Narwhal Surveys and Associated Marine Mammal Observations in Admiralty Inlet, Navy Board Inlet, and Eclipse Sound, Baffin Island, N.W.T., During 1974 - 1976

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December 1983

Canadian Technical Report of Fisheries & Aquatic Sciences No. 1211

Fisheries and Oceans   Pêches et Océans

Canada

STONE

Canadian Technical Report of Fisheries and Aquatic Sciences

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Canadian Technical Report of

Fisheries and Aquatic Sciences 1211

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NARWHAL SURVEYS AND ASSOCIATED MARINE MAMMAL OBSERVATIONS IN ADMIRALTY INLET, NAVY BOARD INLET, AND ECLIPSE SOUND, BAFFIN ISLAND, N.W.T., DURING 1974 - 1976

by

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This is the 162nd Technical Report
from the Western Region, Winnipeg

Cat. no. Fs 97-6/1211 ISSN 0706-6457

Correct citation for this publication is:

Fallis, B.W., W.E. Klenner, and J.B. Kemper. 1983. Narwhal surveys and associated marine mammal observations in Admiralty Inlet, Navy Board Inlet, and Eclipse Sound, Baffin Island, N.W.T., during 1974-1976. Can. Tech. Rep. Fish. Aquat. Sci. 1211: iv + 20 p.

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ABSTRACT

Fallis, B.W., W.E. Klenner, and J.B. Kemper. 1983. Narwhal surveys and associated marine mammal observations in Admiralty Inlet, Navy Board Inlet, and Eclipse Sound, Baffin Island, N.W.T., during 1974-1976. Can. Tech. Rep. Fish. Aquat. Sci. 1211: iv + 20 p.

Reconnaissance and systematic surveys were flown in Admiralty Inlet and adjacent waters during the open water season from 1974 to 1976 to determine marine mammal utilization patterns. An estimate of 9 683 narwhal (Monodon monoceros) in central Admiralty Inlet was recorded on 28 July 1975 with a subsequent decline in numbers in August. In 1976, narwhal utilization was less than the level observed in 1975 with an estimated 1 614 whales present on 14 August. Aerial surveys indicated substantial variations in the timing of narwhal movement into Admiralty Inlet between 1975 and 1976. Fluctuations in the number of narwhal utilizing Admiralty Inlet between and within seasons were also recorded. Beluga (Delphinapterus leucas) were uncommon in the study area during both years. On 28 July 1975, three bowhead whales (Balaena mysticetus) were observed in central Admiralty Inlet. Narwhal utilized bays and inlets on the east side of Admiralty Inlet infrequently during both 1975 and 1976 but were observed in the central portion of Strathcona and Adams sound on occasion. Harp seals (Phoca groenlandica) were very abundant in 1975 but a decrease in size of groups and frequency of occurrence of groups indicated lower utilization of central Admiralty Inlet by harp seals in 1976.

Key words: Aerial surveys; aquatic mammals; Monodon monoceros; Balaena mysticetus; Phoca groenlandica.

RESUME

Fallis, B.W., W.E. Klenner, and J.B. Kemper. 1983. Narwhal surveys and associated marine mammal observations in Admiralty Inlet, Navy Board Inlet, and Eclipse Sound, Baffin Island, N.W.T., during 1974-1976. Can. Tech. Rep. Fish. Aquat. Sci. 1211: iv + 20 p.

De 1974 à 1976, on a effectué des vols de reconnaissance systématiques au-dessus des eaux de l'inlet de l'Amirauté et des eaux adjacentes afin de déterminer l'emploi qu'en font les mammifères marins qui les empruntent lorsqu'elles sont libres de glace. Le 28 juillet 1975, on a estimé à 9 683 le nombre de narvals (Monodon monoceros) dans l'inlet de l'Amirauté, nombre qui a diminué au cours du mois suivant. Le 14 août 1976, on a estimé à 1 614 le nombre de narvals ayant emprunté l'inlet, soit une diminution par rapport à 1975. Selon les relevés aériens, il y a eu des variations considérables dans l'emploi que firent les narvals de l'inlet de l'Amirauté entre 1975 et 1976. On a également noté des fluctuations dans le nombre de narvals qui ont emprunté l'inlet de l'Amirauté pendant, avant et après la saison d'eau libre. Très peu de bélougas (Delphinapterus leucas) ont été aperçus au cours des deux années d'étude. Le 28 juillet 1975, on a observé trois baleines boréales (Balaena mysticetus) au centre de l'inlet de l'Amirauté. Les narvals n'ont pas souvent fréquenté les baies et les anses du côté est de l'inlet en 1975 et en 1976, mais on en a aperçus à quelques reprises dans la partie centrale des détroits Strathcona et Adams. Alors que le phoque du Groenland (Phoca groenlandica) abondait dans l'inlet de l'Amirauté en 1975, on a noté une diminution dans le nombre et la taille des groupes de phoques dans la partie centrale de l'inlet en 1976.

Mots clefs: relevés aériens; mammifères aquatiques; Monodon monoceros; Balaena mysticetus; Phoca groenlandica.

INTRODUCTION

In June 1974, an agreement was signed between the Government of Canada and Mineral Resources International Ltd. to develop a lead-zinc mine at Strathcona Sound (73°05'N; 84°40'W) on northern Baffin Island. Since the effects of increased industrial activity and shipping on the marine mammal resources were not known, a baseline study of marine mammals utilizing the region was proposed to document predevelopment conditions. Before 1974, information on the distribution, abundance and migration patterns of marine mammals in the vicinity of Admiralty Inlet was limited. A compilation of hunter information by Bissett (1968) indicated general distribution and abundance trends for the species harvested by local Inuit. While the present study was designed to focus on Admiralty Inlet and nearby waters, concurrent investigations by Greendale and Brousseau-Greendale (1976), Johnson et al. (1976) and Renewable Resources (1977) in 1976 documented marine mammal migration patterns and abundance in eastern Lancaster Sound.

This study, initiated in 1974, was designed to provide information on the abundance, distribution and movement patterns of marine mammals utilizing waters surrounding the Borden Peninsula. As part of a more general program (Kemper 1976), it was expected that the data collected might subsequently be used to assess the effects of mine development and shipping on biological resources in the region.

STUDY AREA

The study area is located on the north coast of Baffin Island (Fig. 1). Systematic surveys were centered on Admiralty Inlet; reconnaissance surveys were flown over a wide region from Cape York (73°50'N; 87°00'W) to Pond Inlet (72°42'N; 78°00'W). The study area is part of the Lancaster plateau and is within the Arctic lowlands physiographic region (Bostock 1970). Much of the underlying Precambrian rock in this region is overlain with sedimentary strata disrupted by belts of Precambrian material (Thorsteinsson and Tozer 1970). Arctic Bay, Pond Inlet and Nanisivik are permanent settlements in the study area. Residents of Pond Inlet and Arctic Bay have traditionally harvested local marine mammals as a source of food and cash income (ivory and pelts). To the local Inuit, both Admiralty Inlet and the Navy Board Inlet-Eclipse Sound region are important seal and whale hunting areas (Bissett 1968; Dirschl 1982).

The climate of the region is characterized by a long winter (early September to mid-June) with mean January and July temperatures of -28°C to -32°C and +5°C to +8°C respectively (Maxwell 1981).

The open water period in Lancaster Sound and Admiralty Inlet shows considerable annual variation (Lindsay 1977, 1982). In an average year, the ice cover in Lancaster Sound recedes to the northeast coast of Somerset Island by early July (Markham 1981). Ice in the northern portions of Admiralty and Navy Board inlets begins to break up as the season progresses with 9/10 pack ice predominant by 23 July in an average year. Ice breakup continues to proceed from north to south in Admiralty Inlet with open water usually prevailing by approximately 6 August. Open pack-ice (2-5/10) may persist in Eclipse Sound somewhat longer with open water predominant by 13 August (Markham 1981). Freeze-up begins over much of the study area by 1 October with very close pack-ice conditions (9/10) common by 15 October and a continuous cover of fast ice by 30 October. Wide variations in the above pattern often occur; there may be open water as early as July, or moderate pack may persist through August.

Surface currents in Admiralty Inlet are characterized by a counterclockwise gyre with incoming waters flowing down the west shore of Admiralty Inlet and exiting along the east shore (Dirschl 1982). Water depths in Admiralty Inlet are variable, ranging from approximately 300 m at the entrance to Lancaster Sound to 700 m in central areas. Information on water turbidity in Admiralty Inlet is not available but Secchi-disc readings of 6 to 13 m have been recorded in Strathcona Sound (B.C. Research 1975).

METHODS

To achieve an understanding of the numbers and movement patterns of marine mammals in the study area, a combination of transect and reconnaissance surveys were flown. In both 1975 and 1976, systematic surveys were restricted to Admiralty Inlet. Reconnaissance surveys were flown along the shoreline (due to aircraft constraints) of Admiralty Inlet in 1974 and over Admiralty Inlet, Navy Board Inlet and Eclipse Sound in 1975 and 1976. Reconnaissance flights were conducted to evaluate movement patterns and areas of marine mammal concentration within the study area before flying systematic transects. Approximately 50 hours of helicopter flight time were available for marine mammal surveys in 1975 and 1976 . In addition to specific whale surveys, marine mammals were frequently seen and recorded during polar bear and seabird surveys. A concurrent seabird and polar bear monitoring program (Kemper 1976) necessitated a survey design which would satisfy multiple objectives. Since seal populations are best evaluated during the haulout period in June (Stirling et al. 1982), seals recorded throughout the present open water surveys indicate presence or absence only. Information on narwhal behaviour was recorded opportunistically whenever undisturbed social interactions were observed.

Surveys were flown using a Jet Ranger 206B helicopter in 1974 and 1975 and an Alouette II in 1976. Two or three observers occupying the front left and rear passenger seats were used during all flights. During 1975 and 1976, reconnaissance flights were flown at 65 to 122 m a.s.l. (with the exception of a short survey at 350 m a.s.l. in 1976). Animals within an estimated 215 m of each side of the aircraft were recorded during surveys in 1975. In 1976, marine mammals were recorded within an estimated 400 m of each side of the aircraft.

Survey lines in Admiralty Inlet were initially designed as systematically spaced transects but were later altered since the survey aircraft was not equipped with an electronic navigation system. The use of landmarks and dead reckoning to navigate transects necessitated modifications which resulted in minor deviations from a true systematic design. Changes involved variations in transect spacing and nonparallel transects in some cases (Fig. 2). These modifications were considered insufficient to affect the overall design and in subsequent analyses, these surveys were treated as standard systematic surveys.

Systematic transects were flown at altitudes of 91 to 152 m a.s.l. and estimated ground speeds of 130 to 160 km per hour. Observers recorded all marine mammals observed within an estimated 400 m of the aircraft to produce an overall tally for each transect. The number of under-aircraft whales which were not counted was minimized by excellent forward and downward visibility from the front observers position. All whales within the transect strip were counted including neonate calves (which only accounted for 2 or 3 percent of the total). Off-transect animals were not recorded. Since pinnipeds are difficult to evaluate during the open water period, a population index has been calculated only for narwhal.

Minor differences in transect area and high variability in the number of narwhal between transects of equal length led to the use of the density estimate based on equal area transects outlined in Jolly (1969) and Caughley (1977) to calculate an estimate of narwhal in the area under survey. The mean number and variance of narwhal from a given survey was obtained by:

$$\hat{Y} = N\bar{y} \text{ and } Var(\hat{Y}) = \frac{N\ (N-n)}{n}\ S_y^2$$

where

$\hat{Y}$ = the population estimate
N = the number of sampling units in the area under survey
n = the number of sampling units (transects)
y = the number of animals on individual transects
$\bar{y}$ = the average number of animals per transect over the n transects sampled

$$S_y^2 = \frac{1}{n-1}\{\Sigma y^2 - \frac{(\Sigma y)^2}{n}\}$$ = the variance of the transects sampled

Where obvious differences in density existed within the census area, regions of similar density were grouped into blocks and mean estimates calculated for each. The overall estimate was derived by summing individual block estimates. This procedure was necessary since all transects did not represent equal areas within the survey and an estimate based on average density would have been biased by small regions of high or low density.

Information on ice conditions in the study area was compiled during systematic and reconnaissance surveys. In addition, general ice conditions summarized in an ice atlas (Lindsay 1977, 1982) were incorporated to form a more complete representation of ice conditions.

Several limitations and biases associated with the survey procedure became evident during the course of the study. The difficulty encountered in evaluating seal observations has been mentioned earlier and precludes estimating the seal population in Admiralty Inlet. Narwhal detectability is influenced by numerous factors including the aircraft used, survey altitude, transect width and observer experience or fatigue. In addition, other variables including light, sea state and ice conditions can affect the observers ability to see whales. Behaviour and group size are probably of major importance since these factors influence the detectability of whales on the surface and the proportion of whales under water and not visible. Since insufficent data precluded the use of correction factors to offset the limitations and biases indicated above, the estimates presented in this report are best interpreted as population indices which are probably influenced by survey methods.

RESULTS

ICE CONDITIONS

In 1975, ice breakup started earlier than in a "normal year" with open water present in Lancaster Sound to the northeast corner of Somerset Island by mid-June (Lindsay 1982). Admiralty Inlet remained covered by 10/10 fast ice until early July. By mid-July, eastern Admiralty Inlet was open with only scattered ice remaining while the west side remained covered with 7-10/10 ice. Pond Inlet, Eclipse Sound and Navy Board Inlet remained covered with 7-10/10 ice. By 26 July, much of northern Navy Board Inlet was open water and by 28 July, all of Admiralty Inlet was open with only scattered ice pans remaining.

Ice breakup in 1976 was approximately two weeks later; large ice pans and land-fast ice persisted in Admiralty Inlet until mid-August. Similarly, much of Eclipse Sound and Navy Board Inlet remained ice covered with numerous leads until at least 11 August. Central Admiralty Inlet in the vicinity of Yeoman Island had extensive ice pans and shoreline ice persisting until 14 August.

SYSTEMATIC SURVEYS

During 1975 and 1976, seven systematic surveys were flown for which an estimate of the number of narwhal in the census area was calculated (Table 1). Transects were initially designed to sample all of Admiralty Inlet north of Yeoman Island (Fig. 2) but the complete area was never covered during a single survey. Consequently, the estimates of narwhal presented in Table 1 represent only the area under survey and probably form an overly conservative estimate of the number of narwhal utilizing Admiralty Inlet at a given time. Since the area under survey, the region being surveyed and the sampling intensity varied between surveys, comparisons are restricted to surveys flown under similar conditions.

The results of surveys on 28 July and 9 August 1975 indicate how variable the number of narwhal occurring in central Admiralty Inlet can be within one season. Although the northern transects were not flown until 10 August, the low estimated number of narwhal recorded on 9 August (2 117) and 10 August (961) indicate many of the animals recorded on 28 July (9 683) had left Admiralty Inlet.

Surveys flown on 9 and 15 August 1976 in northern Admiralty Inlet indicate a different trend from that observed in 1975 when the estimated number of narwhal decreased after 28 July. In 1976, surveys on 9 and 15 August resulted in estimates of 443 and 1 507 narwhal respectively, indicating an increase in the number of narwhal using northern Admiralty Inlet as the season progressed. Although indicative of the low number of narwhal present, the 9 August 1976 survey must be interpreted with caution since the estimate is based on only two groups of 5 and 28 narwhal.

Surveys flown on 14 and 15 August 1976 in central and northern Admiralty Inlet suggest the high number of narwhal observed on 28 July 1975 do not occur in all years. An overall estimate of narwhal utilizing Admiralty Inlet (approx. 6 680 km^2) cannot be inferred from the present surveys since narwhal could easily be counted twice or missed entirely if surveys on consecutive days are added. In addition, heterogeneous densities within the area under survey indicate the problems associated with extrapolating mean survey densities to the remainder of Admiralty Inlet. The estimates presented in Table 1 should therefore be interpreted as conservative estimates of the number of narwhal utilizing Admiralty Inlet during a survey.

RECONNAISSANCE SURVEYS

In August 1974, five reconnaissance surveys were flown along the eastern shore of Admiralty Inlet between Cape Cunningham and Ship Point. Narwhal were observed on two surveys during the last week in August when 50 and 200 narwhal were noted near the entrance to Adams Sound. During a brief reconnaissance flight on 12 August 1974, Hay and McClung (1976) observed 183 narwhal and two beluga in central Admiralty Inlet. On this survey, most narwhal were observed along the west shore of Admiralty Inlet from the Turner Cliffs to Kakiak Point and near the centre of the Inlet between Stephens Headland and Cape Cunningham. In early September, a group of 12 narwhal was observed in Strathcona Sound near Nanisivik. Subsequent reports by Inuk residents of narwhal in Strathcona Sound indicate that substantial use is made of the area by this species. There appears to be a tendency towards greater utilization in late August and early September when narwhal start making their way north out of Admiralty Inlet into Lancaster Sound.

During 1975 and 1976, a total of 4 176 km of reconnaissance surveys were flown in coastal and offshore zones in the study area (Table 2, 3). Although differences in flight path (offshore vs coastline), survey altitude, sighting conditions and transect width preclude comparisons between years and surveys within a year, these surveys indicated movements and distribution patterns.

NARWHAL MOVEMENT INTO ADMIRALTY INLET

On 26 July 1975, a large group of narwhal (approx. 800-1 200) was observed moving into Admiralty Inlet along the northwest shore of the Borden Peninsula. Narwhal were spread out between Cape Charles Yorke and Baillarge Bay and swam near the surface at an estimated five km per hour. Within this large diffuse herd, many narwhal were grouped into tight pods of five to eight animals with distinct spaces between pods. This type of migratory behaviour contrasts with later surveys when feeding or loafing behaviour was predominant. Most of the narwhal observed on this survey were within a kilometre of shore and many were within a hundred metres. Prior to this survey, two groups of narwhal had been reported from the west shore of Admiralty Inlet. On 19 July, a helicopter pilot (George Jones - Okanagan Helicopters Ltd.) observed an estimated 150 narwhal moving north along the west shore of Admiralty Inlet across from Strathcona Sound. A second group of approximately 300 narwhal moving south was noted near Cape Crauford on the west side of Admiralty Inlet on the same day. The large number of narwhal observed on 26 July is representative of the influx of whales into Admiralty Inlet between 26 and 28 July. As indicated by reconnaissance surveys flown on 23 to 25 July, few narwhal are thought to have been present prior to 25 July. The high number of narwhal indicated by the systematic survey on 28 July illustrates the rapid increase in narwhal utilizing Admiralty Inlet between 25 and 28 July.

In 1976, the initial movement of narwhal into Admiralty Inlet was not recorded since numerous whales were noted in central Admiralty Inlet when the first reconnaissance survey was flown on 8 August. The rapid increase in numbers subsequent to the initial sighting of narwhal in Admiralty Inlet in 1975 was not observed in 1976. Surveys on 14 and 15 August indicate narwhal utilization of central Admiralty Inlet did not reach the level recorded in 1975.

NARWHAL DISTRIBUTION IN ADMIRALTY INLET

Information on narwhal utilization patterns was compiled during both reconnaissance and systematic surveys. In 1975, narwhal appeared to prefer the west shore of Admiralty Inlet, especially in late July and early August. On 28 July, all of the 1 198 narwhal observed during a systematic survey were within several kilometres of the west shore (with most animals within several hundred metres of shore). On 4 August, narwhal were again concentrated along the west shore. Narwhal were more common in central areas of Admiralty Inlet during a survey flown on 9 August and on 23 August, central and eastern regions were being utilized.

In 1976, utilization patterns were markedly different. Specific regions of high concentration were not observed and narwhal appeared to be widely scattered within the area being surveyed.

Although large numbers of whales were not observed south of Yeoman Island, small groups were recorded in this area on occasion. On 2 August 1975, approximately 40 narwhal (primarily females and calves) were reported near Sanuarersuk Island. On the same day, Inuk hunters killed several narwhal on the west shore of Admiralty Inlet across from Iglorsuit Island.

Inlets on the east side of the Admiralty Inlet do not appear to be frequently utilized by narwhal. Since all flights originated at Nanisivik or Arctic Bay, an attempt was made to survey (at least partially) either Strathcona or Adams Sound during departure or return. Narwhal were observed in Adams Sound on 9 and 16 August 1975 (2 and 26 narwhal respectively) and on 14 August 1976 (9 narwhal). In addition, Inuk hunters killed 11 narwhal in Arctic Bay on 10 August 1975. While narwhal do utilize both Strathcona and Adams sounds, their unpredictable and short term use of these areas has resulted in most hunting traditionally taking place along the west shore of Admiralty Inlet.

Though indicative of narwhal distribution in 1975 and 1976, the utilization patterns outlined above remain tentative due to infrequent surveys and limited coverage within a survey. In general, the above descriptions indicate areas frequently utilized and the variability within and between years.

NARWHAL BEHAVIOUR

Since surveys were designed to evaluate the distribution and numbers of narwhal, behavioural observations were recorded only when social interactions were noted. One form of social behaviour which was observed on several occasions involved prolonged contact and interaction between animals in a group. Narwhal were observed lying alongside one another or in a pinwheel arrangement, often with their tusks crossing or lying over another animal's back. On occasion, one narwhal was observed rubbing the body of another whale with its tusk. Schweinsburg (1976) illustrated some of the observed interactions. This type of social behaviour was observed on 27 July 1975 and again on 8 and 10 August 1976. Silverman (1979) provides a comprehensive discussion of these and other closely related behaviours. Precise information on the age-sex composition of animals involved in group interactions was not recorded but it appears most animals involved were males. Occasionally, females were observed in or near groups of males involved in tusk crossing or body rubbing activities. Social interactions of this type appear to be most common early in the open water season, occurring with greatest frequency shortly after narwhal arrived in Admiralty Inlet.

OTHER SPECIES

Beluga

Beluga (Delphinapterus leucas) were infrequently observed during the study and did not appear to extensively utilize Admiralty Inlet or other parts of the study area. In 1975, only one cow-calf pair was observed approximately 400 m offshore at Cape Crauford. Two small beluga herds were observed in Admiralty Inlet in 1976. On 13 August, 17 beluga (mostly adults) were noted along the east shore between Baillarge Bay and Strathcona Sound while on 14 August, six animals were observed north of Yeoman Island in central Admiralty Inlet. In the Navy Board Inlet region, a single beluga was recorded near Adams Island on 9 August 1976.

Bowhead

Bowhead whales (Balaena mysticetus) were encountered in the study area only once. Three bowheads were observed in Admiralty Inlet on 28 July 1975 during a systematic survey. Two whales were recorded several kilometres north of Kakiak Point on the west shore and a third was observed near Peter Richards Islands. An unconfirmed report received the previous day of three bowhead whales on the west shore of Admiralty Inlet 30 km south of Kakiak Point may have been the same animals.

Ringed seal

Ringed seal (Phoca hispida) were common throughout the study area and were observed on most surveys. No region within the study area was noted as having either markedly high or low densities. The difficulties associated with enumerating seals during the open water period preclude a population index for this species.

Bearded seals

Bearded seal (Erignathus barbatus) appeared to be uncommon in the study area and were identified only twice during surveys in 1975 and 1976. The low frequency of sightings may be related to poor sighting conditions during the open water period. This species was seen frequently during visits to the Baillarge Bay northern fulmar colony (Kemper 1976).

Harp seal

Harp seal (Phoca groenlandica) were very common in Admiralty Inlet during 1975 when large groups (50-500+) were often observed in the water or basking on ice floes. In 1975, large groups in excess of 100 animals were common in July. By August, these aggregations had apparently broken apart since most sightings were of small groups of one to thirty seals. In 1976, harp seals did not appear to utilize Admiralty Inlet to the extent noted in the previous year. In early August, large rafts of seals were not observed. Groups of less than 75 animals were most common. Groups of one to fifty harp seal were observed occasionally during the remainder of surveys in 1976 but the number of animals utilizing Admiralty Inlet appeared to be much lower than in 1975. Harp seals were recorded on surveys in Navy Board Inlet and Eclipse Sound but sufficient information to evaluate their abundance in 1975 and 1976 is not available.

DISCUSSION

SURVEY DESIGN

The surveys outlined in this report represent an initial attempt to document the numbers and utilization patterns of marine mammals in Admiralty Inlet. Although systematic surveys were intended to form an estimate of the narwhal population utilizing Admiralty Inlet, the estimates should be considered population indices comparable only to surveys flown under similar conditions.

The use of prominent landmarks for navigation precluded employing randomly located transects which are desirable for an unbiased population estimate (Cochran 1977). Since the transects chosen did not appear to coincide with periodicities in narwhal distribution, a biased estimate is not expected (Caughley 1977). Simulation studies by Caughley indicate estimates derived from systematic transects are usually unbiased and as precise as those obtained using random sampling. One general drawback of systematic surveys relates to the calculation of the standard error and the unknown influence of autocorrelation between transects on this parameter.

Several aspects of the survey methodology relating to observer bias and visibility of narwhal may have influenced the estimate. Survey altitude within and between surveys was not constant and this probably influenced the estimated transect width. Although transect width was recorded as a constant 400 m on each side of the aircraft for each survey, this varied somewhat with changes in altitude. As long as the initial estimate of 400 m on each side of the flight path remains accurate, random variations in altitude within a survey should cancel and not seriously bias the area being sampled. Since strut and window marks (Stirling et al. 1982) are difficult to implement on a helicopter, the use of an inclinometer and altitude information (Davis et al. 1982) would have provided a more accurate estimate of transect width. The use of a low survey altitude may have biased the survey towards a lower estimate as a combination of two factors. Helicopter noise is substantial at the altitude flown and may have resulted in an unknown number of narwhal reacting to the survey aircraft and diving before being tallied. In addition, decreased observability of whales at the periphery of the transect strip when transects are flown at low altitude (Davis and Evans 1982) may have biased the estimate. The use of inexperienced observers during several surveys incorporates a confounding factor which is difficult to evaluate. Inexperienced observers often underestimate the number of animals present (Caughley et al. 1976), but this trend would possibly be offset by a tendency to overestimate width of the transect strip and include narwhal which were off transect. Leatherwood et al. (1978) found significant differences between surveys which could be attributed to different teams of observers.

No attempt has been made to apply correction factors to the narwhal tally from each survey to compensate for whales on the surface but not counted, animals under water and not visible or left-right side visibility biases. The analysis of left-right side observer bias was confounded by the lack of observer continuity between surveys and the lack of separate left-right side information for some surveys. The proportion of whales visible on the surface which are counted depends on numerous factors including narwhal behaviour, group size, observer experience, aircraft speed and transect width. Davis and Evans (1982) indicated that beluga are not equally detectable at increasing distance from the flight path. Although not directly applicable to the present surveys, Davis et al. (1982) reported procedures used in the Beaufort Sea to evaluate the proportion of bowhead whales which are visible but not counted and derive a correction factor to provide a less biased population estimate. A second correction factor to adjust the estimate to account for submerged and not visible bowheads was derived from behavioural observations. Comparable information on narwhal behaviour and detectability was not available for Admiralty Inlet, therefore, correction factors were not applied to the raw counts which may be biased toward a conservative estimate. However, unlike the turbid waters in the Beaufort Sea, clear waters in the study area should have reduced the probability of omitting submerged whales from the tally.

Although the biases discussed above cannot be corrected in the present surveys, most will result in lower estimates of narwhal than are actually present. In general, the population indices reported here provide a conservative estimate of narwhal in the survey area.

SYSTEMATIC SURVEYS

The estimated number of narwhal recorded on 28 July 1975 probably forms a conservative estimate of the number of narwhal utilizing Admiralty Inlet. This survey covered approximately one third of Admiralty Inlet north of Iglorsuit Island and although the recorded density can not be extrapolated to the entire Inlet, some narwhal were probably present outside the area surveyed. In a report outlining a systematic aerial survey flown on 24 August 1978, Koski and Davis (1979) estimated approximately 7 000 narwhal in Admiralty Inlet. This survey indicates that the high number of narwhal estimated to be present on 28 July 1975 is not an anomaly and that numerous narwhal often utilize Admiralty Inlet during the open water period. When compared to population estimates of narwhal utilizing the Canadian Arctic, it is evident that a substantial proportion utilize Admiralty Inlet. Mansfield et al. (1975) reported a conservative estimate of 10 000 narwhal in Canadian and northwest Greenland waters while Greendale and Brousseau-Greendale (1976) estimated 8 000 to 10 000 migrated past Cape Hay in 1976. Davis et al. (1978) estimated 20 000 to 30 000 narwhal in Canadian waters alone. A moderate extrapolation of the 28 July 1975 estimate (9 683 narwhal) to account for regions outside the survey area indicates the estimate by Mansfield et al. may be overly conservative. If the estimate proposed by Davis et al. is used, one third or more of the Canadian narwhal population makes at least occasional use of Admiralty Inlet.

During the three years of this study, Inuit from Arctic Bay and Pond Inlet harvested narwhal throughout the open water period. Much of the narwhal hunting in Admiralty Inlet occurred near Kakiak Point while in the Eclipse Sound region, most hunting was centred around the camp at Kaunak. During 1974 to 1976 the communities of Arctic Bay and Pond Inlet both had quotas of 100 narwhal per year and reported catches slightly in excess of their quotas (Fisheries and Oceans, marine mammal harvest statistics). Although the total number of narwhal killed during the hunt is difficult to assess, Finley and Miller (1980) indicated that a substantial proportion of the whales killed are not recovered. In the near future, narwhal will probably be subjected to greater hunting pressure as a result of an increasing human population and the economic incentive provided by high ivory prices (Kemper 1980). Since precise demographic parameters of the narwhal population utilizing Admiralty Inlet remain unknown, the impact of present and future hunting patterns is difficult to assess. However, a long-term decrease in the narwhal population using Admiralty Inlet may indicate an excessive proportion of the population is being removed.

NARWHAL MOVEMENT PATTERNS AND DISTRIBUTION

In a report outlining the numbers and migration patterns of narwhal in the Canadian Arctic, Johnson et al. (1976) and Renewable Resources (1977) indicate most narwhal move into adjacent waters in August after passing through Lancaster Sound in June and July. This pattern of narwhal movement was apparent in 1975 when a major influx of narwhal into Admiralty Inlet occurred on 26 July. Maximum narwhal density in central Admiralty Inlet was recorded in late July with fewer narwhal noted on subsequent surveys. The decrease in utilization from late July to August 1975 probably reflects a general movement out of Admiralty Inlet into adjacent regions. Renewable Resources (1977) documented the presence of narwhal in Prince Regent Inlet and along the southern coast of Devon Island in 1976.

Although the movement of narwhal into Admiralty Inlet was not observed in 1976, incidental observations recorded during studies in Lancaster Sound by LGL and Renewable Resources consultants provide information on mid-July movements. Johnson et al. (1976) observed 325 and 277 narwhal in Admiralty Inlet on 12 and 26 July respectively with most whales along the fast ice edge. Similarly, Renewable Resources (1977) recorded 1 640 narwhal along the same fast ice boundary on 20 July 1976. These results indicate a somewhat earlier migration of narwhal into Admiralty Inlet in 1976 than in 1975 when the first major influx was noted on 26 July. Despite moving into the region earlier in 1976, narwhal were prevented from penetrating into central Admiralty Inlet by the persisting fast ice. Subsequently, some animals may have moved off in search of ice-free waters. Systematic surveys conducted in August 1976 indicated narwhal density in central Admiralty Inlet did not reach the levels recorded in 1975. These results suggest annual fluctuations in narwhal utilization of waters adjacent to Lancaster Sound may be common and related in part to ice conditions. Silverman (1979) indicated the movement of narwhal into inlets and fiords is related to calving and intensive feeding along the ice edge early in the season. Silverman also noted annual fluctuations in narwhal distribution in the Pond Inlet region similar to those recorded in the present study. A subsequent study by Finley and Gibb (1982) indicated the strong relationship between narwhal and Arctic cod (Boreogadus saida) and the possible influence of cod numbers or distribution on utilization of different areas by narwhal. A similar relationship may also be responsible for the observed changes in narwhal distribution in Admiralty Inlet both within and between years. Despite the infrequent use of bays and inlets on the east side of Admiralty Inlet during the present study, numerous narwhal do utilize these areas on occasion. Koski and Davis (1979) reported 232 narwhal in Strathcona Sound on 14 August 1978. Since narwhal which enter Strathcona or Adams sounds are often hunted by residents of Arctic Bay or Nanisivik, their brief stay may be partially the result of such harassment.

Although Arctic cod may strongly influence the seasonal distribution of narwhal, Finley and Gibb (1982) proposed that fast ice edges restrict narwhal movement and determine utilization patterns. The major influx of narwhal into central Admiralty Inlet through open pack-ice in 1975 and the buildup of narwhal along the fast ice edge in 1976 support this hypothesis. If prevented from entering desired areas for a prolonged period by unfavourable ice conditions, narwhal may leave the region and seek alternative feeding areas.

Despite being excluded from areas with an unbroken ice cover, narwhal will use lead systems to penetrate far into regions of almost continuous ice cover. All of the narwhal observed during a reconnaissance survey in Eclipse Sound in August 1976 were in a series of leads which did not appear to be connected to the Pond Inlet fast ice edge. The use of leads undoubtably allows narwhal to gain access to desired areas weeks in advance of complete ice breakup.

OTHER SPECIES

Although several beluga were observed during surveys in 1975 and 1976, their general absence substantiates reports by Bissett (1968) and Davis et al. (1980) that beluga are uncommon in central Admiralty Inlet. One unusual incursion of beluga into Strathcona Sound occurred in August 1979 when 31 beluga were shot close to shore near Cape Strathcona by Inuk hunters (N. Snow[1], personal communication). Sergeant and

[1] Petro-Canada Ltd., Calgary, Alberta.

Brodie (1975) noted that beluga are most often found in shoreline or estuarine areas but do not indicate specific factors which may limit beluga distribution to such regions. The occurrence of numerous beluga along the Admiralty Inlet fast-ice edge in June 1982 (Finley et al. 1983) indicates beluga do penetrate into northern Admiralty Inlet in certain years but subsequently move on to summering areas farther west (Sergeant and Brodie 1975).

The sighting of three bowhead whales during the 28 July 1975 survey is significant since this indicates some bowhead still utilize Admiralty Inlet. Davis et al. (1980) noted that northern Admiralty Inlet was a whaling area when the species was commercially harvested, implying a former abundance of bowheads in the region. The use of bowhead bones in the construction of dwellings at Thule sites in the area also provides evidence of former abundance of the species in this region. The lack of bowhead sightings during other surveys or during incidental flights by Johnson et al. (1976) and Renewable Resources (1977) indicates this species is relatively rare in Admiralty Inlet. Reeves et al. (1983) present a thorough summary of bowhead distribution and migration patterns in the eastern Canadian Arctic which serves to emphasize the relatively low abundance of this species.

The most abundant pinniped recorded during surveys was the harp seal. Although these results may not accurately reflect the relative abundance of pinnipeds due to visibility biases, surveys in 1975 indicate several thousand harp seals utilized Admiralty Inlet. Bissett (1968) also reported that numerous harp seals utilize Admiralty Inlet even though few are taken by Inuk hunters. The decrease in harp seal sightings during surveys in 1976 is comparable to a similar trend in narwhal observations. Although the factors which caused a decrease in the number of harp seals utilizing Admiralty Inlet from 1975 to 1976 remain unknown, the dependence of this species on Arctic cod (Finley and Gibb in press, as cited by Finley and Gibb 1982) may be of considerable importance.

RECOMMENDATIONS

To provide a more accurate and complete population estimate, future aerial surveys in Admiralty Inlet should incorporate several modifications:

1) The use of standardized aerial survey methods is advised. Procedures for aerial surveys in remote areas have evolved somewhat since surveys were completed in 1976. Modifications include the use of fixed-wing aircraft, window and strut marks or inclinometers to determine transect width, radar altimeters to maintain constant altitude, the use of experienced observers only and electronic navigation systems to accurately determine flight path. A review of procedures outlined in Caughley et al. (1976), Caughley (1977), Eberhardt et al. (1979), Caughley and Grigg (1981), Davis et al. (1982) and Stirling et al. (1982) is recommended before future surveys are initiated.

2) Surveys should be designed to cover the largest area possible if an overall population estimate is desired. Unpredictable and large scale movements by narwhal between regions make population estimates based on several regional estimates obtained on different days somewhat tenuous and difficult to evaluate. If a large area is to be surveyed, the use of more than one survey aircraft may be appropriate.

3) When heterogeneous densities are believed to occur in the census region, a preliminary survey to determine distribution patterns may be warranted. Stratification of the survey area and proportional sampling based on results of the preliminary survey will probably provide a more precise estimate.

4) Specific habitat information (ice conditions, water depth, etc.) should be recorded during surveys for use in determining environmental variables which influence marine mammal distribution.

5) The use of aerial photography in conjunction with standard survey procedures would increase the accuracy of the estimate, especially if areas of high density are present. A comparison of simultaneous visual and photographic results may also prove useful in deriving a correction factor for animals present at the surface but not counted by the observers.

6) Observations on cetacean diving behaviour would prove invaluable in developing a correction factor to evaluate whales which are in the area under survey but are submerged and not visible to the observer. Since dive sequences are likely to vary with different behaviours (i.e. feeding, resting, migration, etc.), a substantial observation series is required before a reliable correction factor can be determined.

7) A program to evaluate all major narwhal summering areas simultaneously is essential to more fully understand seasonal utilization patterns. An analysis of climatic features and habitat differences between these areas may provide insight into factors which influence variations within and between years as observed in Admiralty Inlet. A program of this nature would also provide information on the discreteness of narwhal stocks utilizing specific summering areas.

8) Studies to assess the effects of increased industrial activity and shipping on the marine mammal resources of the area should be undertaken. Behavioural observations and an evaluation of distribution patterns would provide insight into the short and long-term effects of industrial development. In addition, a continued program of aerial surveys is essential to monitor changes in the number of narwhal utilizing Admiralty Inlet.

ACKNOWLEDGMENTS

This study was initiated under the direction of Mr. S. E. Stephansson whose subsequent change in employment in August 1975, left the studies to be completed by other personnel within the Fisheries and Marine Service of the former Department of the Environment.

Mr. Michael Lawrence was primarily responsible for carrying out the remainder of the surveys conducted in 1975 assisted by D. Furnell, G. Lacho and C. O'Brien. Their assistance is greatly appreciated.

During 1974 and 1976 the field study was ably assisted by A. Burnett, R. Fudge, S. Harbicht, C. Mack, B. Martin, M. Robertson and W. Siemieniuk.

Dr. R. E. Schweinsburg kindly cooperated in the shared helicopter charter which was used for polar bear, seabird and marine mammal surveys in 1975.

We are especially grateful to the helicopter pilots George Jones, Arne Veideman and the late Tom Lamb, without whose services this study could not have been conducted.

Mr. Jim Marshall, Strathcona Mineral Services, kindly provided logistic support at Nanisivik and during 1974 made the helicopter on charter to Strathcona Mineral Services available for the marine mammal surveys which were undertaken.

Funding for this study was provided by the Fisheries and Marine Service of the Department of the Environment and by the Department of Indian Affairs and Northern Development.

We are also grateful to Mr. Fred Alt and the Polar Continental Shelf Project for logistic support out of Resolute Bay during 1976.

The manuscript was typed by Mrs. S. Ahlgren and reviewed by M. Kingsley, T. Strong and M. Lawrence.

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Table 1. Narwhal densities and population indices for systematic surveys flown in Admiralty Inlet, 1975-1976.

Date	Survey Area (km^2)	Transects Flown	Percent Coverage	No. of Narwhal Observed	Density ($whales \cdot km^{-2}$)	Mean Estimate	Standard Error
28 July 1975	2 220	1-11 (Fig. 2)	12.4	1 198	4.36	9 683	2 089
9 Aug. 1975	2 225	1-11 (Fig. 2)	12.4	305	1.10	2 117[a]	698
10 Aug. 1975	2 345	12, 14, 15, 17, 18, 19 (Fig. 2)	8.0	75	0.99	961[a]	486
23 Aug. 1975	836	1, 2, 3, 4, 5 (Fig. 2)	13.9	253	2.18	1 820	314
9 Aug. 1976	2 060	Fig. 6	7.5	33	0.22	443	426
14 Aug. 1976	2 057	Fig. 6	7.0	113	0.79	1 614	347
15 Aug. 1976	2 008	Fig. 6	7.2	119	0.75	1 507[a]	737

[a] mean estimate calculated by partitioning area under survey into blocks of similar density and sampling intensity.

Table 2. Reconnaissance surveys flown in the study area during 1975.

Date	Area Surveyed	Survey Length (km)	No. of Narwhal Observed	Comments
23 July	Central Admiralty Inlet (Fig. 3)	249	0	
24 July	Central Admiralty Inlet (Fig. 3)	300	0	
25 July	Northern Admiralty Inlet (Fig. 3)	428	5	
26 July	Northern Admiralty Inlet (Fig. 3)	155	800 - 1 200	All narwhal moving into Admiralty Inlet along northwest coast of Borden Peninsula between Cape Joy and Baillarge Bay.
26 July	Northern coast of Borden Peninsula and west coast of Navy Board Inlet (Fig. 3, 7)	130	400 - 500	Narwhal moving north in central Navy Board Inlet near Low Point.
30 July	West coast of central Admiralty Inlet (Fig. 3)	125	2 000 - 3 000	Narwhal moving both north and south along west shore.
1 Aug.	Strathcona and Adams sounds (Fig. 4)	300	40 - 50	Narwhal in Admiralty Inlet between Strathcona and Adams sounds
4 Aug.	Central Admiralty Inlet (Fig. 4)	433	99	Most narwhal along west shore.
12 Aug.	Milne Inlet and Tremblay Sound (Fig. 7)	200	≈200	All narwhal (primarily cow-calf pairs) in northern Tremblay Sound.
16 Aug.	Northern Admiralty Inlet (Fig. 4)	201	235	26 narwhal in Adams Sound. 155 moving south along west shore.
23 Aug.	Northern Borden Peninsula and Navy Board Inlet (Fig. 7)	350	3	

Table 3. Reconnaissance surveys flown in the study area during 1976.

Date	Area Surveyed	Survey Length (km)	No. of Narwhal Observed	Comments
8 Aug.	Central Admiralty Inlet (Fig. 5)	89	151	
9 Aug.	North coast of Borden Peninsula and west coast of Navy Board Inlet (Fig. 8)	188	4	
10 Aug.	Central Admiralty Inlet (Fig. 5)	180	119	Directional movement not evident.
11 Aug.	Northern coast of Borden Peninsula and west coast of Navy Board Inlet (Fig. 8)	260	0	
11 Aug.	West coast of Borden Peninsula across Eclipse Sound to Pond Inlet (Fig. 8)	112	267	All narwhal observed in leads in east central Eclipse Sound.
11 Aug.	Pond Inlet to west coast of Eclipse Sound via Milne Inlet (Fig. 8)	196	64	Most narwhal in leads in Milne Inlet and the mouth of Tremblay Sound.
14 Aug.	Central and southern Admiralty Inlet (Fig. 5)	280	1	

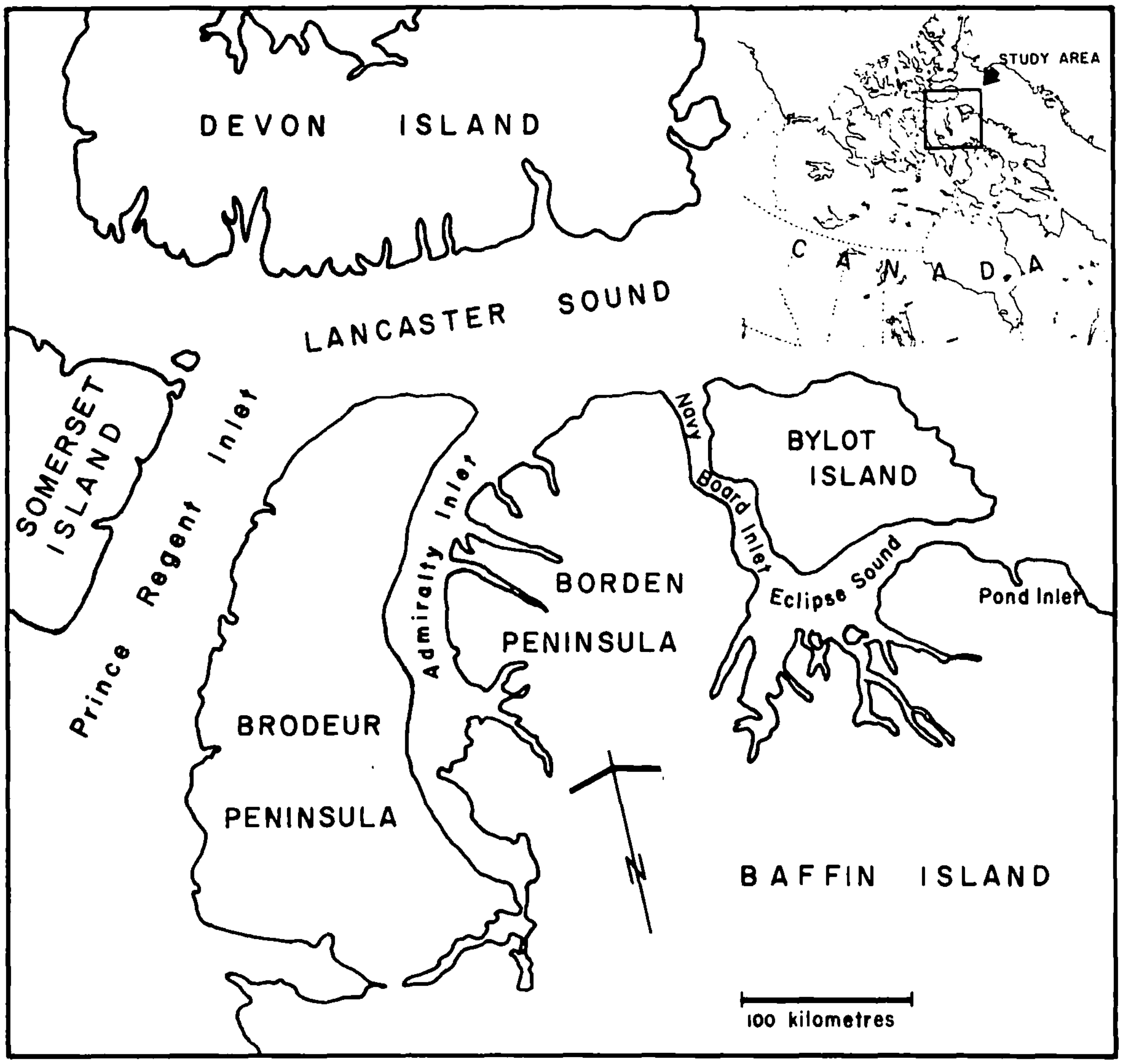

Fig. 1. The study area on northern Baffin Island, N.W.T.

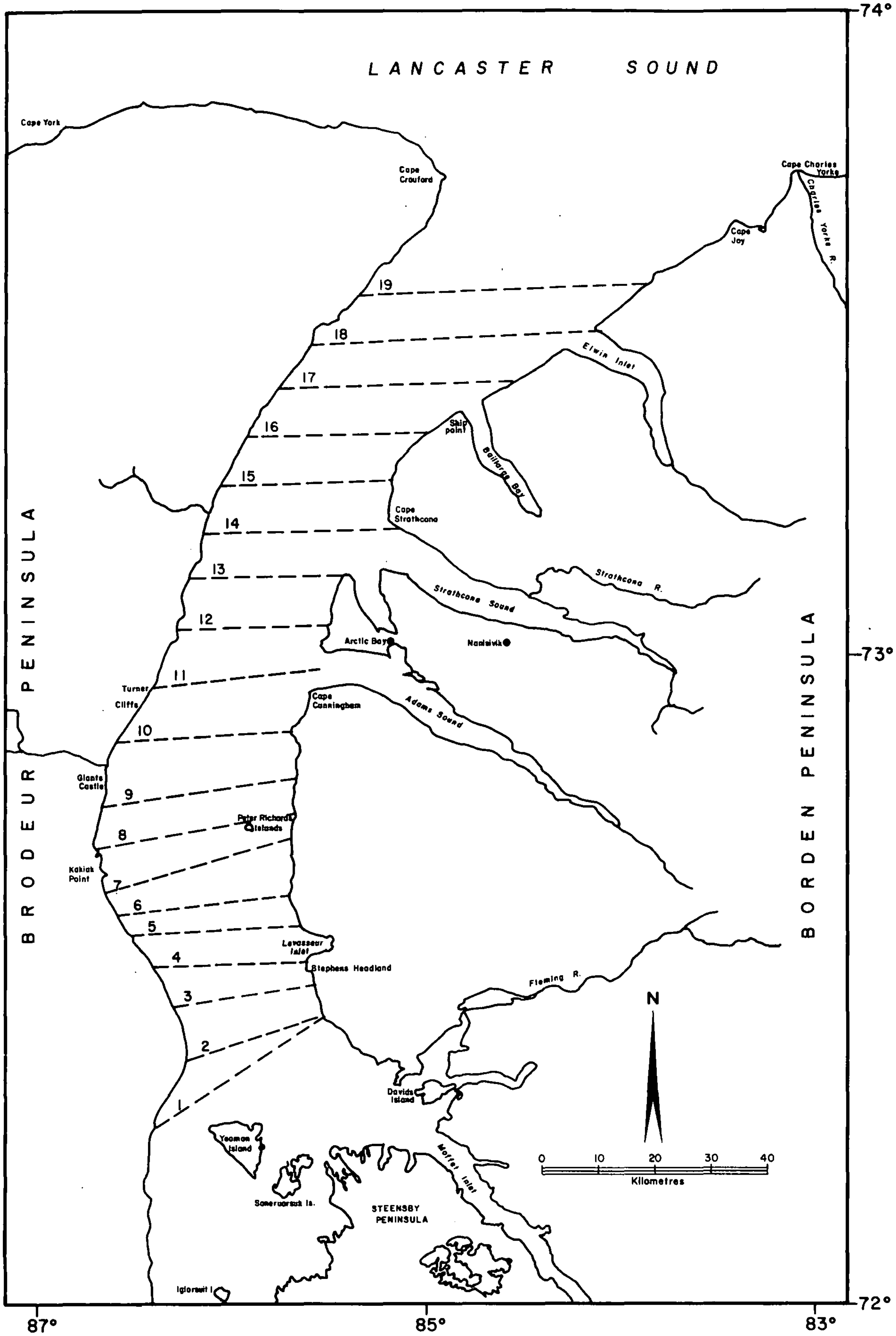

Fig. 2. Transects used to sample Admiralty Inlet during systematic aerial surveys in 1975.

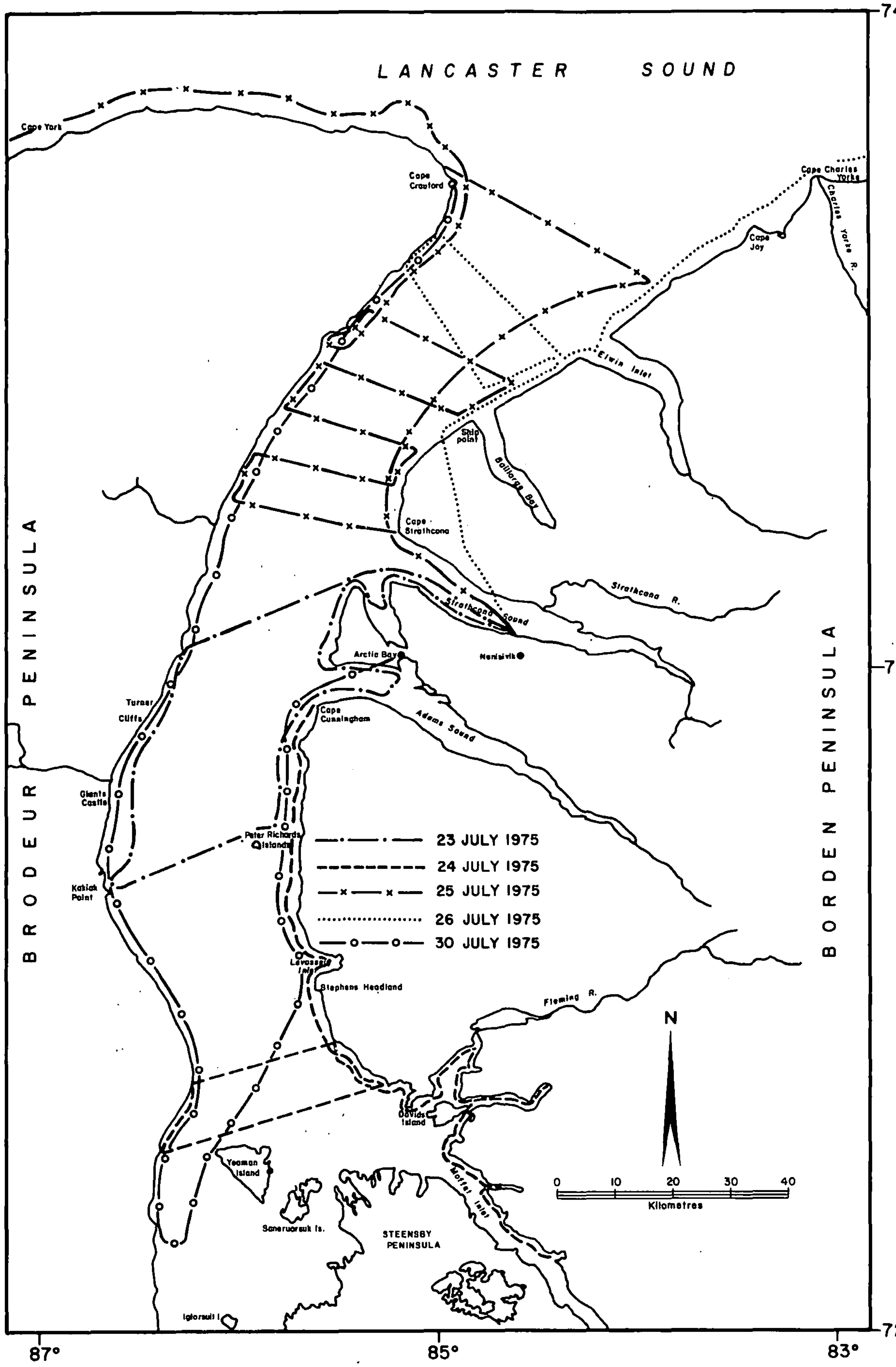

Fig. 3. Flight paths of reconnaissance surveys flown in Admiralty Inlet during July 1975.

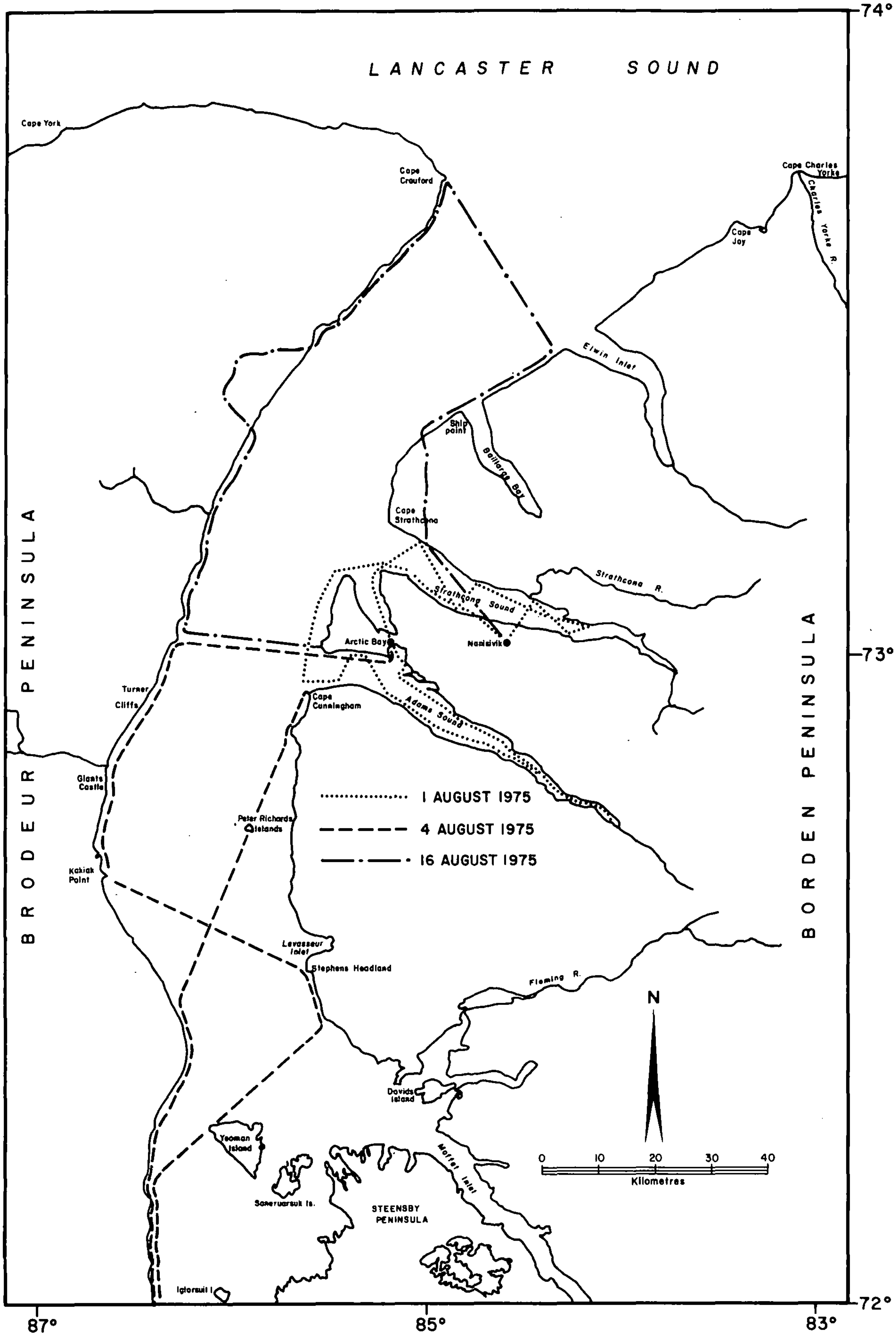

Fig. 4. Flight paths of reconnaissance surveys flown in Admiralty Inlet during August 1975.

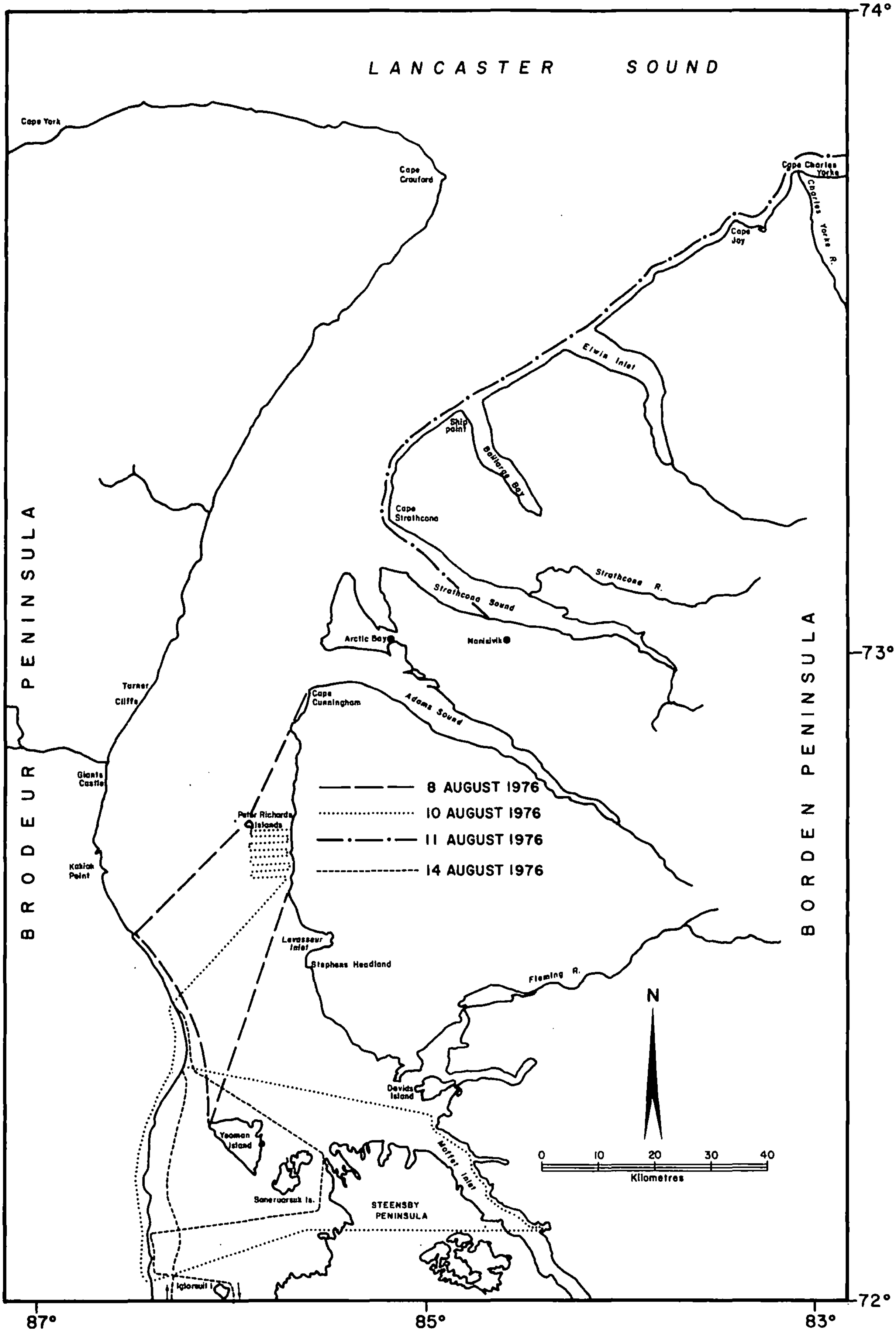

Fig. 5. Flight paths of reconnaissance surveys flown in Admiralty Inlet during August 1976.

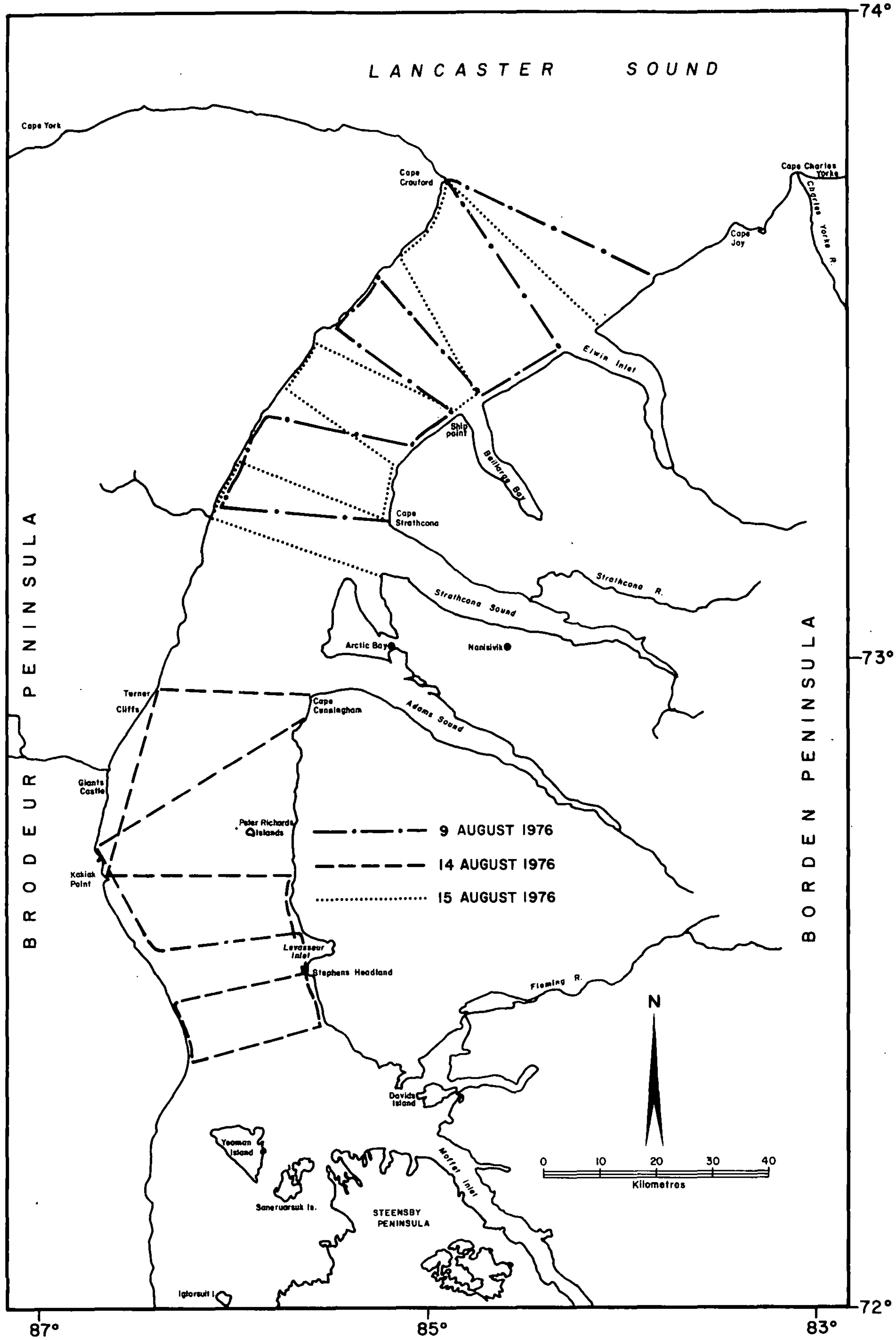

Fig. 6. Transects used to sample Admiralty Inlet during systematic aerial surveys in August 1976.

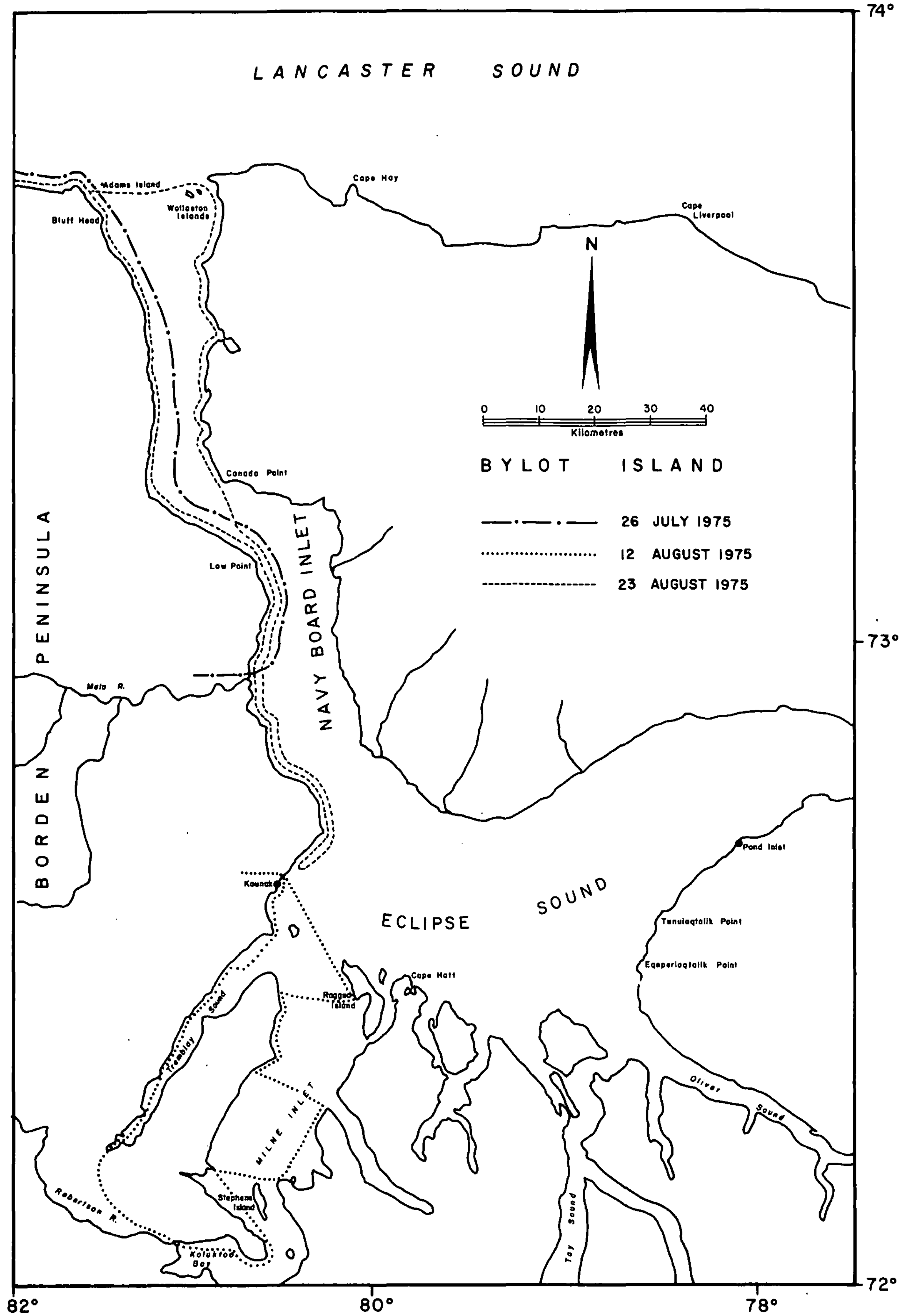

Fig. 7. Flight paths of reconnaissance surveys flown in Navy Board Inlet and Eclipse Sound during July and August 1975.

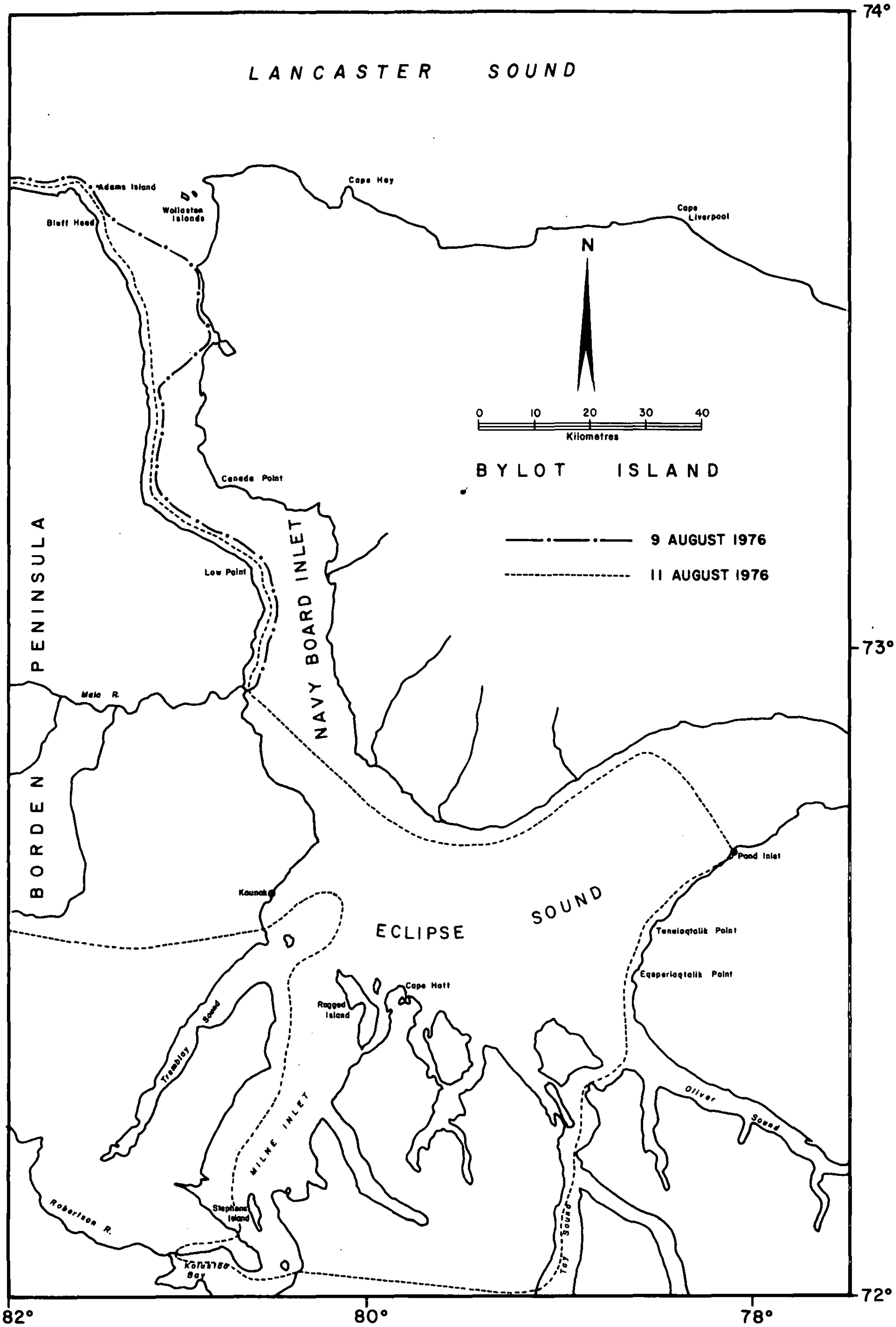

Fig. 8. Flight paths of reconnaissance surveys flown in Navy Board Inlet and Eclipse Sound during August 1976.

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