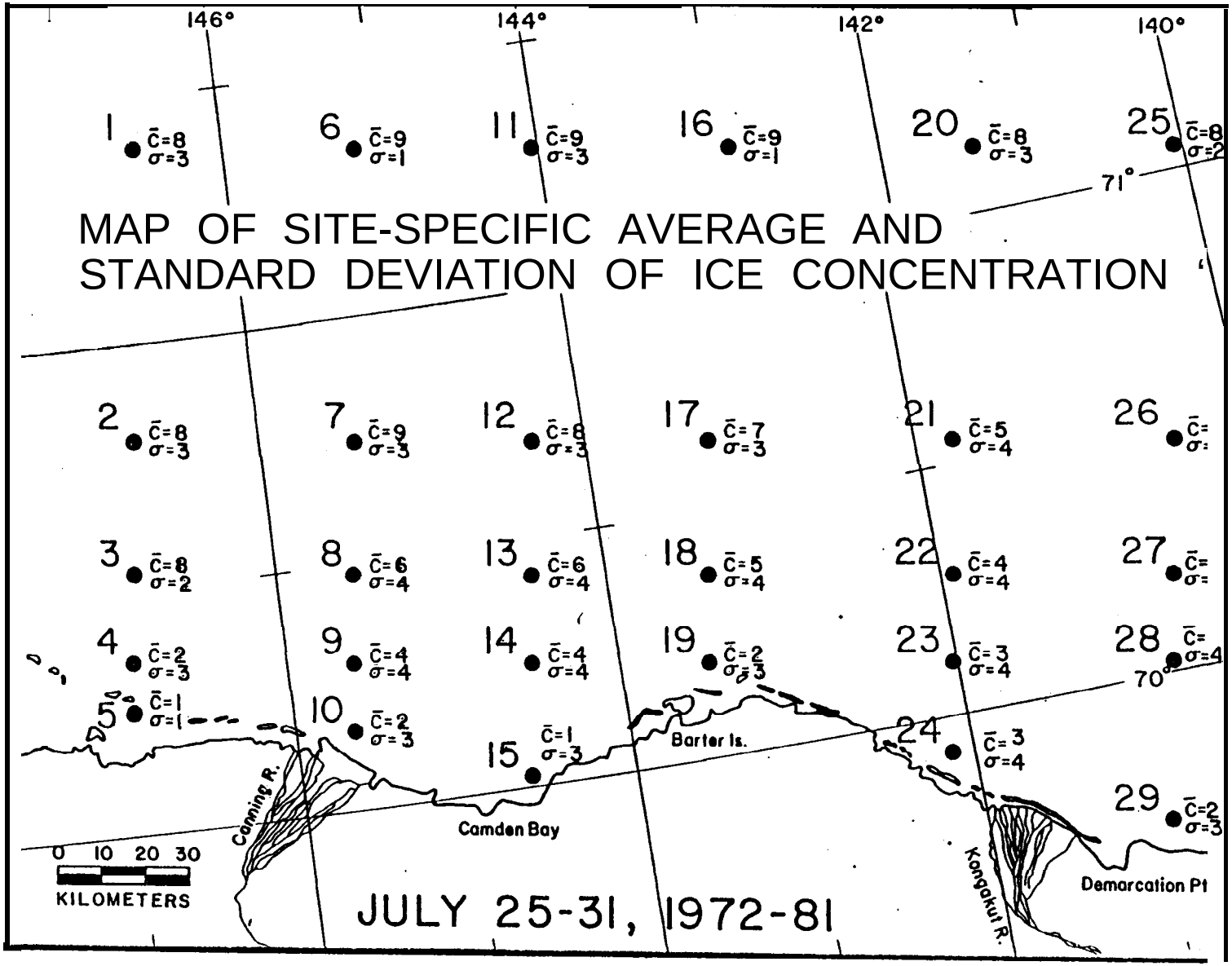
Barter Is.
Canning R.
Camden Bay
Kongakut R.
Demarcation Pt.
0 10 20 30
KILOMETERS
NO DOMINANCE
1 0-10% ICE COVER
2 11-50% ICE COVER
3 51-90% ICE COVER
4 91-100% ICE COVER

$\bar{c}$ = average ice concentration in tenths of ice cover.

σ = average ice concentration in tenths of ice cover



Ice Concentration for August 8-14

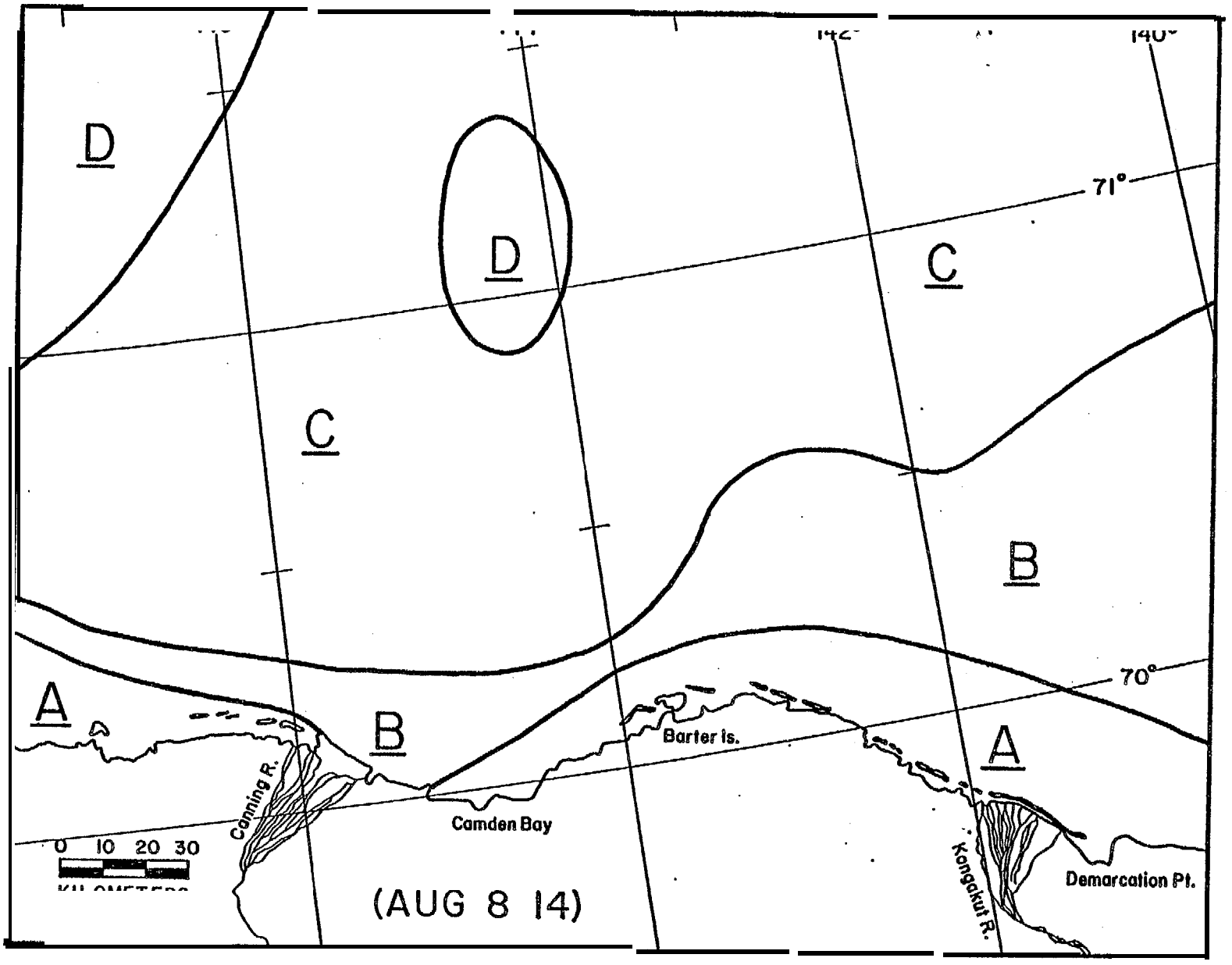
A= 0-25% average ice concentration
B= 26-50% average ice concentration
C= 51-75% average ice concentration
D= 76%-100 average ice concentration

Ice concentration during this period continues to decrease. Most pronounced is the growth of the 51-75% concentration zone in the far offshore portion of the study area. In many respects the nearshore portion of the western sector of the study area has changed the least, with the 0-25% and 26-50% zones changing location very little. (The 51-75% zone expanded considerably seaward, but less than in the eastern portion of the study area.)

Continuing the trend seen earlier, the ice concentration decreases most in the eastern portion of the study area. Most noticeable here is the broad band of 0-25% ice cover now appearing along the coast from Camden Bay eastward.

The map of site-specific average concentration and standard deviation values shows that the variation in concentration is around 30% throughout the study area during this period, regardless of the average concentration.

It is interesting to note that a small portion of shore near the Canning River delta still contains 26-50% average ice cover. However, the site-specific map shows that the average concentration here is only around 30% or just within the range of this denser categroy.


D
D
C
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B
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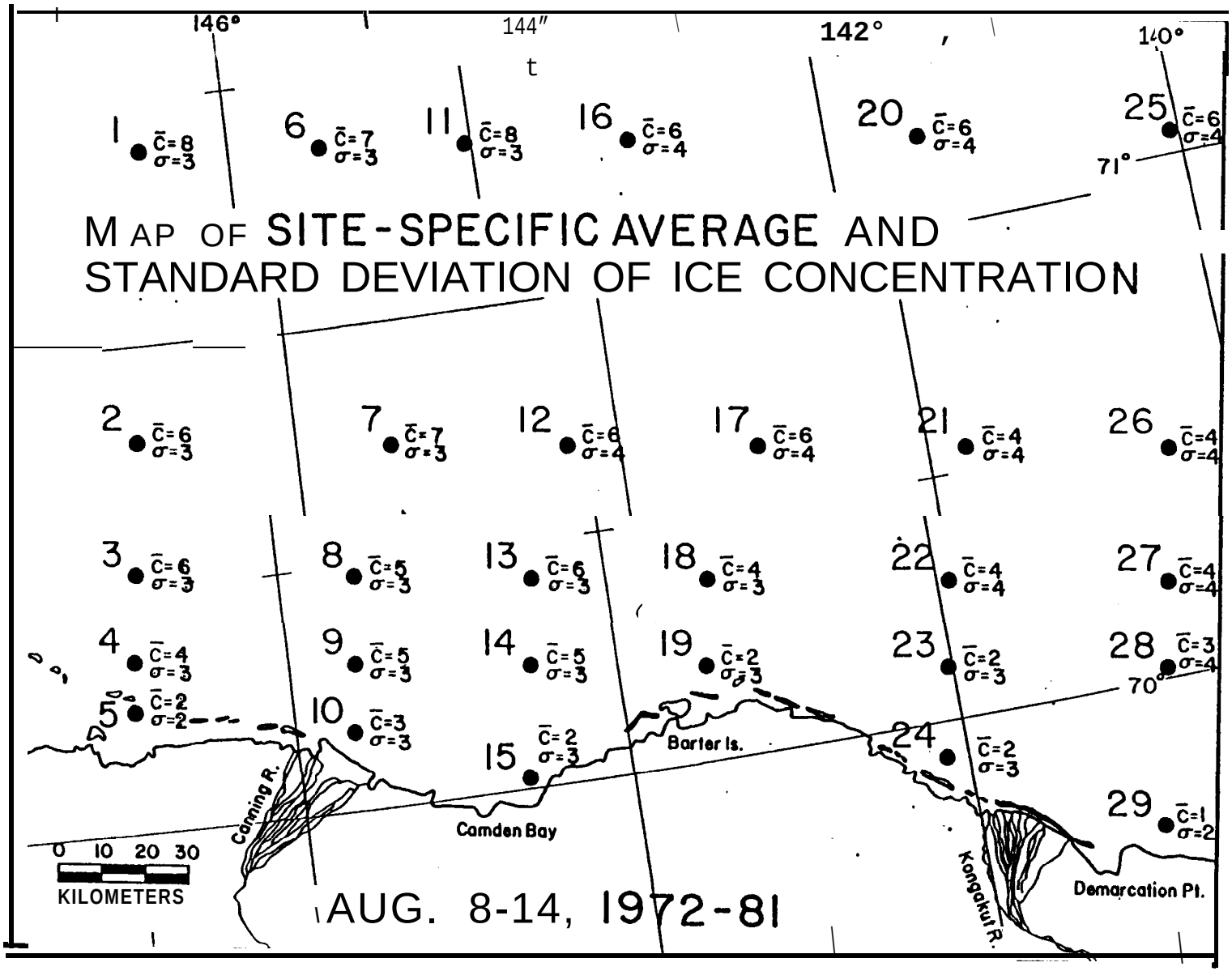
B
A
71°
70°
Barter Is.
Canning R.
Camden Bay
Kongakut R.
Demarcation Pt.
0 10 20 30
(AUG 8 14)

$\bar{c}$ = average ice concentration in tenths of ice cover

σ = average ice concentration in tenths of ice cover

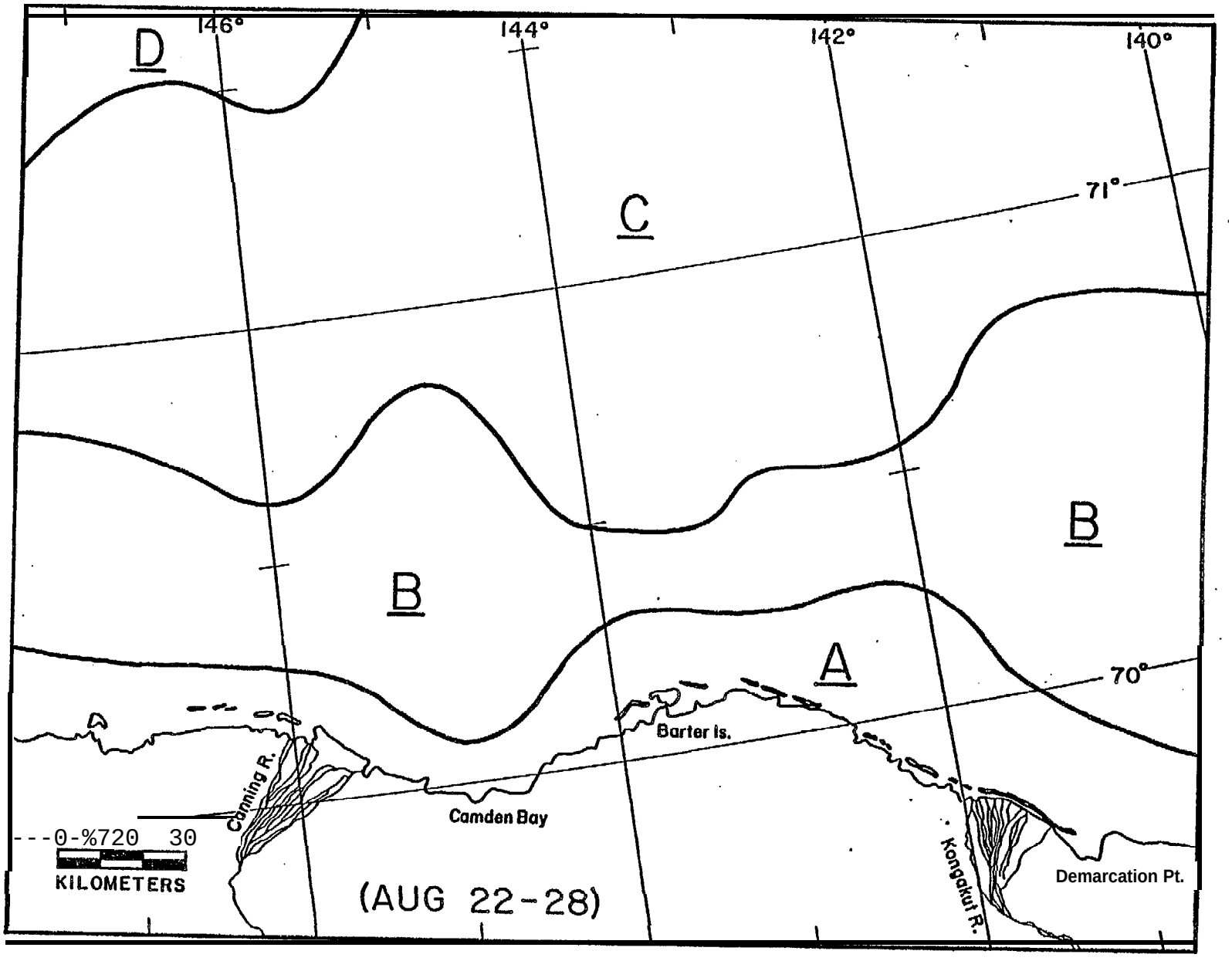


Ice Concentration for August 22-28

A= 0-25% average ice concentration
B= 26-50% average ice concentration
C= 51-75% average ice concentration
D= 76-100% average ice concentration

The most significant change between the last period and this is the expansion of the zone of 26-50% concentration. In addition, the area of increased ice concentration off the mouth of the Canning River has disappeared. (In fact, according to the site-specific ice concentration map, it now has a concentration of 10%, even less than most other coastal areas.)

The standard deviation ranges from 30% in coastal areas to around 40% in the offshore region. This indicates that even at this late date, ice concentrations in the coastal areas can range well beyond the 0-25% average values found in the coastal zone. In addition, just 30 km offshore from Barter Island, concentration values average around 40% with a standard deviation in the vicinity of 40%. This indicates that the probability of encountering a high concentration of ice in this region is significant even at this late date.


146°
144°
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71°
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D
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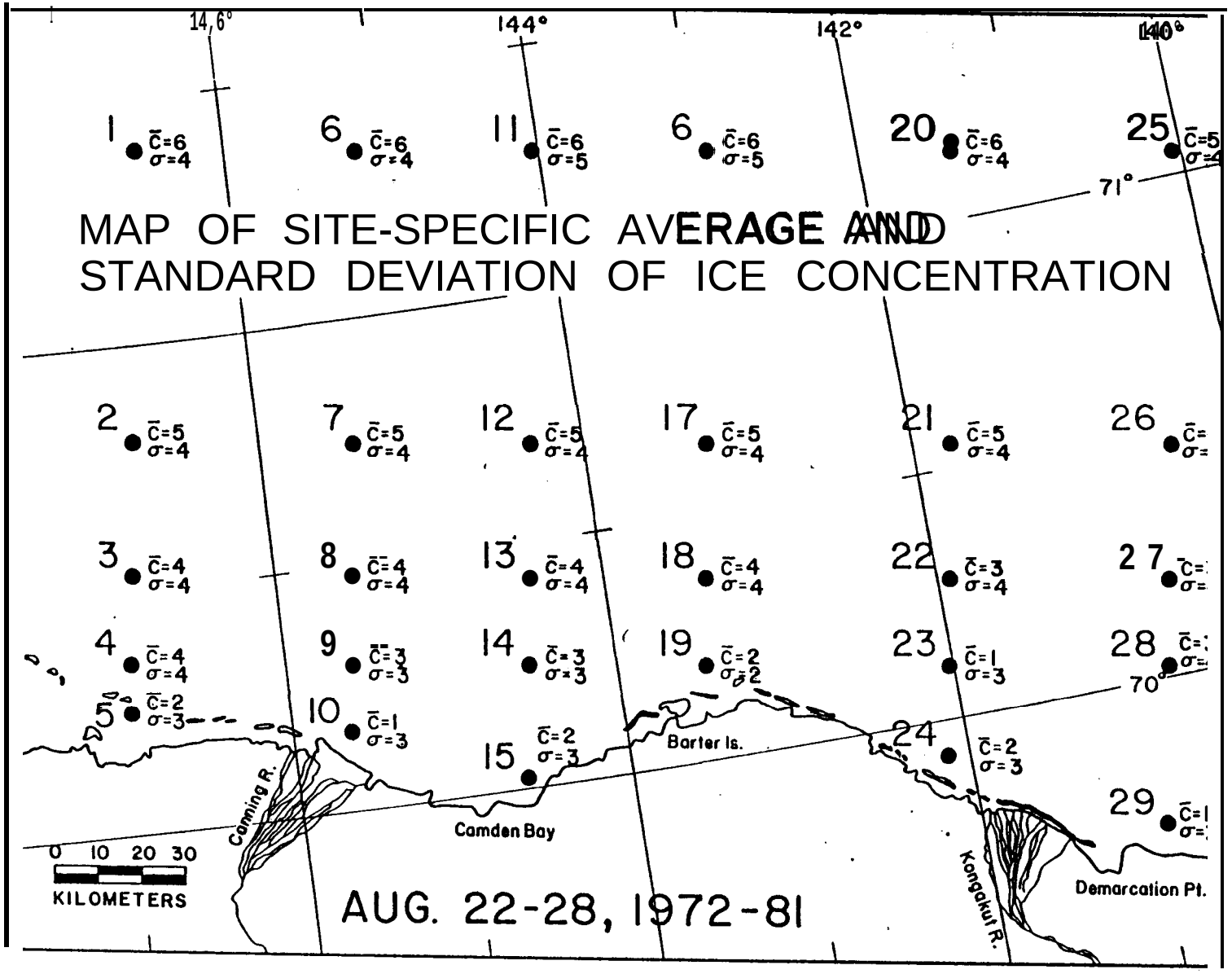
A
Barter Is.
Canning R.
Camden Bay
Kongakut R.
Demarcation Pt.
0-%720 30
KILOMETERS
(AUG 22-28)

$\bar{c}$ = average ice concentration in tenths of ice cover

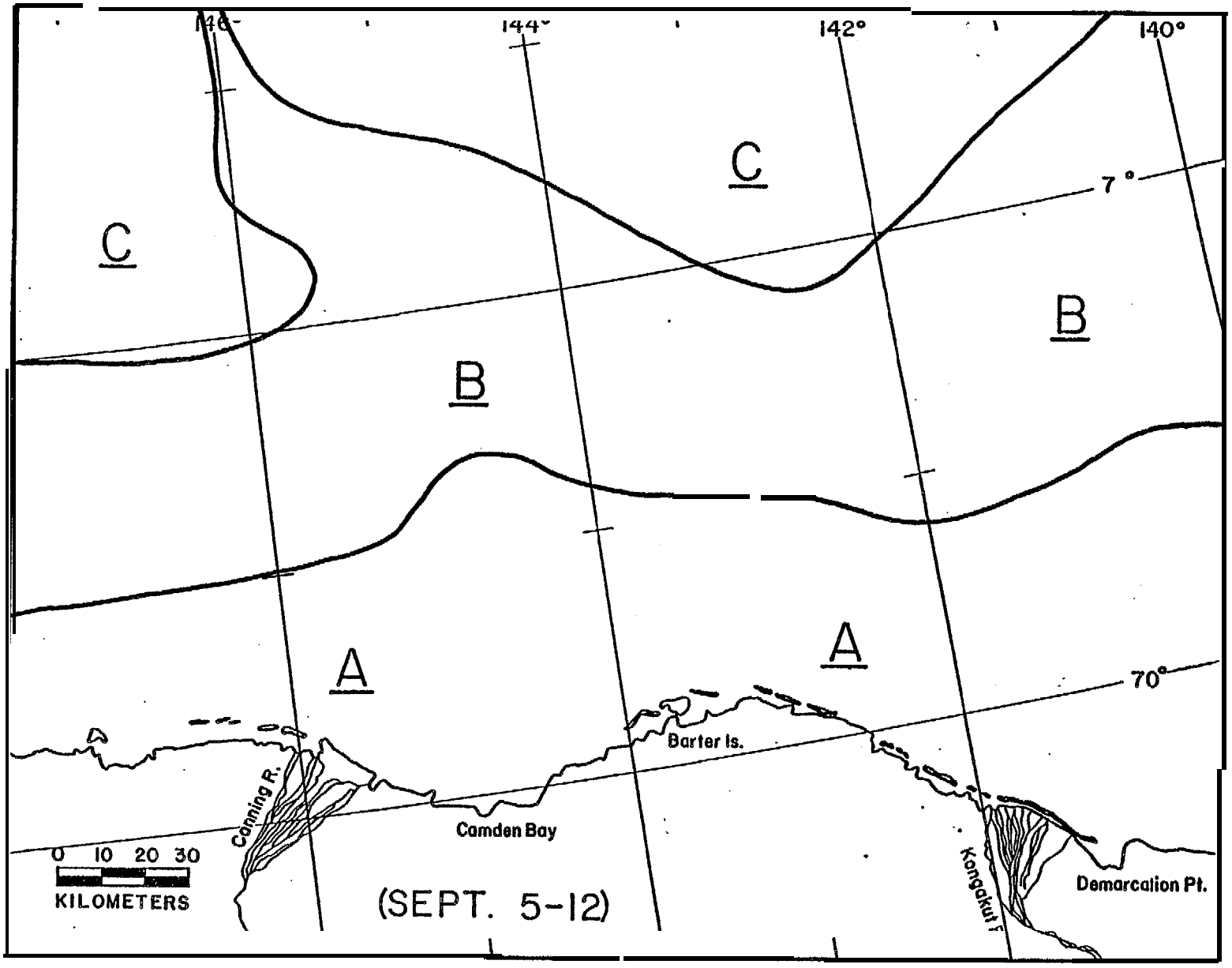
σ = average ice concentration in tenths of ice cover



Ice Concentration for September 5-12 ,

A= 0-25% average ice concentration
B= 26-50% average ice concentration
C= 51-75% average ice concentration
D= 76-100% average ice concentration

Ice concentration has decreased significantly over the entire study area since the last observation period. Comparing the zonal ice concentration map with the site-specific concentration map, it can be seen that although there is now a zone of low concentration along the coast, the average concentration within this zone is 10% not far offshore. Furthermore, the standard deviation from this average value is around 20%. Hence, this coastal area is not characteristically ice-free even at this advanced date. Ice concentrations 30 km offshore have decreased to the point that concentrations on the order of 50% represent the top end of the one standard deviation range of values.


146°
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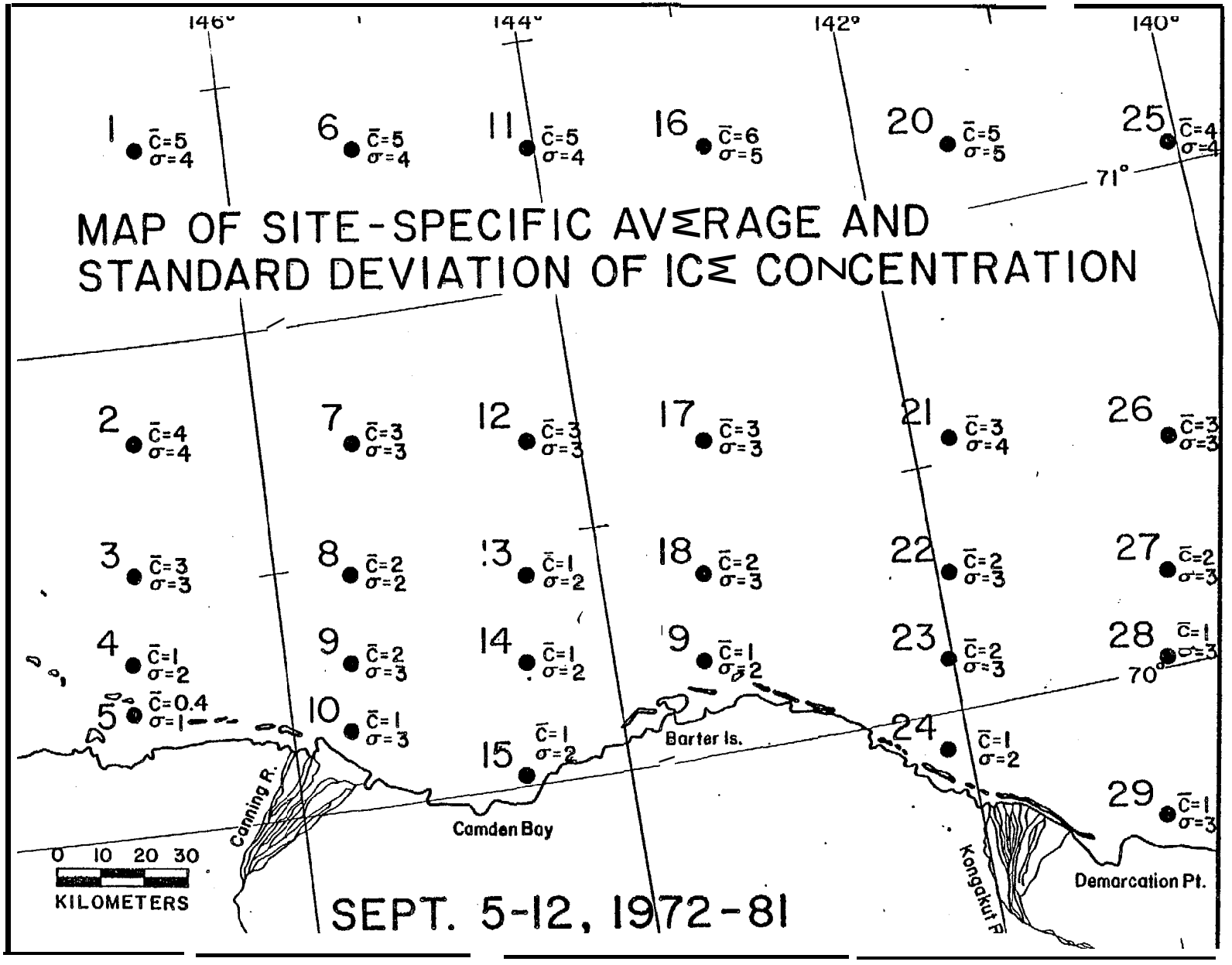
Barter Is.
Canning R.
Camden Bay
Kongakut R.
Demarcation Pt.
0 10 20 30
KILOMETERS
(SEPT. 5-12)

$\bar{c}$ = average ice concentration in tenths of ice cover

σ = average ice concentration in tenths of ice cover



Ice Concentration for September 19-26

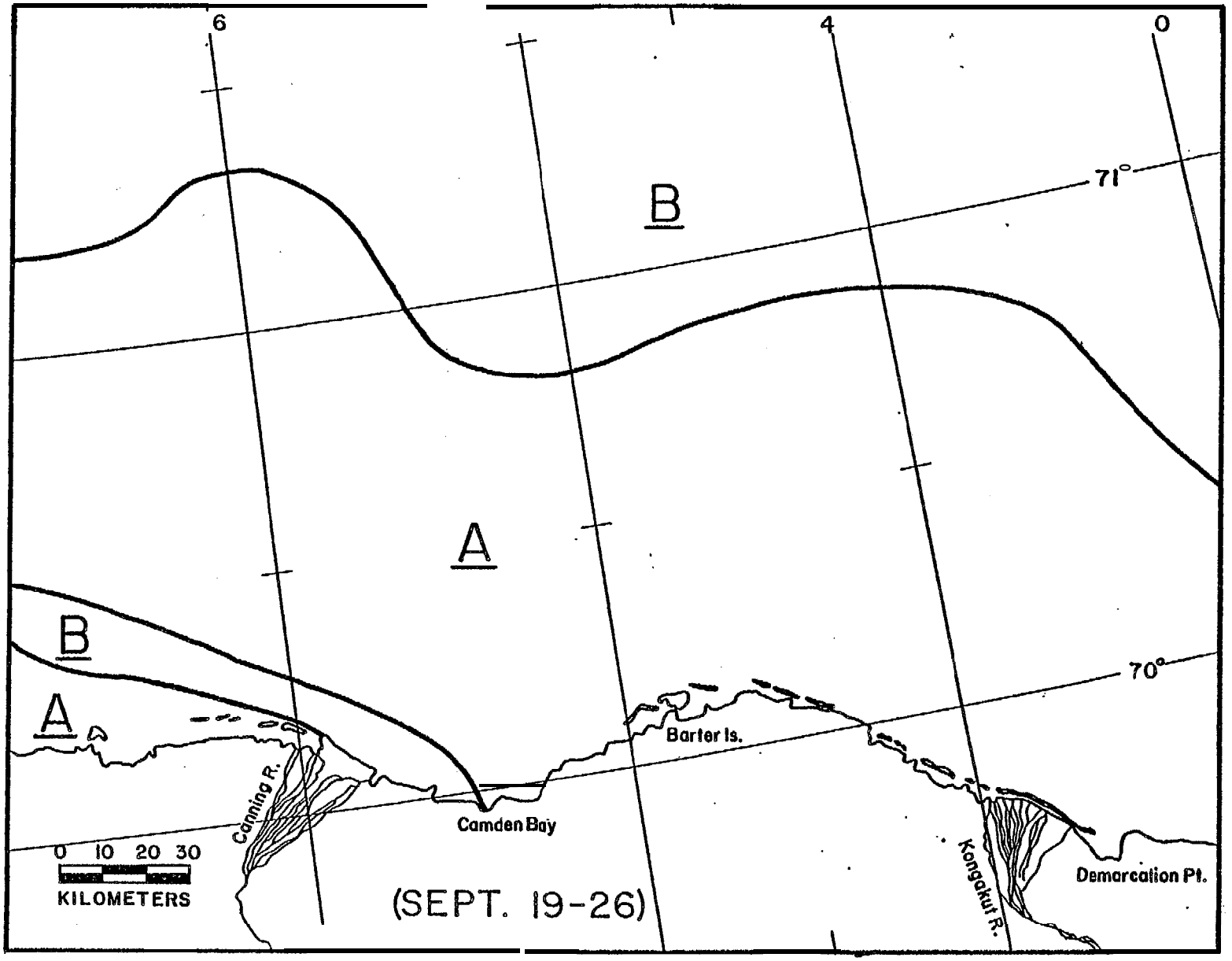
A= O-25% average ice concentration
B= 26-50% average ice concentration
C= 51-75% average ice concentration
D= 76-100?? average ice concentration

In general, ice concentrations have continued to decrease throughout the study area with the noticeable exception of a band of 26-50% concentration suddenly appearing in the western sector of the study area.

Throughout much of the study area, ice concentration values are now on the order of 20% with standard deviations on the order of 30%. This places the occurrence of a 50% concentration in these areas in the category of an extreme event.

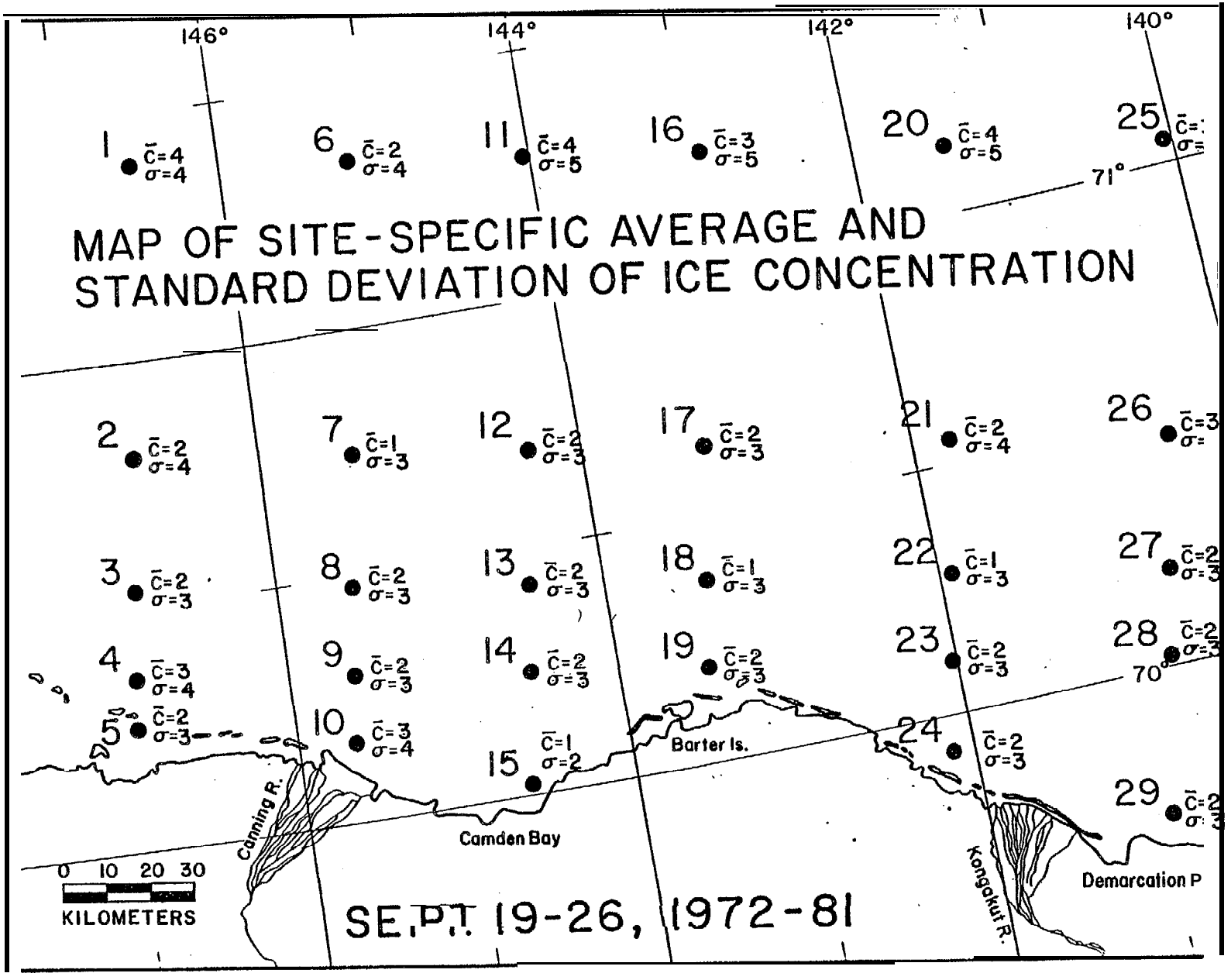
Despite the general decrease of ice concentration, a band of 26-50% concentration can be found extending west-northwestward from the coast in the Canning River delta to Camden Bay region. At first it was thought that this was the result of some statistical anomaly. However, upon examination of the yearly ice maps, it could be seen that for two years the ice exhibited an enhanced concentration in that area. The site-specific ice concentration map shows that this band contains only slightly higher ice concentration than the surrounding zone. Although the higher concentration zone is indicated by the statistics and zonal concentration designations, the actual change in average concentration here appears to be representative of actual conditions.

Examination of satellite imagery indicates that this statistical band of enchanced concentration resulted in the occurrence of a band of 50-70% ice concentration in that location on one and possibly two occasions. It appears that this ice consists of first year pack ice floes which have been concentrated into this band as a result of westward-moving pack ice interacting with the northeastward facing coast in this region.


6
4
0
71°
70°
B
A
B
A
Barter Is.
Canning R.
Camden Bay
Kongakut R.
Demarcation Pt.
0 10 20 30
KILOMETERS
(SEPT. 19-26)

$\bar{c}$= average ice concentration in tenths of ice cover

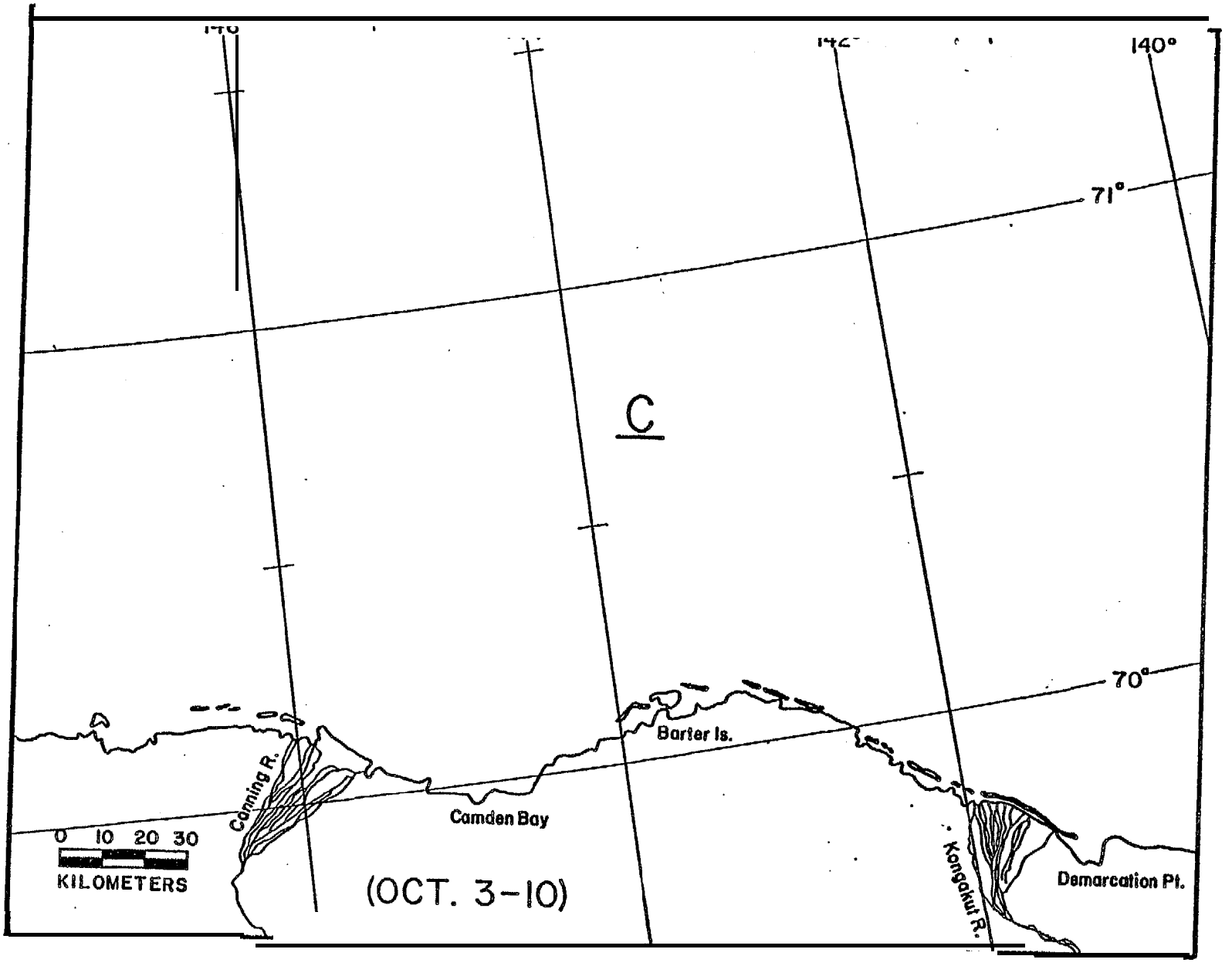
σ = standard deviation in tenths of ice cover



Ice Concentration for October 3-10

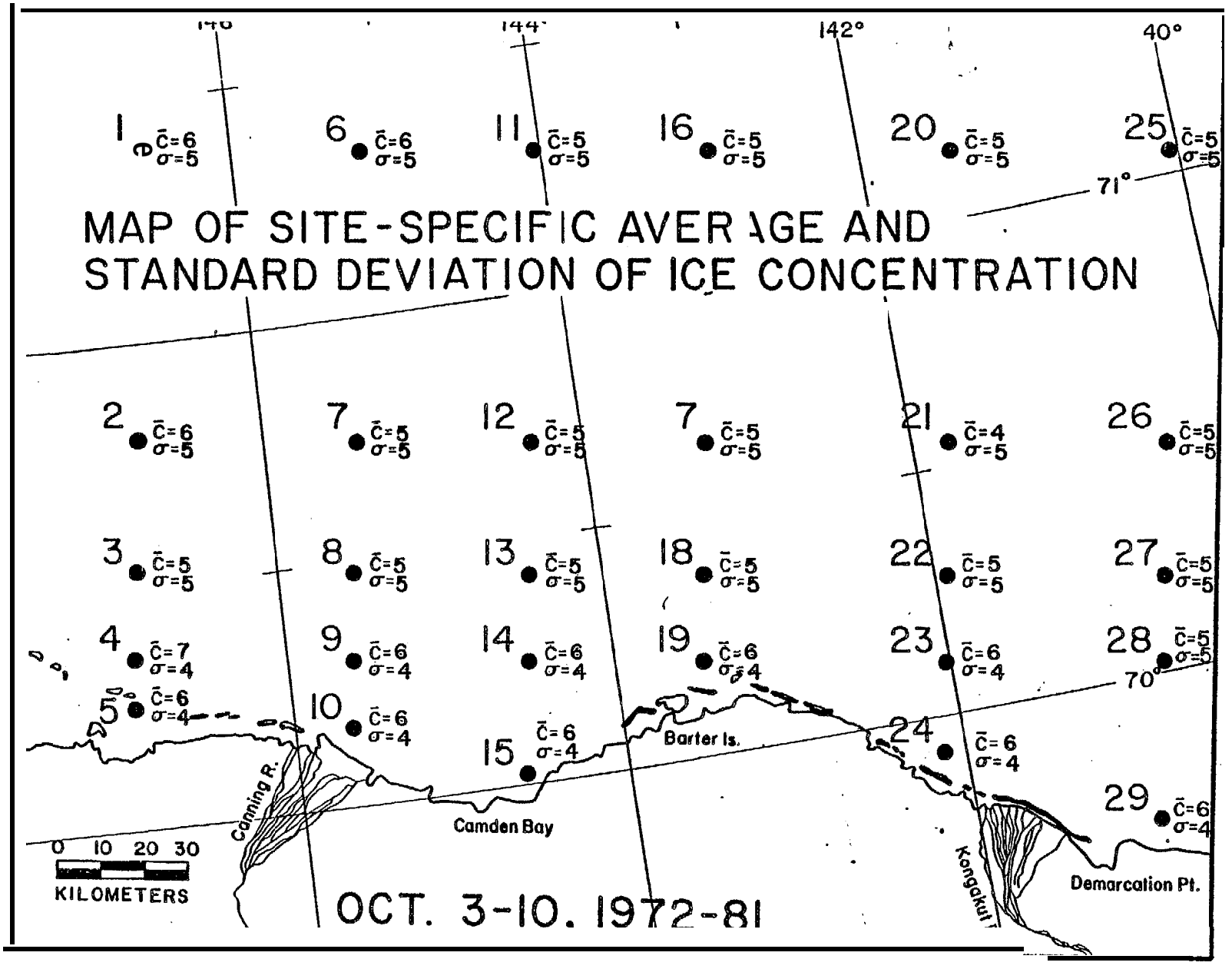
A= 0-25% average ice concentration
B= 26-50% average ice concentration
C= 51-75% average ice concentration
D= 76-1OCW average ice concentration

Ice concentration throughout the study area is within the 51-75% concentration range. Clearly, fall freeze-up takes place during this period with sufficient frequency to significantly affect these average values. However, the standard deviation is also quite large, indicating a wide year-to-year variation in time of freeze-up.


140°
71°
C
70°
Barter Is.
Canning R.
Camden Bay
0 10 20 30
KILOMETERS
(OCT. 3-10)
Kongakut R.
Demarcation Pt.

$\bar{c}$ = average ice concentration in tenths of ice cover

σ = standard deviation in tenths of ice cover



Variations in Concentration at a Given Location for Each Year

Average and standard deviation values give a representation of expected normal ice behavior. However, environmental assessment often requires attention to be given to extreme events which may have occurred within a study area, and therefore, might be expected to occur again. In order to obtain a measure of extreme ice concentration events, eight locations within the study area were chosen for special analysis. These are located along three lines extending offshore from the Canning River delta, Barter Island, and the Kongakut River. For each location, a family of curves has been compiled showing the variation in ice concentration during each year of observation. These curves are included to show the high degree of inter-annual variation of ice concentration to be found in the study area and to illustrate the magnitude of the extreme events found even over the relatively brief span of years included in this study.

These curves are presented in three series, one for each lineal set of observation locations. These curves were drawn for the period starting in early June and ending in early October. Data were not scaled for the period following the October 3-10 interval because the sea was universally frozen by that time. Hence, all curves presented here return to 10 tenths following the last time interval shown.

A. Canning River Series

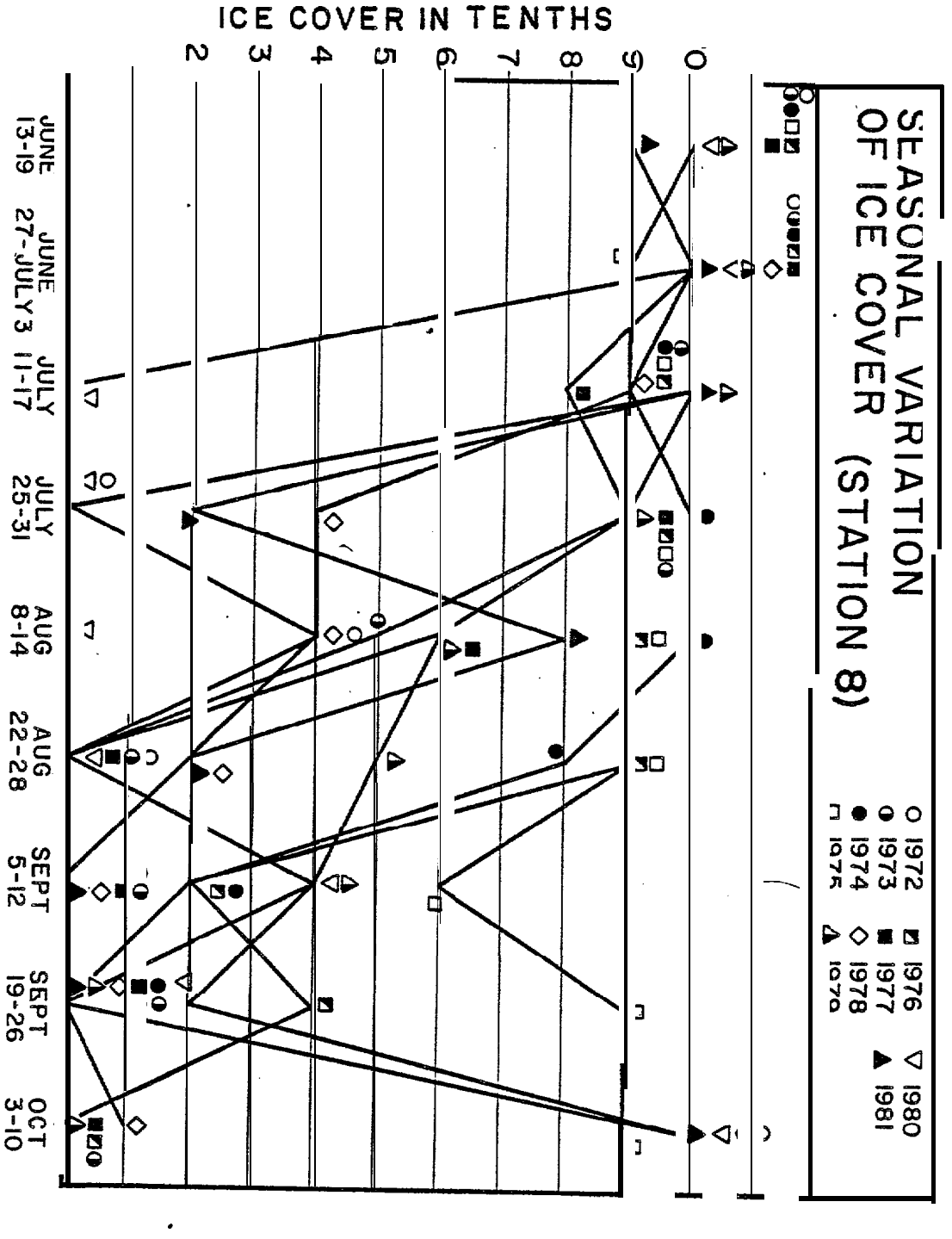
(For station locations, see site-specific average ice concentration maps.)

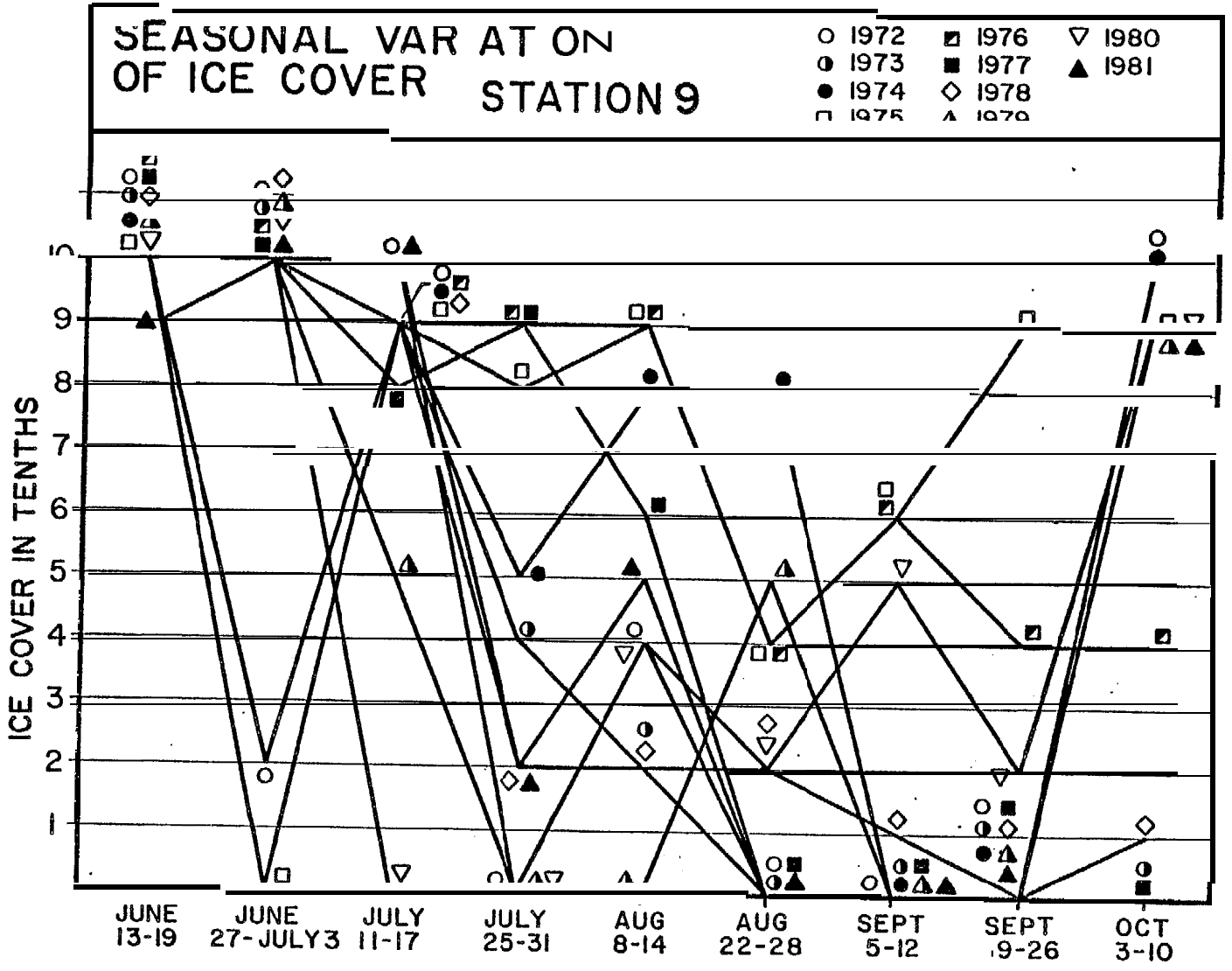
At station 8, located 40 km offshore, we see a wide variation in ice concentration throughout the summer season. Clearly, entirely open water cannot be guaranteed at any time.

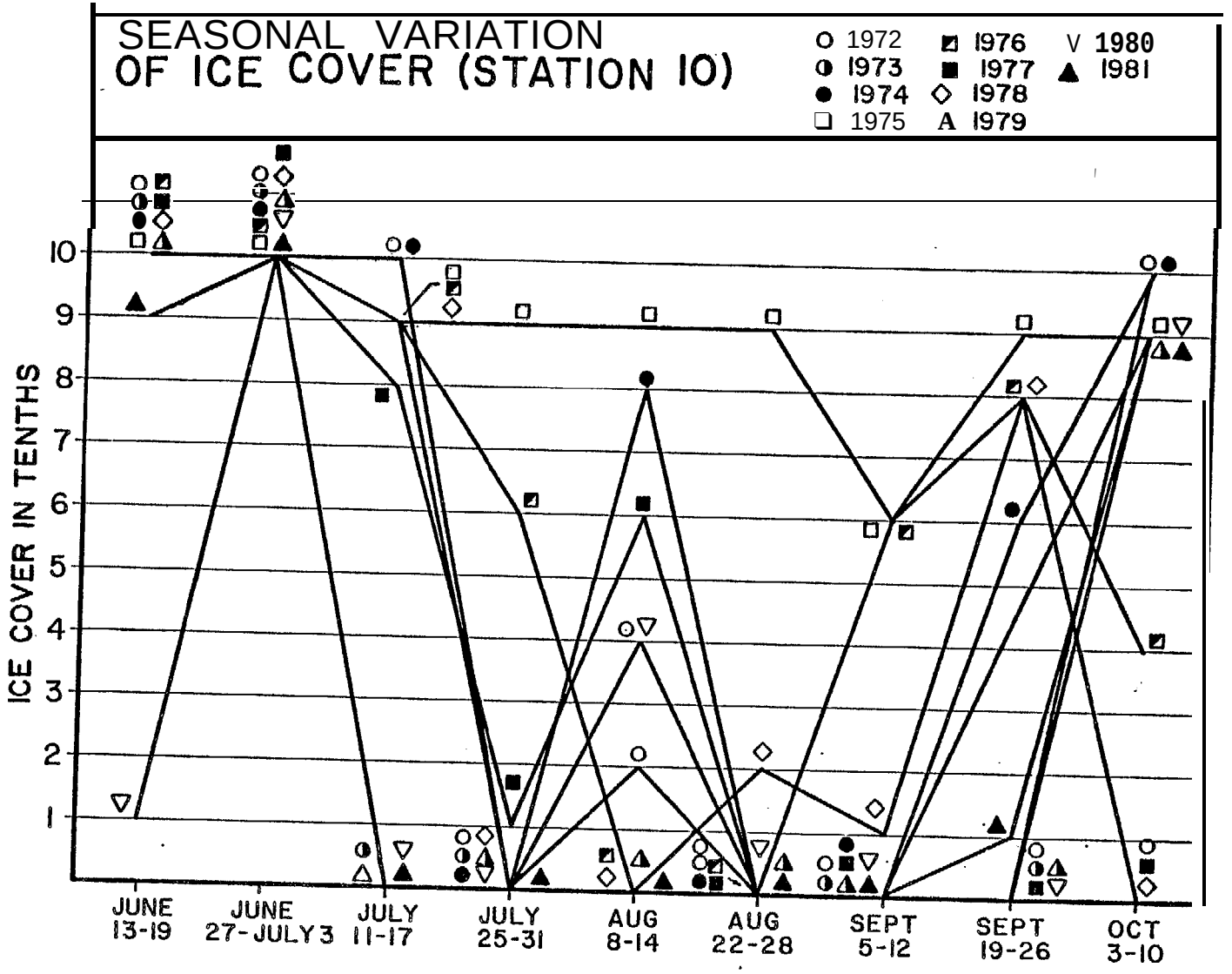
At station 9, located 20 km offshore, a wide variation in concentration can also be seen throughout. the summer. Again, although entirely. open water occurs occasionally, the normal condition is a few tenths. ice cover.

At station 10, located 5 km offshore, we see a very short period between August 22-28 and September 5-12 when ice-free conditions can be found on more than 50% of observed occasions. Even then, on 3 out of the 10 years of observation, this location had greater than zero ice concentration and during 1975 the ice concentration was around 75%.

It is interesting to note the high degree of correlation shown for a marked increase in ice concentration during the August 8-14 period.


SEASONAL VARIATION
OF ICE COVER (STATION 8)
1972
1973
1974
1975
1976
1977
1978
1979
1980
1981
ICE COVER IN TENTHS
0
1
2
3
4
5
6
7
8
9
JUNE 13-19
JUNE 27-JULY 3
JULY 11-17
JULY 25-31
AUG 8-14
AUG 22-28
SEPT 5-12
SEPT 19-26
OCT 3-10

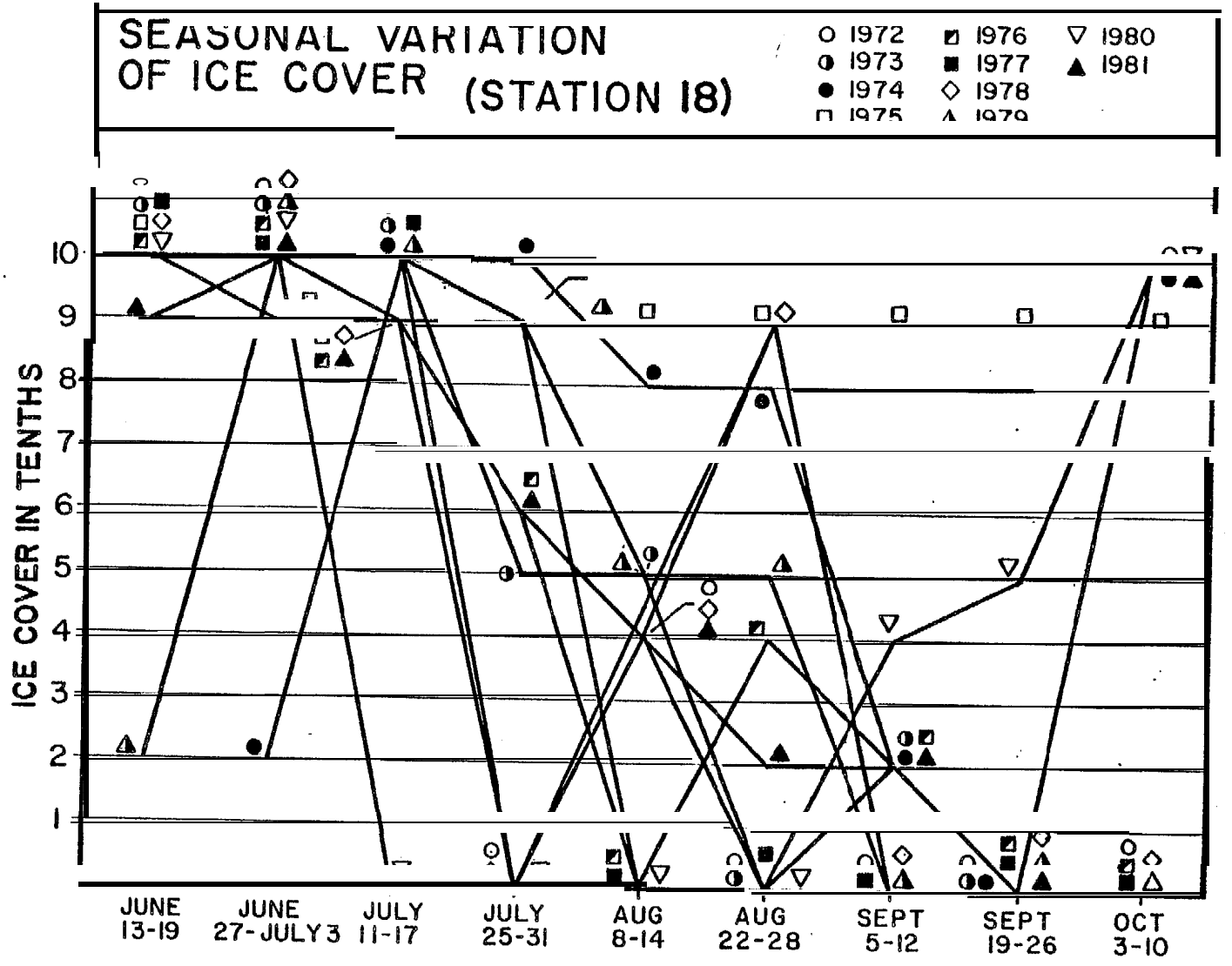

SEASONAL VAR AT ON
OF ICE COVER
STATION 9
1972
1973
1974
1975
1976
1977
1978
1979
1980
1981
ICE COVER IN TENTHS
10
9
8
7
6
5
4
3
2
1
JUNE 13-19
JUNE 27-JULY 3
JULY 11-17
JULY 25-31
AUG 8-14
AUG 22-28
SEPT 5-12
SEPT 19-26
OCT 3-10

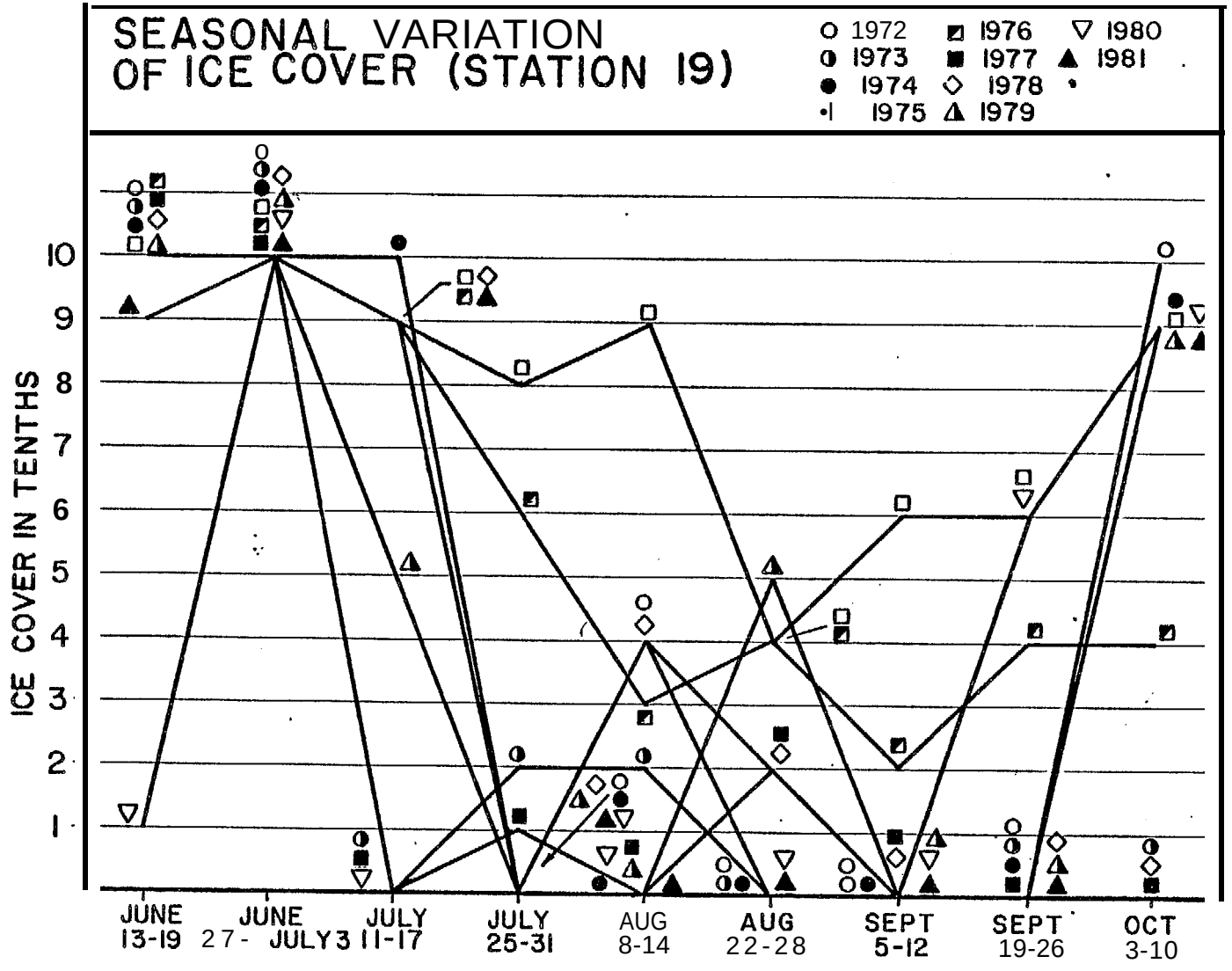

SEASONAL VARIATION
OF ICE COVER (STATION 10)
1972
1973
1974
1975
1976
1977
1978
1979
1980
1981
ICE COVER IN TENTHS
10
9
8
7
6
5
4
3
2
1
JUNE 13-19
JUNE 27-JULY 3
JULY 11-17
JULY 25-31
AUG 8-14
AUG 22-28
SEPT 5-12
SEPT 19-26
OCT 3-10

B. Barter Island Series

At station 18, located 30 km offshore, we see a wide variation in ice concentration throughout the summer with a minimum occurring around September 5-12. The average ice concentration at that time is around 20%. Following this time and continuing until early October is a period when open water is most likely at this location.

At station 1,9, located 5 km off Barter Island, we again find a wide variability of ice cover throughout the summer season. Clearly, at no time during the summer is open water a dominant condition. The lowest ice concentration occurs between late August and early September.


SEASONAL VARIATION
OF ICE COVER (STATION 18)
1972
1973
1974
1975
1976
1977
1978
1979
1980
1981
ICE COVER IN TENTHS
10
9
8
7
6
5
4
3
2
1
JUNE 13-19
JUNE 27-JULY 3
JULY 11-17
JULY 25-31
AUG 8-14
AUG 22-28
SEPT 5-12
SEPT 19-26
OCT 3-10

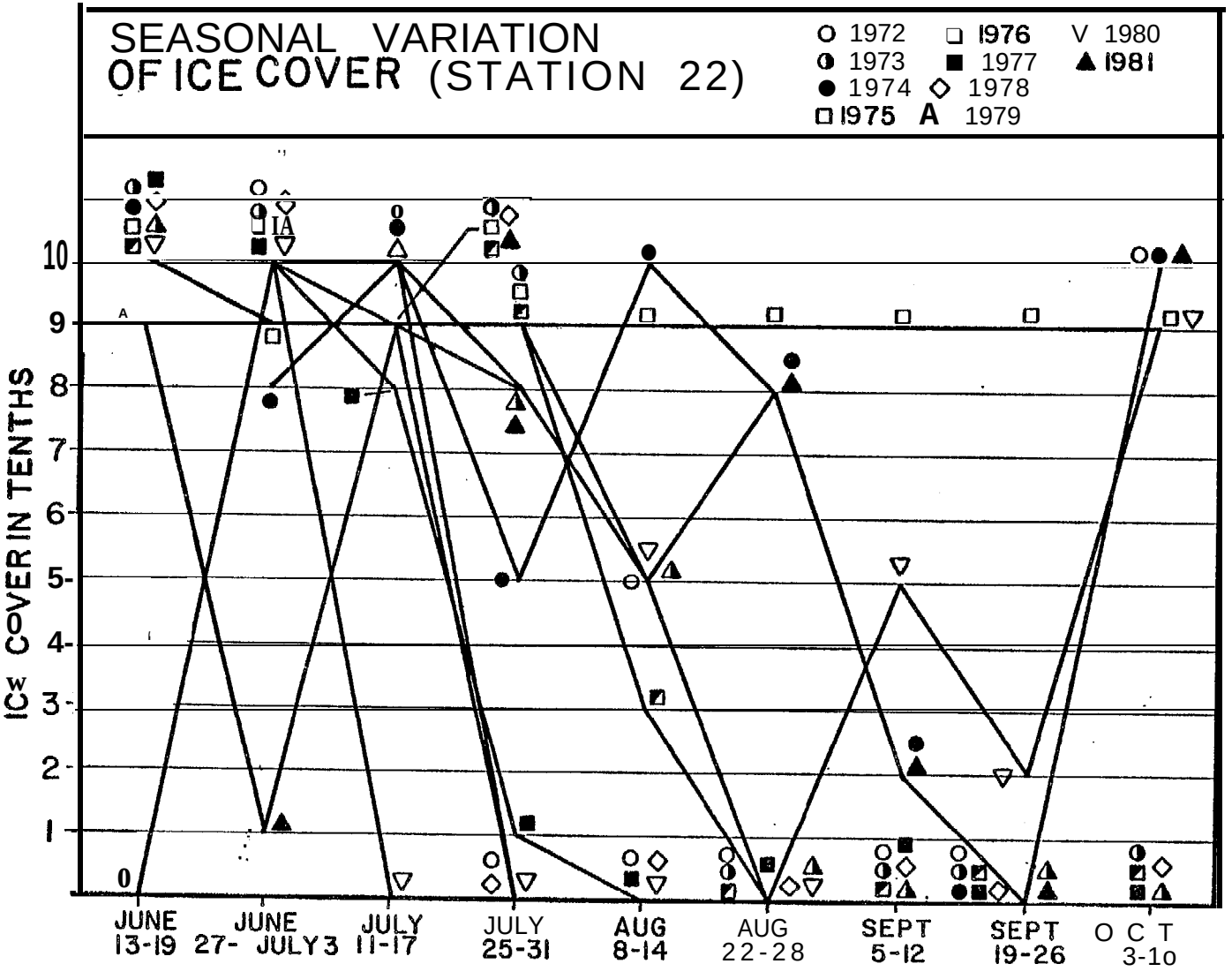

SEASONAL VARIATION
OF ICE COVER (STATION 19)
1972
1973
1974
1975
1976
1977
1978
1979
1980
1981
ICE COVER IN TENTHS
10
9
8
7
6
5
4
3
2
1
JUNE 13-19
JUNE 27- JULY 3
JULY 11-17
JULY 25-31
AUG 8-14
AUG 22-28
SEPT 5-12
SEPT 19-26
OCT 3-10

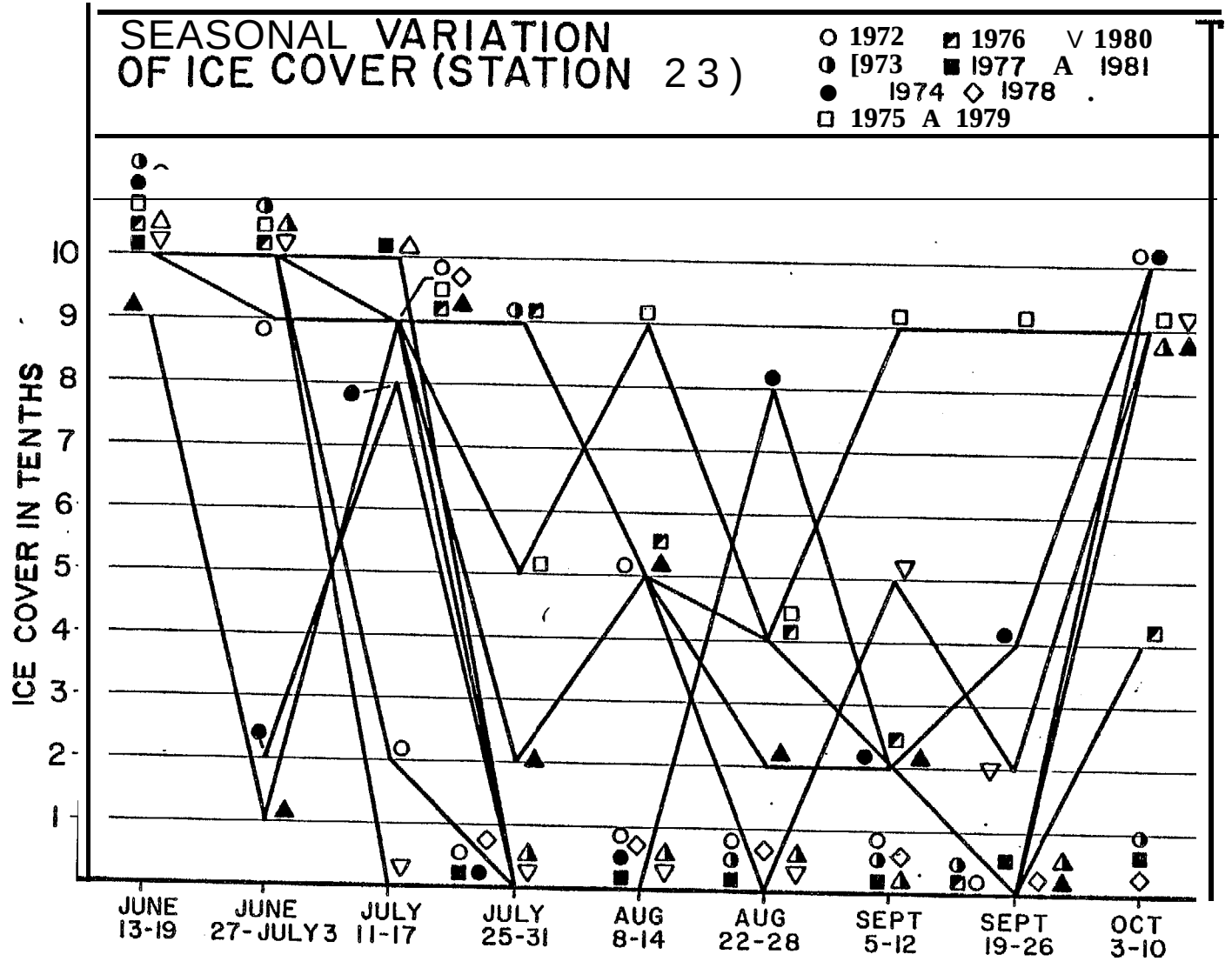
C. Kongakut River Series

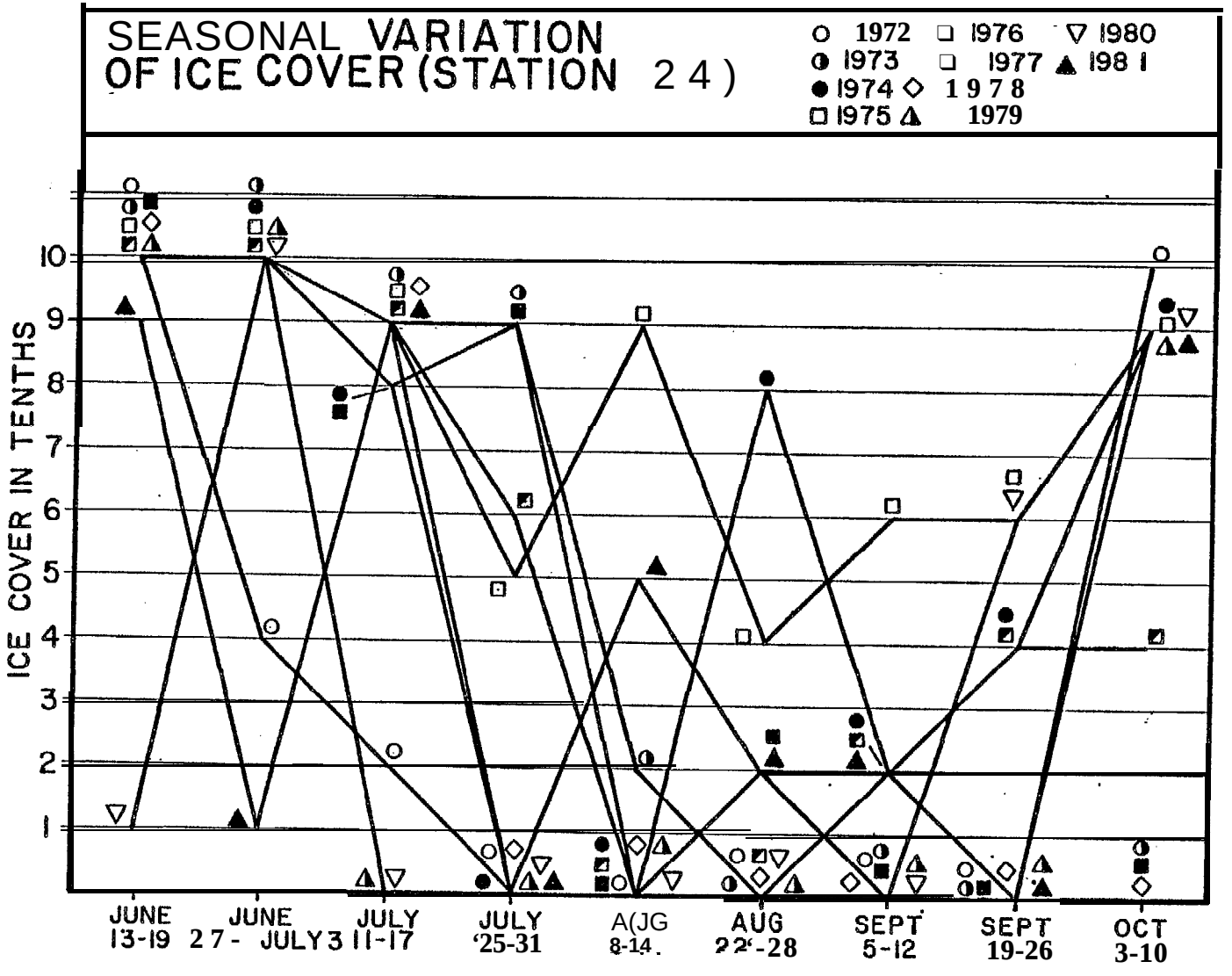
At station 22, 40 km offshore, we see a great variability in ice concentration all during the summer. However, toward September, this variability decreases considerably, and low ice concentration tends to be found. Between August 22-29 and September 19-26, ice-free conditions were found on 6 of 10 observed occasions, and ice concentration on those other occasions tended to be low with the exception of 1975.

At station 2'3, 20 km offshore, again a great variability in ice concentration is found throughout the ice season. There is no period of dependably ice-free conditions during any interval of the summer.

At station 24, 5 km offshore, the variability in ice concentration is great during the entire summer. Only during August 8-14 are ice-free conditions found on more than 50% of observed occasions.


SEASONAL VARIATION
OF ICE COVER (STATION 22)
1972
1973
1974
1975
1976
1977
1978
1979
1980
1981
ICE COVER IN TENTHS
10
9
8
7
6
5
4
3
2
1
0
JUNE 13-19
JUNE 27- JULY 3
JULY 11-17
JULY 25-31
AUG 8-14
AUG 22-28
SEPT 5-12
SEPT 19-26
OCT 3-10


SEASONAL VARIATION
OF ICE COVER (STATION 23)
1972
1973
1974
1975
1976
1977
1978
1979
1980
1981
ICE COVER IN TENTHS
10
9
8
7
6
5
4
3
2
1
JUNE 13-19
JUNE 27-JULY 3
JULY 11-17
JULY 25-31
AUG 8-14
AUG 22-28
SEPT 5-12
SEPT 19-26
OCT 3-10


SEASONAL VARIATION
OF ICE COVER (STATION 24)
1972
1973
1974
1975
1976
1977
1978
1979
1980
1981
ICE COVER IN TENTHS
10
9
8
7
6
5
4
3
2
1
JUNE 13-19
JUNE 27 - JULY 3
JULY 11-17
JULY 25-31
AUG 8-14
AUG 22-28
SEPT 5-12
SEPT 19-26
OCT 3-10

Conclusions

The data presented in this report show a statistical trend toward open water conditions along the coast of the eastern Beaufort Sea with time during the summer. The maps of average ice concentrations show that a broad band of O-25% ice concentration can be found along the coast in late summer, However, the maps of site-specific average concentrations and standard deviations show that average ice concentrations tend to be on the order of 10-20% at the least, with standard deviations on the order of 20%. Furthermore, the site-specific graphs of yearly ice concentrations show that very high ice concentrations were found throughout the study area in 1975, indicating that extreme ice concentrations can be found in the study area well beyond the calculated average values.

The statistical significance of the wide variability reported here is indicated by means of the standard deviation calculations: an average concentration of 10% with a standard deviation of 20% would indicate that on 70% of observed occasions one would expect to find an ice concentration between O and 30% at that location. As the preceding discussions have indicated, this is representative of the least average concentration and standard deviation found 5 km offshore during the summer in the study area.

Implications to OCS Environmental Assessment .

1. The probability of a summertime oilspill encountering open water conditions varies with time and location. While this report contains material to make site-specific judgments, some generalizations can be made:

   - The statistics and year-to-year records indicate that nowhere in the 'offshore region can an absolute guarantee be made that open water conditions would coincide with a spill at any time of the summer. Thus, there is always a finite probability that summertime clean-up would be performed in the presence of some ice.

2. Similarly, sea ice used for bird and mammal resting platforms has a finite probability of occurring throughout the study area at all times and locations beyond the barrier islands.

3. There are some areas statistically free of ice in early summer. The most dependable ice-free areas are lagoons and deep coastal embayments. High resolution analysis could identify these areas.

4. If Bowhead whales follow the pack ice edge upon their return migrations it is possible that their route will take them within a few km of shore, and within the zone of OCS oil and gas activities.