Distribution and abundance of Canadian High Arctic belugas, 1974-1979

William R. Koski[1], Rolph[1] A. Davis and Kerwin J. Finley[1,2]

[1]*LGL Limited environmental research associates, 22 Fisher Street, P.O. Box 280, King City, Ontario, Canada L7B 1A6*
[2]*K.J. Finley Ecological Research, 10232 Summerset Place, Sidney, British Columbia V8L 4X2, Canada*

ABSTRACT

We conducted >236,000 km of aerial surveys and some supplementary studies of belugas (*Delphinapterus leucas*) in the central and eastern Canadian High Arctic in 1974-79. Belugas that wintered in the "North Water" in Baffin Bay moved southwest into Lancaster Sound in April and early May. The main westward migration into Lancaster Sound occurred over a 2 to 3 week period during late June to late July. Estuaries along Somerset Island were occupied for ≤3 weeks from mid-July to mid-August. Little feeding occurred in estuaries. From mid-August until fall migration began in mid-September belugas occupied estuaries and offshore waters in Peel Sound.
Fall migration eastward through Lancaster Sound was exclusively along the south coast of Devon Island, highly co-ordinated, and rapid; most of the population passed through the sound in <1 week. The whales then moved north along the east coast of Devon Island; some entered Jones Sound while others crossed directly to SE Ellesmere Island. Most calving occurred in July and early August; calving was not seen in estuaries and probably occurred offshore. Excluding calves, adults and yearlings formed 77% and 8.4%, respectively, of the population. The proportion of calves during mid-August was consistent with a triennial calving cycle. During late summer, belugas fed on coastal concentrations of polar cod (*Boreogadus saida*), under pan ice offshore (probably on cod), and in deep offshore waters. The size of the Canadian High Arctic population in the late 1970s was estimated to be at least 10,250 to 12,000 animals without allowing for animals that may have passed between surveys or that were below the surface at the time of the counts.

Koski, W.R., Davis, R.A. and Finley, K.J. 2002. Distribution and abundance of Canadian High Arctic belugas, 1974-1979. *NAMMCO Sci. Publ.* 4:87-126.

INTRODUCTION

Beluga whales (*Delphinapterus leucas*) that enter the central Canadian High Arctic in summer are part of the "Canadian High Arctic" population. This population is believed to winter off Western Greenland and in the "North Water" of northern Baffin Bay (Finley and Renaud 1980, Doidge and Finley 1993, Heide Jørgensen and Reeves 1996, Richard *et al.* 1998b). The Canadian High Arctic population is hunted by Canadian and Greenlandic Inuit, and surveys conducted in the late 1980s and early 1990s off Western Greenland suggested that it may have declined

considerably over the last two decades, probably due to large catches in Western Greenland (Doidge and Finley 1993, Heide-Jørgensen 1994, Heide-Jørgensen and Reeves 1996). The latter authors estimated that the population that winters off Western Greenland had declined by as much as 62% from the early 1980s to the early 1990s. However, the numbers of belugas in summering areas in the central Canadian High Arctic do not appear to have declined as dramatically, if at all (Innes *et al*. 2002). It is unknown whether the apparent decline off Western Greenland was due to an actual decline in population, to changes in winter distribution, or to a combination of these two factors.

Prior to the early 1970s the size of this population had not been estimated. The first rough estimate of 10,000 was based on a reconnaissance survey of estuarine concentrations by Sergeant and Brodie (1975). The interest in hydrocarbon resources in the Canadian High Arctic during the 1970s led to several wide-ranging surveys of marine mammals. LGL Limited and the authors conducted most of these surveys in the central and eastern Canadian High Arctic in 1974-79. In this paper, we present information on the spring, summer and autumn distribution and migration routes and we estimate the size of the population in the late 1970s. These results are presented for comparison with later studies of the same beluga population (Smith *et al*. 1985, Martin and Smith 1992, Martin *et al*. 1993, Smith and Martin 1994, Richard *et al*. 1998a, Innes *et al*. 2002).

METHODS

A total of approximately 236,000 km of aerial surveys were conducted during 1974-79 in marine areas of the central and eastern Canadian High Arctic. Supplementary data were obtained from aerial photographs, by ground observations at four coastal vantage points, by examination of stomach contents of belugas killed by Inuit, and from incidental observations during various biological studies in 1974-79.

Aerial surveys

Surveys of coastal and (less intensively) offshore areas of the central Canadian High Arctic were conducted in 1974-77 and 1979 (funded by the Polar Gas Project 1974-77 and Canada Department of Fisheries and Oceans in 1979); surveys of eastern Lancaster Sound were conducted in 1976 (funded by Norlands Petroleums Ltd.); and surveys of the eastern Canadian High Arctic were conducted in 1978-79 (funded by Petro-Canada Explorations, Inc). Surveys off SE Melville Island in 1977 were funded by Petro-Canada.

Almost all surveys were conducted from twin-engine, high-wing aircraft, usually a Cessna 337 in 1974-75 and DeHavilland Twin Otters in 1976-79. Some special surveys were conducted in helicopters. During most systematic surveys, Global Navigation Systems (GNS-200 in 1974-76, GNS-500 in 1978-79) or On-trac II (in 1977) were used for accurate navigation when landmarks were not visible, and a radar altimeter was used to maintain the desired survey altitude above sea level (ASL). During systematic surveys, sightings were tape-recorded and subsequently mapped for each 2-min (5 to 7.5 km) segment of transect.

During systematic (and most other) surveys, observers were seated in the co-pilot's (right front) seat and in a rear seat on the opposite side of the aircraft. A third observer was often present behind the front observer. Sightings within and beyond a designated transect width were distinguished; "on-transect" sightings were used to estimate the density of mammals per km^2.

Three main types of surveys were conducted: (1) low-altitude (30-50 m ASL) systematic surveys for both marine mammals and seabirds, (2) medium-altitude (90-150 m) systematic surveys for marine mammals, and (3) high-altitude systematic or reconnaissance surveys at variable heights (generally >150 m). Transect widths during such surveys were 400 m, 0.8-1.6 km, and 1.6 km or undefined, respectively. Ground speeds were generally 160-185 km/h, 220-240 km/h, and >220 km/h, respectively. During the second and third types of surveys we often interrupted the survey to circle and/or photograph noteworthy concentrations of mammals.

Observers do not see or record all animals that are present in a survey area. Some animals that

are at the surface at the time of a survey are missed, and some animals are below the surface where they cannot be seen when the survey aircraft is present (Eberhardt 1978, Harwood *et al*. 1996, Innes *et al*. 2002). The data presented here do not include correction factors to account for animals that were missed by the primary observers for either reason, and so, are minimum estimates of the numbers that were present. The variable heights at which surveys were conducted and the purpose of the surveys also potentially affect the numbers of belugas that were recorded. During low altitude surveys (50 m ASL) there was a greater chance that some belugas were missed because observers attempted to record all birds and mammals that were present.

Transects along coasts and ice edges were usually centred 200 m from the interface during low-altitude surveys with transect width 400 m, and 400 to 1,000 m from the interface during medium- and high-altitude surveys. In 1976, 1978 and 1979, we also conducted many low-altitude "nearshore" surveys, which were parallel to and centred 1,200 m seaward of coasts and ice edges.

1974 surveys
Low-altitude surveys (21,170 km) were conducted, mostly from 3-29 June and from 31 July-4 September, along coasts and ice edges from southern Boothia Peninsula north to western Devon Island and west to eastern Melville Island (west of Bathurst Island)(Fig. 1, 2). We also obtained some coverage of offshore waters, especially in Barrow Strait (Finley *et al*. 1974, Davis *et al*. 1975).

1975 surveys
In June and August, low-altitude surveys (20,275 km) were conducted of most marine areas that had been surveyed in 1974 (but not SE Prince of Wales Island or NW Devon Island). High-altitude surveys over open water (>4,215 km) included four surveys in July and August of 10 transects across Barrow Strait (Fig. 2); these surveys were designed to assess numbers of marine mammals offshore. From 20 July-25 August a helicopter (Hughes 500) was used to survey (3,000 km) whales concentrating along eastern Somerset Island, especially in Creswell Bay. Shore-based observations of marine mammals at Creswell Bay were also obtained (Finley 1976).

1976 surveys
From 1 June-3 July, helicopters (Bell 206 and FH 1100) were used for 11 low-altitude surveys along ice edges and coasts along the northern edge of Barrow Strait, plus 3 surveys along the ice edge across western Barrow Strait (1,477 km, Fig. 1).

From 11 August-30 September 1976, high-altitude surveys (9,276 km) were conducted in Peel Sound (8 surveys), Barrow Strait (14 surveys), eastern Somerset Island (5 surveys) and McDougall Sound (2 surveys, Finley and Johnston 1977).

From 2 May-28 September, a standard route in eastern Lancaster Sound was surveyed weekly at low altitude (22 surveys, 28,635 km). The route consisted of (1) eight N-S transects across Lancaster Sound, (2) coastal or ice edge transects parallel to and 200 m from the north and south shores, and (3) nearshore transects 1.2 km from the north and south shores (Fig. 1, 2; Johnson *et al*. 1976, Davis *et al*. 1978b). Ferry flights also provided high-altitude reconnaissance of northern Admiralty Inlet and western Lancaster Sound.

1977 surveys
On 19 April and 7-8 June, all isolated areas of open water along eastern Bathurst Island and northwestern Devon Island were surveyed for overwintering mammals (2,500 km, Fig. 1). Additional surveys were conducted in these and adjacent areas from 16 July-7 September (7,920 km., Fig. 2, Davis *et al*. 1978a). Reconnaissance flights (3,000 km) for summering mammals were conducted in Peel Sound, Prince Regent Inlet (both eastern and western sides) and Barrow Strait; vertical photographs of the major beluga summering concentrations were obtained.

From 3 July-28 August, parts of the east and south coasts of Melville Island were surveyed at 30 m and 100 m ASL (1,480 km, McLaren and Renaud 1977).

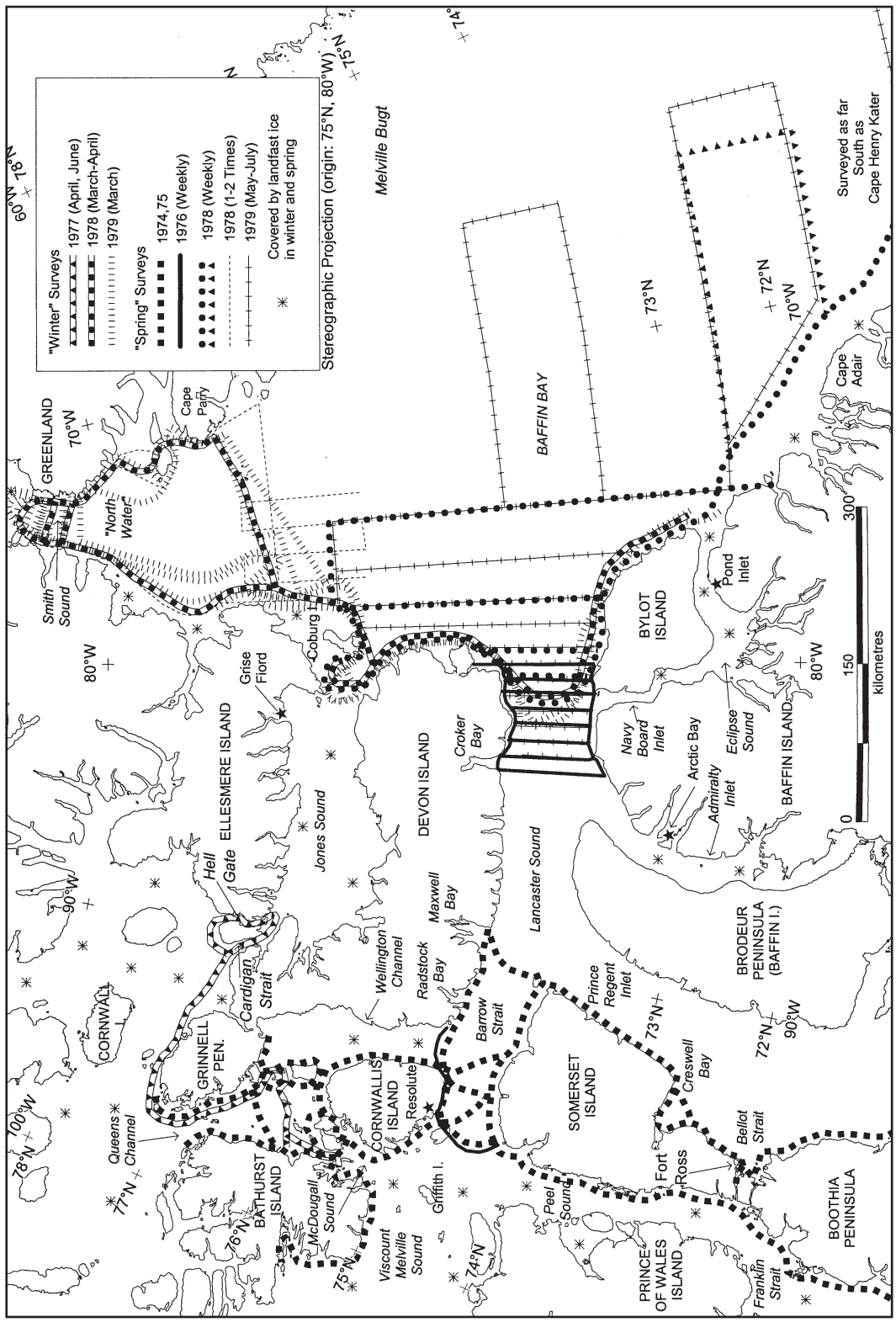


Fig. 1.
Main aerial survey routes during the overwintering and spring migration periods (March-July), 1974-79. Additional surveys of landfast ice in the Barrow Strait, Peel Sound and Viscount Melville Sound areas (west to Melville Island) are not shown.

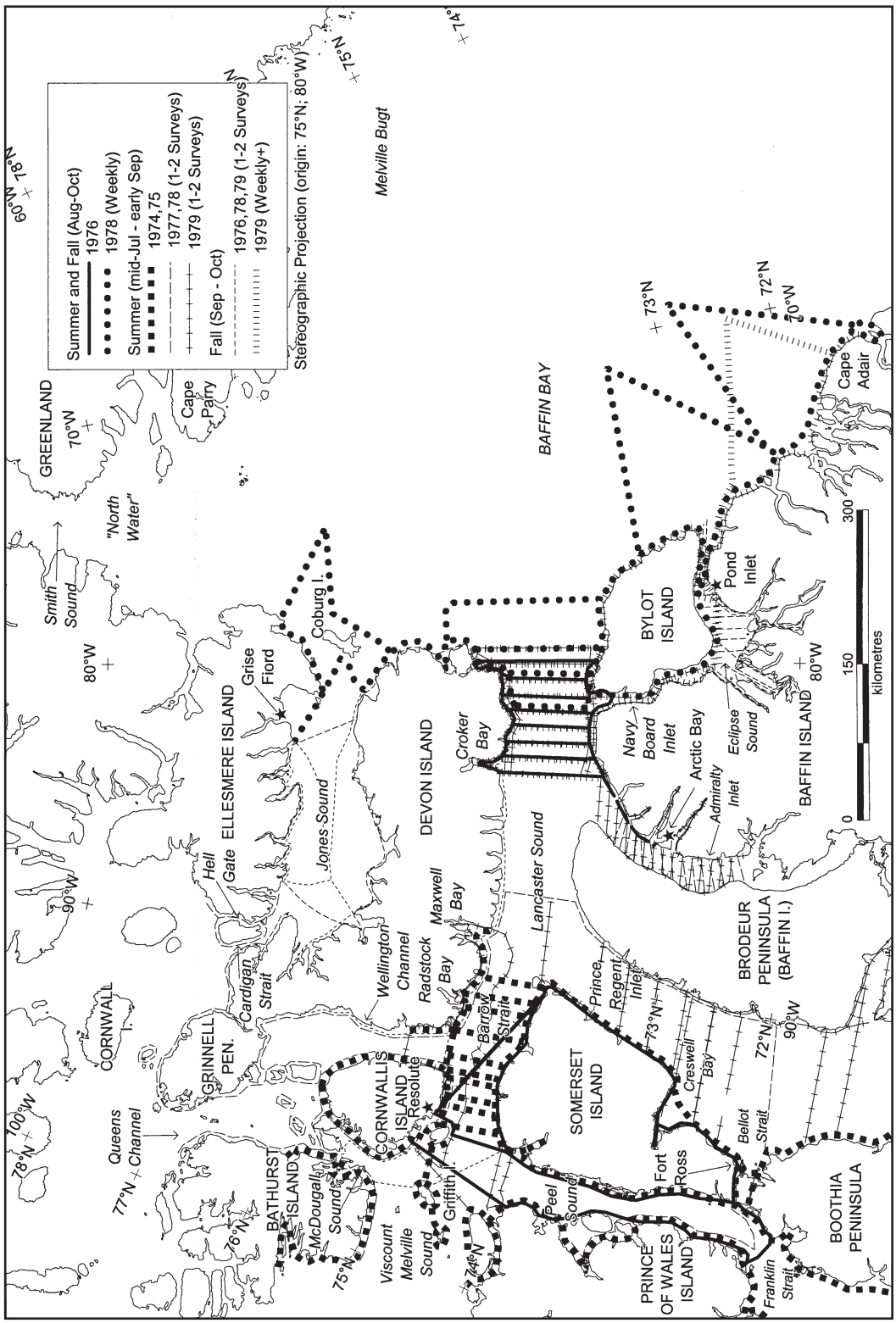


Fig. 2.
Main aerial survey routes during the summering and fall migration periods (August-October), 1974-79.

1978 surveys

The coasts, ice edges and offshore waters of a large area of NW Baffin Bay and adjacent channels were surveyed weekly, at low altitude, from 4 May-10 October (22 surveys, 60,678 km, Koski and Davis 1979). The heavily dotted line on Fig. 1 shows the route for the 11 surveys up to 11 July (see also Fig. 5); Fig. 2 shows the route for 8 surveys after 21 August. There were 3 surveys of a similar route in the intervening period. These low-level surveys for marine mammals and seabirds were supplemented with various mammal surveys, including:

(1) twelve medium-altitude surveys from 12 May-2 August of a route over offshore Baffin Bay east of Baffin Island (7,528 km, route indicated by triangles on Fig. 1),
(2) medium-altitude surveys of leads forming in Lancaster Sound and Prince Regent Inlet during break-up on 18-19 July (475 km),
(3) medium-altitude surveys for summering mammals in Eclipse Sound, Navy Board Inlet and Admiralty Inlet (1,600 km), and
(4) reconnaissance surveys around most of Devon Island on 13-15 September, during the peak of eastward migration of belugas (3,000 km).

1979 Surveys

The coasts, ice edges and offshore waters of a large area of NW Baffin Bay and adjacent waters were surveyed weekly at 50 m and 100 m ASL from 9 May-22 July (31,260 km, Koski 1980). The hatched line on Fig. 1 shows the route for the 9 surveys up to 22 July. In addition, offshore surveys were conducted south and east of the area shown on Fig. 1 (see Fig. 11 in Koski and Davis 1994).

The autumn survey route was flown 12 times at 4-7 day intervals from 11 September-17 October (Fig. 2) (Koski and Davis 1980). Survey altitude was 90 m ASL. These surveys for both birds and marine mammals were supplemented with medium-altitude surveys (150 m ASL) for marine mammals during August and September including:

(1) a survey along S. Devon Island on 22 July (130 km),
(2) one to two surveys of summering areas in each of Prince Regent Inlet, Barrow Strait, Wellington Channel, Pond Inlet, Admiralty Inlet, and Jones Sound (6,579 km), and
(3) surveys along S. Devon Island on 19 and 20 September (900 km).

Aerial photography

Vertical or oblique photographs of herds were often taken during surveys, usually with a 6 x 7 cm medium-format camera. In 1977, special photographic surveys were flown over coastal concentrations of belugas. A vertically-aimed motor-driven camera (6 x 6 cm format) with a 40 mm lens was mounted in a Cessna 337 aircraft operated by Norcor Engineering and Research Ltd. High-level sequences (750 m

Table 1. Shore-based watches for migrating marine mammals. For locations, see Fig. 2.

Waterbody Watch Site	Co-ordinates	Height (m ASL)	Observations	
			Dates	Hours
Bellot Strait[a] S Somerset Island	72°01'N, 94°31'W	70	29 Aug - 23 Sep 1976	195
Crozier Strait[b] E Bathurst Island	75°31'N, 97°24'W	60-100	24 Jul - 23 Aug 1977	240
S Lancaster Sound[c] W of Cape Hay, Bylot Island	73°45'N, 80°19'W	300	28 Jul - 9 Aug 1978[d]	140
W Baffin Bay[c] Cape Adair, Baffin Island	71°30'N, 71°35'W	220	13 Sep - 7 Oct 1978 20 Sep - 16 Oct 1979	260 277

[a]Details in Finley and Johnston (1977). No data on 5, 9, 13, 14 Sept.
[b]Details in Salter (1979). Included ten 24-h watches plus observations every 6 h on other dates.
[c]Details in Koski and Davis (1979, 1980).
[d]Additional casual observations until 6 Sept. 1978.

ASL) were taken with color film (Kodak Ektachrome 200).

Shore-based watches

At various times we watched systematically for migrations of marine mammals past four coastal vantage points (Table 1). Weather permitting, crews of 2-3 people conducted continuous daylight watches with the aid of binoculars and spotting scopes at each of these locations.

RESULTS

Ice conditions

Ice strongly affects the seasonal distribution and migration patterns of High Arctic belugas (Vibe 1967). Their summer range is ice covered from about October to June, and their spring migration to these areas is influenced by the timing of break-up. Whales that linger too long on the summer range risk entrapment by newly-forming ice (Freeman 1968, Heide-Jørgensen *et al*. 2002).

In winter, the only areas of open water in the Canadian Arctic Archipelago during the years of our surveys were a few polynias near northwestern Devon Island and in Bellot Strait (Fig. 3). Most of the channels in the archipelago were covered by thick, landfast ice that persisted until July or early August. A few channels (Lancaster Sound, Prince Regent Inlet, Barrow Strait) contained temporary leads and areas of open water but usually were either completely covered by pack ice or, in some winters, 100% covered by landfast ice. Most of Baffin Bay was covered by "close pack ice" in winter. Open-water areas in NW Baffin Bay occurred off Jones Sound, along SE Devon Island and across Smith Sound (Fig. 3).

Ice edges were a common feature through the winter, spring and early summer. They were the borders between landfast ice and either pack ice or open water. For most of the year an ice edge extended from NW Greenland across Smith Sound to Ellesmere Island and then south along the western margin of Baffin Bay, excluding whales from areas to the west and north (Fig. 3). However, open water or pack ice generally extended westward into eastern Jones Sound and into Lancaster Sound, even in winter.

As spring advanced, the proportion of Baffin Bay covered by pack ice gradually decreased. In most years, a lead formed along the west coast of Greenland. On the Canadian side, in general, there was more open water north than south of the entrance to Lancaster Sound and pack ice remained off eastern Baffin Island throughout the summer. The ice edge across Jones Sound consistently remained intact until late July, but break-up in Lancaster Sound was more variable and usually earlier. The ice usually began to clear from Lancaster Sound by May, generally leaving an ice edge at position [2] on Fig. 3. Later, the landfast ice in Barrow Strait broke up, forming an ice edge at position [3]. In some years (*e.g.*, 1974, 1976) the ice cleared west to position [3] by late May; in 1978 and 1979, however, landfast ice persisted west of position [1] until mid-to-late July and early August, respectively.

Open water began to appear along the western side of Prince Regent Inlet in June. However, most other channels, bays and fiords in the eastern and central archipelago remained covered by landfast ice until mid-July or even August. The polynias in Queens Channel and adjacent areas gradually expanded during June and early July, but remained isolated from the open water in more easterly channels until at least mid-July. Even after landfast ice disappeared from bays and coasts, pan ice was often blown against the shore by onshore winds.

Freeze-up began in protected bays and channels during early or mid-September. During calm weather freeze-up was very rapid, even in the more exposed channels.

Spring migration

Spring movements of belugas in NW Baffin Bay, Lancaster Sound and the Canadian Arctic Archipelago were heavily influenced by ice conditions. In 1978 and 1979, Lancaster Sound was covered by landfast ice until July or early August and whales could not move west beyond the ice edge marked [1] on Fig. 3 until that time. In 1976, leads extended as far west as Maxwell Bay (S Devon Island) by late April, and to Barrow Strait in May (R.R.C.S. 1977). The 1978-79 surveys (Fig. 1) included eastern Lancaster Sound and overlapped with the 1976

Fig. 3.
Major ice characteristics within the study area.

study area. Comparison of results from 1976 and 1978-79 provided information about the behaviour of belugas in spring seasons when Lancaster Sound was open vs. ice covered.

Eastern Canadian High Arctic

1976

Our weekly surveys of Lancaster Sound began on 2 May. During our first two surveys in early May, we found few belugas. However, during five surveys from 16 May-15 June numbers ranged from 124 to 142. The distribution within the study area was variable and suggestive of a slow westward movement through Lancaster Sound. An influx began about 20 June (387 recorded including "off transect" sightings not shown on Fig. 4) and continued to mid-July. The peak number recorded was 487 during the 4-5 July survey. By the end of July, only 22 belugas were seen on the survey route.

During their westward migration through Lancaster Sound, most (84%) of the 2,240 belugas recorded were within 1.6 km of coasts or coastal ice edges. However, our surveys covered approximately 25% of the area within 1.6 km of the coasts and ice edges, but only 3% of the offshore waters. Thus the 84% figure may overestimate the relative utilisation of waters near coasts and ice edges during spring and early summer. Of the 1,874 belugas recorded within 1.6 km of coasts and coastal ice edges, 86% were along the northern margin of the sound and only 14% were along the southern margin. Both margins were surveyed with equal intensity, so these percentages are comparable. During the main migration period (20 June-26 July), 94% of the whales within 1.6 km of coasts were along the northern margin of the sound.

1978

During three surveys 4-18 May, 400 to 600 belugas were seen during each survey (Table 2). On 4-7 May none were seen south of Lancaster Sound, and highest densities were along the Jones Sound ice edge. During mid-May, landfast ice prevented the whales from entering Lancaster Sound, and movements were both north and south along the coasts and ice edges.

An influx of belugas occurred prior to the 22-24 May (Table 2). Densities were high (16.8/km^2) along the Lancaster Sound ice edge. Distribution and movement patterns suggest that they had arrived from the north or northeast at latitudes north of 75° N. None were seen in off-

Table 2. Numbers and densities of belugas recorded during aerial surveys of northwestern Baffin Bay and eastern Lancaster Sound, 4 May-26 July 1978. The survey route is the heavily dotted line on Fig. 1 (see also Fig. 5).

Survey Period	Area surveyed (km^2)[a]	Number of belugas[b]	Density (no./km^2)[c]		
			All coasts and ice-edges	Near-shore	Lancaster Sound ice-edge
4-7 May	1,002	401	1.1	0.0	2.2
8-14 May	942	599	1.3	0.3	0.1
15-18 May	934	565	1.4	0.1	1.2
22-24 May	938	2,152	5.4	0.5	16.8
29 May-2 June	1,045	916	2.3	0.4	7.9
8-10 June	1,021	1,261	2.9	0.5	4.0
12-16 June	1,159	1,578	3.3	0.3	17.8
19-23 June	1,194	1,761	3.7	0.3	11.5
26-30 June	1,209	1,853	3.9	0.3	28.5
3-8 July	1,312	2,118	4.2	0.4	15.7
10-11 July	772[d]	2,688	6.7	0.4	68.9
21-26 July	708	370	1.1	0	-[e]

[a]Transect width was 0.4 km; thus the length of survey (in km) was 2.5 times the value listed in this column.
[b]Excluding whales seen adjacent to the transects.
[c]Transects along coasts and ice-edges were centered 200m off the interface; nearshore transects were 1200m off the interface.
[d]Survey incomplete due to fog.
[e]Ice-edge broke up between 12 and 20 July.

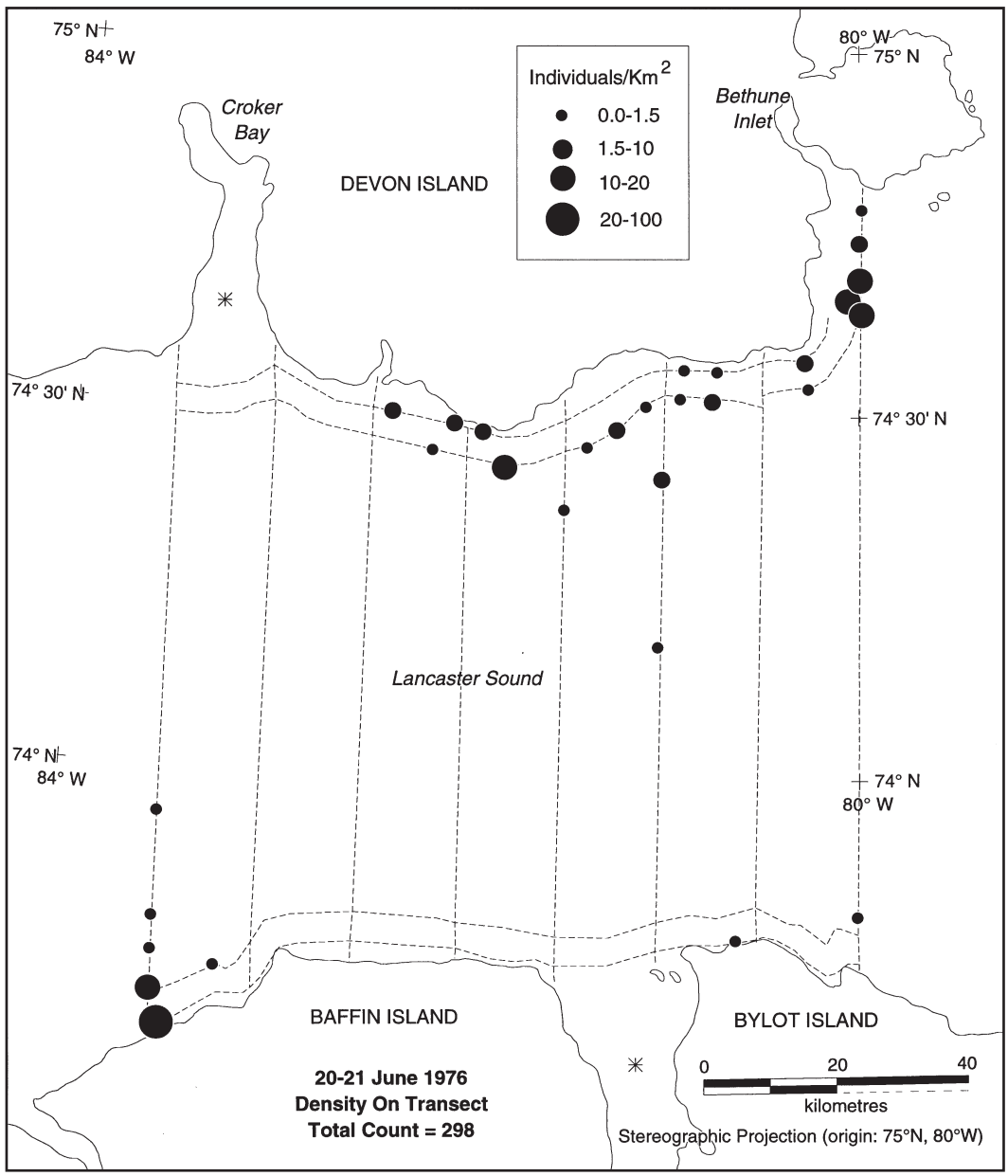


Fig. 4. *Distribution of belugas in eastern Lancaster Sound, 20-21 June 1976. Symbols show densities in 2-min survey segments (transect width 0.4 km); density 0.4/km² represents a sighting of a single whale. For legibility, nearshore transect positions have been displaced seaward from their actual positions. * indicates areas of landfast ice.*

shore Baffin Bay (Fig. 5) and few were seen south of Pond Inlet. The 455 belugas seen along the north coast of Bylot Island were swimming southeast.

The numbers recorded during surveys decreased substantially in late May (Table 2). The reason for the decline is not clear since the animals could not enter Lancaster Sound or move south of Pond Inlet where the coast was blocked by heavy pack ice. Our surveys included transects along and centred 200 m and 1,200 m from all coasts and ice edges; thus it is unlikely that the decline of over 1,200 animals was due to inadequate survey coverage in coastal areas. Some belugas must have moved either into offshore waters among the pack ice or north of our survey route.

We surveyed northern Baffin Bay on 31 May-1 June; only 349 belugas were recorded. We also surveyed the east coast of Ellesmere Island (281 belugas), the Smith Sound ice edge at 78º 45´ N (8 belugas), and the coast of Greenland south to Saunders Island (76º 35´ N) (29 belugas). The remaining 31 whales were sighted

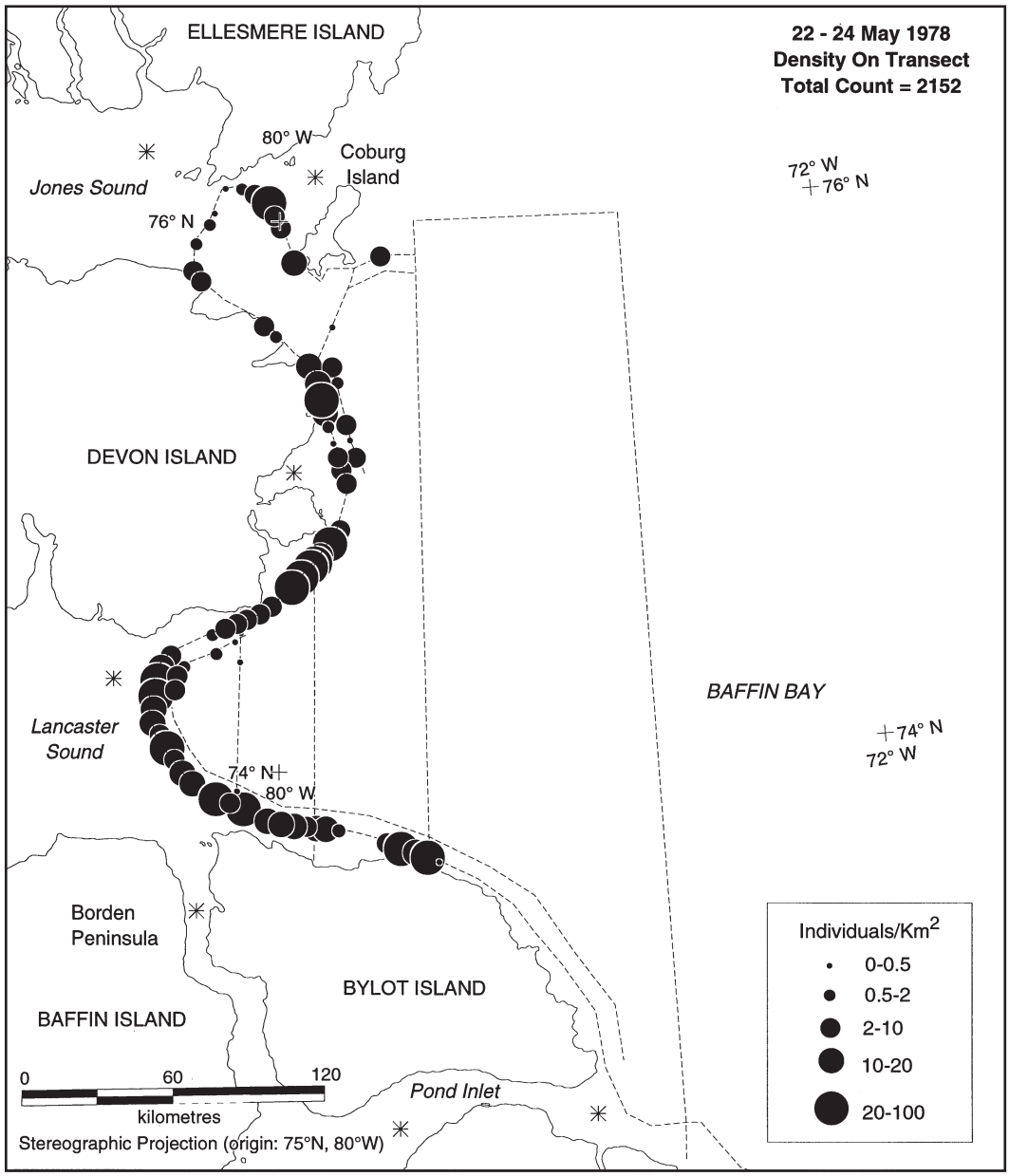


Fig. 5. *Distribution of belugas in NW Baffin Bay and eastern Lancaster Sound, 22-24 May 1978. Plotted as in Fig. 4.*

more than 25 km from shore along a grid of transects (180 m ASL) of total length 700 km (Fig. 1). Most of the offshore animals were moving north (74%) and west (10%); 16% were not moving. These results indicate that some belugas do move through offshore waters of extreme northern Baffin Bay. However, there was no evidence that the decline noted in our regular survey area in late May was due to a major northward movement into extreme northern Baffin Bay. It appears, instead, that many belugas moved into offshore waters when they were unable to migrate into Lancaster Sound. In fact, small numbers were noted along the western edge of the Baffin Bay pack ice off the entrance to Lancaster Sound on 1 and 16 June.

In addition to the weekly surveys, we conducted 10 surveys (some extending 250 km offshore) from 12 May - 2 August over the pack ice in Baffin Bay to the east of NE Baffin Island (Fig. 1). These surveys covered a total of 6,022 km^2, but only 15 belugas were seen. Similarly there was no evidence of a migration northwest along the east coast of Baffin Island where we conducted weekly surveys. This confirms that

most belugas entered Lancaster Sound from the northeast.

The numbers of belugas recorded increased steadily through June and a build-up at the Lancaster Sound ice edge began in mid-June (Table 2). The peak of migration occurred in early and mid-July; over 2,900 belugas (including animals adjacent to the transect strip) were recorded during an incomplete survey on 10-11 July. Nearly 1,700 whales (68.9/km^2) were present along the southern half of the Lancaster Sound ice edge; fog prevented surveys of the northern half. Fog hindered surveys until 20 July, and the ice edge began to break up sometime between 12 and 17 July. Belugas penetrated far into the newly developing leads; 728 were recorded in a lead about 150 km west of the ice edge on 17 July, and 320 were seen between northeastern Somerset Island and Maxwell Bay (250 km to the west) on 19 July. Few belugas (370) were recorded on our regular survey 21-26 July (Table 2), and the last westward migrants were noted during the 28 July-2 August survey.

In summary, the main movement of belugas into Lancaster Sound in 1978 occurred between 4 and 20 July. These whales apparently moved across Baffin Bay north of 74º 30´ N and then moved south along coasts and ice edges along Ellesmere and Devon islands to Lancaster Sound. Few belugas crossed Baffin Bay south of 74º 30´ N, or approached Lancaster Sound from the southeast.

1979

From 9 May-15 July weekly surveys were attempted of the route shown in Fig. 1. Fog often prevented completion of this route, particularly coastal and ice-edge transects (Table 3). The first complete survey was conducted 17-22 May and by this time at least 1,437 belugas were present (Fig. 6). Sightings of small numbers of belugas on offshore transects from 74º 30´-76º 00´ N, sightings of whales moving south along the ice edge northeast of Coburg Island (north of 76º), and the gradually increasing counts during each complete survey, all suggest that small numbers of belugas moved into the study area through offshore waters north of 74º 30´ during mid-May to late June. Only a few belugas were sighted south of Lancaster Sound and the distribution of sightings suggests that those whales probably "overshot" Lancaster Sound after entering our study area from the northeast. No belugas were seen during extensive surveys of offshore Baffin Bay from 69º 30´-74º 30´ N although 29,931 to 38,988 narwhals (*Monodon monoceros*) were estimated to be present in offshore Baffin Bay during those same surveys (Koski and Davis 1994).

Major influxes of belugas entered Lancaster Sound during early July but bad weather prevented completion of surveys during early July to early August. Numbers along coasts and ice edges increased throughout the season but the Lancaster Sound and eastern Devon Island ice edges were not surveyed during the mid-July period. Densities on offshore transects in Lancaster Sound were 0.054/km^2 during 19-23 June, 0.202/km^2 during 28 June-2 July, and 0.234/km^2 during 8-15 July. In addition, the location of the ice edge moved west between 2 and 8 July so that the offshore area increased between the latter two surveys. Based on densities observed in offshore Lancaster Sound, the number of belugas present there increased from 483 during 19-23 June to 2,526 during 8-15 July.

In summary, slightly larger numbers of belugas were present in NW Baffin Bay in mid-May of 1979 than in 1978. Small numbers of belugas entered the study area during May and June and the main movement appears to have occurred during July, but incomplete survey coverage did not permit accurate determination of the timing. Belugas entered the study area primarily through offshore waters north of 74º 30´.

Central Canadian Arctic archipelago

Less intensive surveys were conducted in western Lancaster Sound, Barrow Strait and Prince Regent Inlet in June 1974 and June-July 1975. Lancaster Sound contained open water in both these seasons, so the 1974-75 surveys provide results complementary to those from eastern Lancaster Sound in the "normal ice year" of 1976. Also, in 1976 we surveyed the ice edges and coasts along the northern edge of Barrow Strait from SW Devon Island to Griffith Island,

Table 3. Numbers and densities of belugas recorded during aerial surveys of northwestern Baffin Bay and eastern Lancaster Sound, 9 May-15 July 1979. The survey route is the hatched line on Fig. 1 (see also Fig. 6).

Survey Period	Area surveyed (km^2)[a]	Number of belugas[b]	Density (no./km^2)[c]		
			All coasts and ice-edges	Near-shore	Lancaster Sound ice-edge
9 May	192[d]	200	1.3	-	-
12-15 May	1,578[d]	497	1.1	-	-
17-22 May	2,064	1,437	2.5	-	12.0
24-26 May	1,374[d]	2	-	-	-
1 June	362[d]	740	2.8	-	-
10-14 June	3,066	1,924	3.3	0.5	14.7
19-23 June	1,730	2,048	3.6	-	25.0
28 June - 2 July	2,352	2,267	3.6	1.2	33.7
8-15 July	1,403[d]	671	1.0	0.5	-[e]

[a]Transect width was 0.4 km for surveys at 50 m ASL and 0.8 km for surveys at 90 m ASL. The length of survey (in km) was 1.25-2.5 times the value listed in this column, depending on the number of km of survey flown at each altitude during each survey period.
[b]Excluding whales seen adjacent to the transects.
[c]Transects along coasts and ice-edges were centered 200 m off the interface; nearshore transects were 1200 m off the interface.
[d]Survey of coasts and ice edges in and north of Lancaster Sound incomplete due to fog.
[e]The ice-edge broke up on 2 August.

11 times from 1 June-3 July. Other channels in the central Canadian High Arctic were also surveyed during spring in 1974-75 (Fig. 1), but were either totally ice-covered or contained only isolated polynias where no whales were seen.

1974

In 1974, eastern Barrow Strait was ice free by April or early May; from then until late July a landfast ice edge extended across western Barrow Strait (position [3] on Fig. 3). We surveyed all coasts and ice edges around Barrow Strait on five occasions from 3-29 June; we also surveyed a small portion of the offshore waters (Fig. 1). Belugas were present by 3 June but we recorded only 84 individuals, all during surveys of coasts and ice edges. Evidently, very few belugas reached Barrow Strait before July.

1975

In 1975, a landfast ice edge extended across eastern Barrow Strait from NE Somerset Island to Maxwell Bay on SW Devon Island until 25 June. Another landfast ice edge extended across northern Prince Regent Inlet in early June; this ice began to crack by mid-June and the western third of the inlet was ice free as far south as Bellot Strait by early July.

We surveyed the Barrow Strait ice edge on 1, 7, 12, 16 and 23 June and found 0, 57, 22, 22, and 22 belugas, respectively. We also found 230 belugas during an incomplete survey of the pan ice in northern Prince Regent Inlet on 16 June. Thus, at least a few hundred belugas were present in extreme western Lancaster Sound and northern Prince Regent Inlet in early June, but no increase in numbers was evident during June.

The landfast ice cleared from eastern Barrow Strait in late June, creating an ice edge across Barrow Strait at position [3] on Fig. 3. Surveys of all coasts and ice edges in this area, and of an offshore transect between NE Somerset Island and Maxwell Bay, revealed only 7 belugas on 7 July and 162 on 12-13 July. A survey of the entire east coast of Somerset Island on 9 July recorded only 270 belugas (Table 4).

The main influx of belugas into the central Canadian High Arctic began in mid-July. Surveys (10% coverage) of eastern Barrow Strait on 17-18 July found a density of 0.27 belugas/km^2 in areas more than 4 km from shore (Fig. 7). This extrapolates to about 2,700 in these offshore waters; this is a minimum estimate because it does not include corrections to

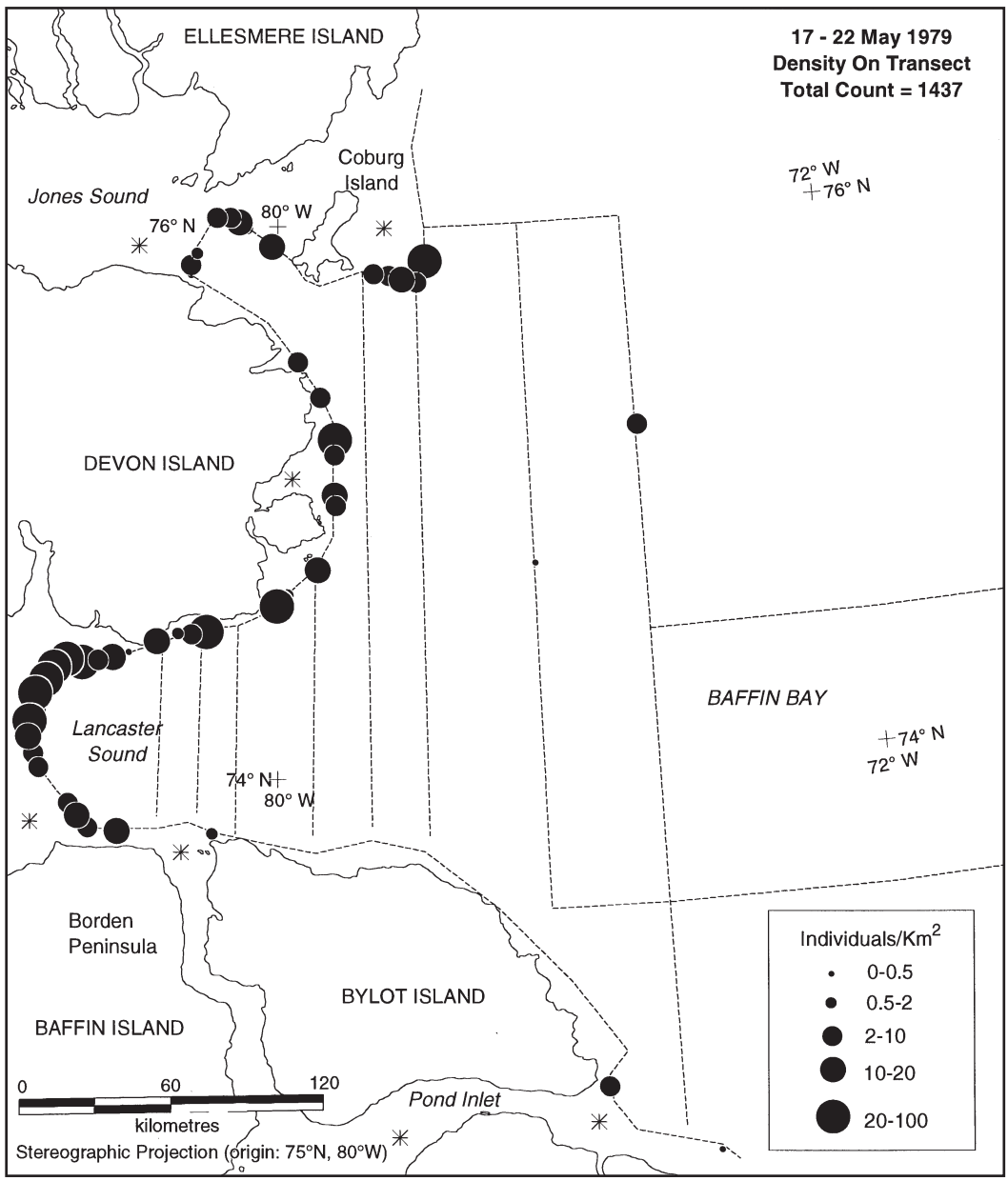


Fig. 6. *Distribution of belugas in NW Baffin Bay and eastern Lancaster Sound, 17-22 May 1979. Plotted as in Fig. 4.*

account for whales missed by observers or to account for the diving behaviour of belugas. The major influx of belugas into the summering area at Creswell Bay, Somerset Island, occurred between 21 and 24 July; only 241 were seen there on 21 July but 3,376 were counted on the 24th. Another survey of the offshore transects revealed that about 2,700 belugas (no corrections) were still present in eastern Barrow Strait on 27-28 July. Thus, the principal influx of belugas into the central Arctic occurred from 15-28 July in 1975.

1976

In 1976, like 1974, eastern Barrow Strait was ice free by late May. During 11 surveys along the northern edge of the strait 1 June-3 July, we saw 222 belugas near SE Cornwallis Island on 22 June, 98 and 114 in the same area on 28 June and 3 July, and 123 near eastern Griffith Island on 28 June. None were seen during three earlier surveys (8, 19 and 29 June) along the ice edge between Griffith Island and NW Somerset Island. Thus, the appearance of belugas along the northern margin of Barrow Strait in 1976

Table 4. Numbers and distribution of belugas in the central Canadian High Arctic, July - August 1975.

	July				August		
Area[a]	7-9	17-18	21	27-28	3	6-8	19-22
Somerset Island							
1. Cunningham Inlet	0	0	0	142	-	0	0
2. Killalugaluit Bay	0	100	1	297	-	91	0
3. Garnier Bay	0	10	436	1,000	-	0	0
4. river delta	0	0	210	0	-	0	0
5. Elwin Bay	259	215	-	207	944	-	0
6. Batty Bay	5	0	-	0	87	-	0
7. Creswell Bay (N shore)	5	0	241	2,131	(1,928)	-	248
8. Creswell Bay (S shore)	0	-[b]	-	963	-	-	-
9. river deltas	0	-	-	104	-	-	-
- Other coastal areas	1	141	85	5	46	11	171
Total Somerset	270	466	973	4849	(3,005)	(102)	419
Radstock Bay (SW Devon Island)	-	200	-	367[c]	-	-	1,150
Offshore Barrow Strait[d]	-	2,700[d]	-	2,700[d]	-	0	0
Total	(270)[e]	3,366	(973)	7,916	(3,005)	(102)	1,569

[a]Area numbers correspond to locations on Fig. 3.
[b]'-' means not surveyed.
[c]Surveyed on 26 July.
[d]Estimated numbers based on 10% survey coverage (see Fig. 6).
[e]Parentheses denote incomplete survey.

coincided with the onset of the main migration through eastern Lancaster Sound. No surveys were conducted elsewhere in the central Canadian High Arctic during the spring of 1976.

Summering

Distribution

After the westward migration of belugas though eastern Lancaster Sound, the species was virtually absent from the eastern Canadian High Arctic. In 1976, we observed only 3 individuals during five summer surveys (31 July-7 September) of eastern Lancaster Sound; our route was as in Fig. 4, but transects along ice edges followed receding ice edges into bays. In 1978, only 14 were recorded during three surveys of NW Baffin Bay and eastern Lancaster Sound (Fig. 2) conducted 3 August-2 September.

Belugas were also extremely rare in Jones Sound, Admiralty Inlet, Navy Board Inlet, Eclipse Sound and Pond Inlet in August and early September. We found no belugas in Jones Sound during surveys on 21 August 1979. We found four in Admiralty Inlet on 24 August 1978 and none on 3 September 1979. During repeated surveys of Navy Board Inlet-Eclipse Sound-Pond Inlet in 1978 and 1979 we saw 3 single whales (2 and 8 August 1978 and 17 September 1979).

The principal summer range is west of Admiralty Inlet, and consists mainly of the coasts and offshore waters of western Lancaster Sound, Prince Regent Inlet, Peel Sound and eastern Barrow Strait.

Arrival at estuaries

The timing of arrival at estuaries depended on timing of arrival in the Canadian Arctic Archipelago and timing of break-up of landfast ice in and adjacent to estuaries. In 1975, the principal estuaries became ice free in early July (*e.g.* Cunningham Inlet – 7 July, Creswell Bay – 2 July). However, the main migration into the Canadian Arctic Archipelago did not occur until 15-28 July, and occupation of most estuaries did not occur until late July (Table 4).

In 1976, the peak westward migration through Lancaster Sound occurred from late June to mid-July. However, the main summering estu-

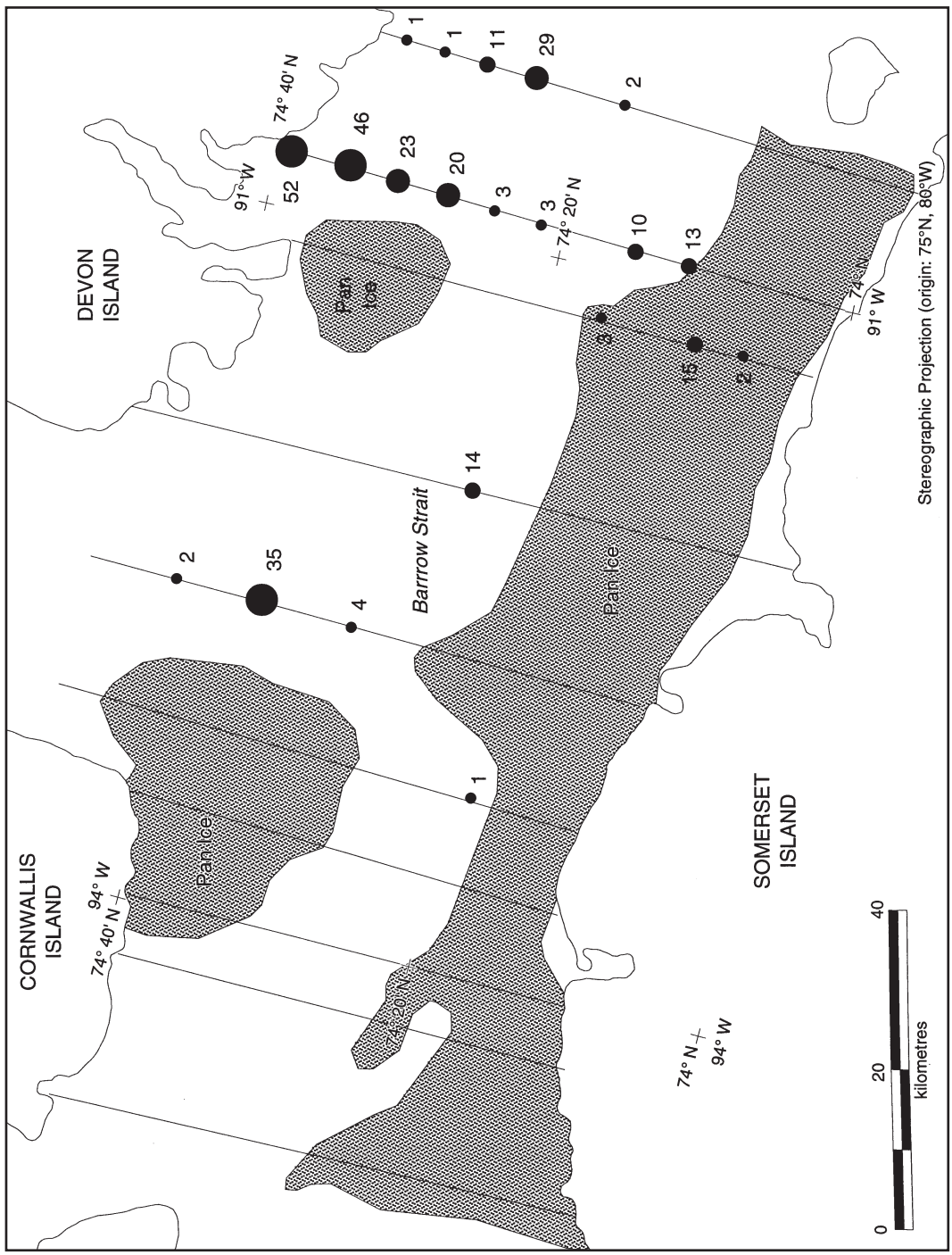


***Fig. 7**. Distribution of belugas in Barrow Strait, 17-18 July 1975. Symbols show numbers seen in 2-min survey segments (transect width 1.6 km). The same 10 transects were also surveyed on 27-28 July, 8 August and 22-24 August 1975.*

aries and bays remained ice covered until late July. On 14 July, many (900+) belugas were observed south of the landfast ice in the southeastern part of Creswell Bay (A. Clarke, cited in Finley and Johnston 1977). On 28 July, Clarke saw "thousands" from the edge of the landfast ice in Creswell Bay south to Bellot Strait. The ice had disintegrated sufficiently on 29 July to allow many whales to enter the northern side of Creswell Bay.

In 1978, the migration through eastern Lancaster Sound was delayed by ice until sometime between 12 and 17 July. Ice remained in the summering areas until late July. Belugas arrived in Creswell Bay on 26 July (B. Kemper,

Table 5. Numbers and age composition of belugas in Creswell Bay, Somerset Island, July - August 1975.

Month Day	Number at North shore	Number at South shore	Number classified by age (N shore)	Percent composition[a] Adult	Immature	Neonate
July						
17	-	-	-	-	-	-
20	100	-	-	-	-	-
21	241	-	-	-	-	-
24	3,376	189	385	77	19	4
25	1,156	-	542	66	30	4
26	1,304	-	672	61	36	3
27	2,131	963	1,770	60	36	4
28	1,213	-	-	-	-	-
29	1,100[b]	-	-	-	-	-
29	1,545[b]	-	-	-	-	-
30	2,484	745	1,754	54	42	4
31	-	-	374	64	30	6
August		-				
3	1,928	-	987	54	41	5
4	344	-	-	-	-	-
5	1,162	-	696	65	25	10
7	2,096	-	-	-	-	-
11	2,147	-	-	-	-	-
14	3,897	-	1,336	62	26	12
16	-	-	-	-	-	-
21	248	-	122	48	35	17[c]
25	-	0	-	-	-	-

[a]Surveys were conducted from a slow moving helicopter at an elevation of 90-150 m. An attempt was made to classify all animals within 400 m of the aircraft. Neonates were identified by pale coloration, relative size, and association with females. Immatures ranged from small dark-colored calves to large light brown or gray animals.
[b]Counts at 04:45 and 11:55 (CDT); both are negatively biased due to turbid water.
[c]This figure not considered typical because of small sample size.

DIAND, pers. comm.) but we have no data on the numbers involved.

In 1979, the ice edge remained intact across Lancaster Sound until 2 August. Arrival in estuaries was not documented but must have been later than most years. During 17-20 August, 155 belugas were counted in Creswell Bay, 202 in or adjacent to Cunningham Inlet and 312 along the ice edge across Peel Sound. During the same period 2,200 (no corrections) belugas were estimated to have been present in offshore Barrow Strait and northern Prince Regent Inlet based on offshore transect surveys (Fig. 2).

Use of estuaries

Creswell Bay–1975

Belugas traditionally occupy Creswell Bay in large numbers. In 1975, they occupied the bay almost continuously from 20 July-16 August. We conducted regular counts from a helicopter of the animals along the north shore and, less often, along the south shore of the bay. The numbers present were quite variable (Table 5) due to tide-related changes in distribution, movements between the north and south shores, and movements out of Creswell Bay.

The north and south coasts of the bay contain extensive foreshore flats and shoals. The shoals reach their maximum offshore extent of 6.5 km near the Creswell River and become narrower to the east and west. At low tide, many shoals are exposed and intervening areas are covered by less than 4 m of water. The water deepens abruptly beyond the foreshore flats and deep water extends throughout the central portion of the bay. Tides were unmeasured, but were probably similar to those at Fort Ross (peak amplitude = 2.9m), 75 km south of Creswell Bay.

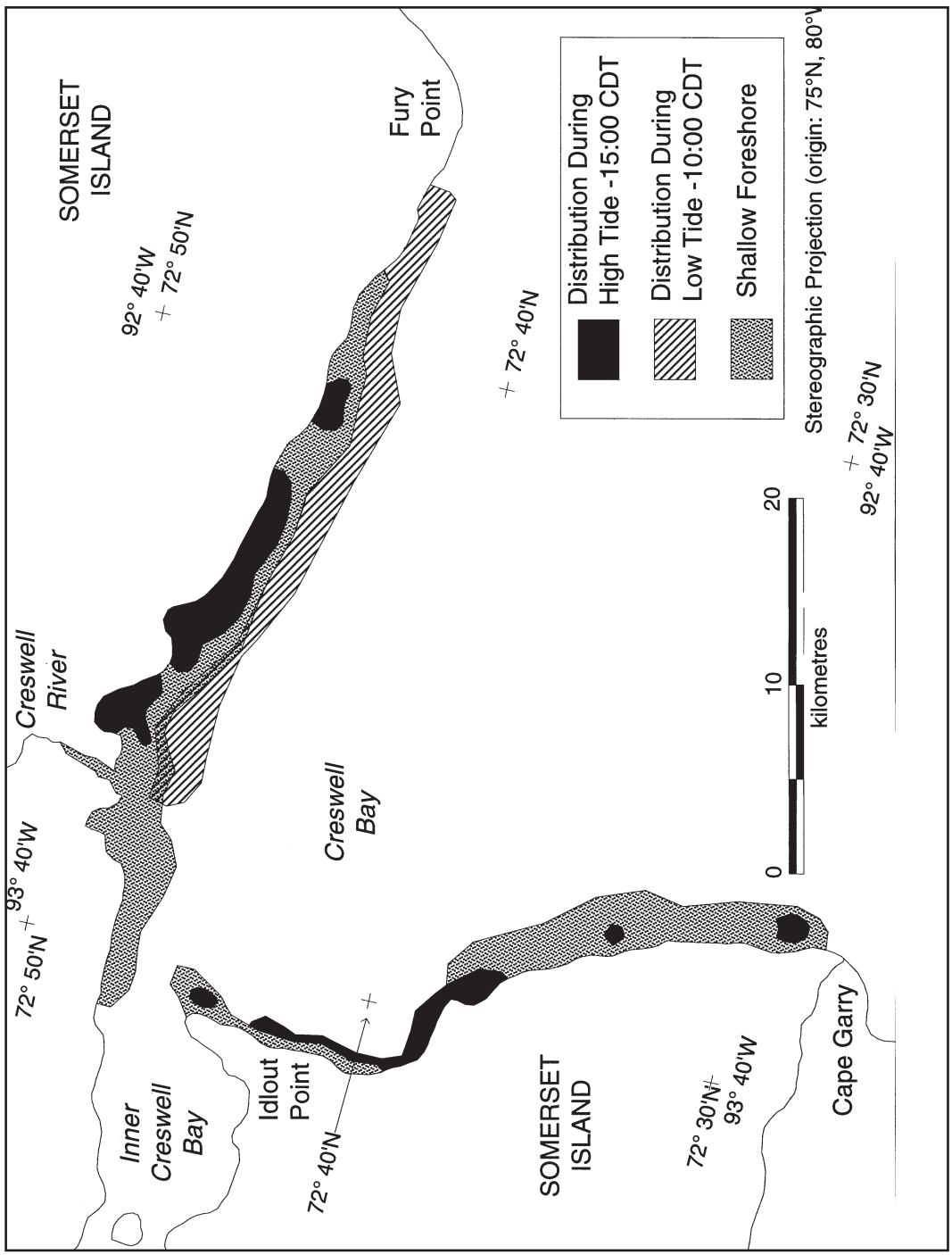


Fig. 8. *Distribution of belugas at Creswell Bay, Somerset Island, during high and low tides on 27 July 1975. The south shore between Idlout Point and Cape Garry was not surveyed during low tide.*

At high tide, belugas concentrated over the inner foreshore along the north coast of Creswell Bay. On 3 August the surface water temperature was 1.8° C at the edge of the foreshore flats off the mouth of Creswell River and 3.0-5.3° C in areas about 3 km farther west. Twice daily, during low tide, the belugas dispersed along the outer edge of the foreshore area (Fig. 8). These tide-induced movements were regular, with one exception (see below), throughout the period that belugas occupied Creswell Bay. A notable exodus from Creswell Bay occurred at high tide in the late evening (22:00 CDT) of 3 August. Many whales moved east along the coast to Fury Point (Fig. 8). This exodus coincided with the arrival from Prince Regent Inlet of pack ice

Table 6. Distribution of belugas along the north and east coasts of Somerset Island, 1976 and 1977.

Area[a]	1976	1977[b]	
	11 August	30 July	11 August
1. Cunningham Inlet	0	400[c]	0
2. Killalugaluit Bay	207	0	0
3. Garnier Bay	0	0	5
4. Elwin Bay	145	75	238
5. Batty Bay	69	0	398
6. Creswell Bay (N shore)	2,377	2,077	2,507
7. Creswell Bay (S shore)	86	0	0
- Other coastal areas	536	109	20
Total	3,420	2,661	3,168

[a]Area numbers correspond to locations on Fig. 3.
[b]Based on counts from aerial photographs (6x7 cm format).
[c]1,500 were observed in Cunningham Inlet on 16 July 1977.

(30-40% coverage) off Fury Point; the next day only 344 belugas were found in the bay (Table 5). The pack ice could not be surveyed but we saw belugas in scattered small groups among the ice pans. The pan ice began to disperse on 5 August and large groups returned westward at 22:00 on that date.

Reasons for the exodus are unknown. Our observations confirmed that at least some of the whales from Creswell Bay were in the pack ice, but we did not obtain direct evidence of feeding under the ice. The presence of substantial amounts of ice near an estuarine concentration of belugas could pose a threat since the ice might blow into the area during high tide and trap the whales when the tide receded. However, belugas live among pack ice during most of the year and are unlikely to react to potential entrapment by ice until it actually enters the estuaries.

The numbers of belugas in Creswell Bay increased in August and reached a peak of at least 3,897 animals on 14 August (Table 5). All these animals had vacated the north coast of Creswell Bay by 16 August.

Other areas–1975

Day-to-day variation in numbers of belugas present in estuarine areas was noted not only at Creswell Bay, but at all bays and estuaries along Somerset Island in 1975 (Table 4). Coastal areas along northern Somerset Island were occupied less consistently and for shorter periods than were areas along the east coast, probably due to the pack ice that frequently beset the north coast. There was apparently much movement among areas; for example, a grossly deformed adult photographed in Elwin Bay on 3 August was re-photographed in Creswell Bay on 11 August.

Annual variation in estuarine use

There was both within-year variation in use of estuarine summering areas by belugas and between-year differences. Our data for 1975 are presented in Table 4 and our less complete data for 1976 and 1977 appear in Table 6. Cunningham Inlet is a good illustration of variation in annual use. During aerial surveys on 2 August 1974 and 16 July 1977, we estimated 1,100+ and 1,500 to be present, respectively. However, data from 1975, 1976 and other dates than 16 July in 1977 indicate much less intensive use of Cunningham Inlet (Table 4, 6). The data for Elwin Bay show similar variability: 944 were recorded there in 1975 (Table 4), but numbers were lower in 1976 and 1977 (Table 6).

Creswell Bay was the most consistently used bay in the central Canadian High Arctic with peak numbers of at least 2,400-3,900 in each year 1975-77 data (Tables 4 - 6).

The status of belugas along the west coast of Brodeur Peninsula, Baffin Island, is poorly understood. Heyland (cited by Sergeant and Hay

1979) found 2,250 along this coast in 1973 and 857 in 1974; the survey dates and coverage are unpublished. We surveyed the entire east coast of Brodeur Peninsula (south to 72º 03' N) on 30 July 1977 and found only 315 belugas.

Late summer distribution

The estuaries along Somerset Island that were used by summering belugas were abandoned by mid-August; some were vacated earlier. A large fraction of the population moved into Peel Sound but our surveys in late summer accounted for no more than half of the estimated population. These surveys are reviewed below.

Prince Regent Inlet

In most years, few belugas remained along the northern and east coasts of Somerset Island in late summer. In 1976, large numbers (2,000+) vacated the traditional summering area in outer Creswell Bay in mid-August and moved into inner Creswell Bay (Fig. 8) where they remained until 4 September, apparently feeding on polar cod (see **Feeding**). Belugas were seen only infrequently and in small numbers (<100) in inner Creswell Bay in 1974, 1975 and 1977. Surveys along the rest of the north and east coasts of Somerset Island in the last half of August in 1974 and 1975 also recorded few (<450) belugas.

A survey of the east coast of Boothia Peninsula recorded no belugas on 18 August 1974; however, this survey was flown at 45 m ASL over the land-water interface and any whales >200-300 m from shore are unlikely to have been seen. Intensive aerial surveys (8 complete surveys, 11 August-24 September) and shore-based observations (195 h, 29 August-23 September) of Bellot Strait in 1977 recorded only 22 belugas; all were seen on 28 August.

Offshore Prince Regent Inlet was surveyed on 17-18 August 1979; about 600 belugas were estimated to have been present in offshore waters and 170 were present in coastal areas, primarily Creswell Bay (155 whales). The west coast of Brodeur Peninsula was also surveyed on 18 August 1979 but no belugas were seen. During 30 August - 4 September 1979, no belugas were seen during 728 km of offshore surveys. Thus, belugas appear to have abandoned Prince Regent Inlet in late August for areas in northern Peel Sound and Barrow Strait.

The north and east coasts of Somerset Island and perhaps the east coast of Boothia Peninsula were not heavily used by belugas after mid-August in most years.

Barrow Strait and northward

Systematic surveys (10% coverage) of offshore eastern Barrow Strait on 8 and 22-24 August 1975 did not record belugas (see Fig. 7 for survey routes). Miscellaneous surveys across Barrow Strait in late summer of 1974-1977 recorded only a few belugas. However, in 1979, offshore Barrow Strait had extensive pack ice in late August and early September and Peel Sound was covered by fast ice until at least 5 September. We conducted two surveys of coastal and offshore areas in Barrow Strait in 1979; based on extrapolations from our surveys, over 1,600 and over 700 belugas (no corrections) were estimated to be present during 17-20 August and 30 August-4 September, respectively.

The south coast of Devon Island east to Maxwell Bay was used inconsistently in late summer. On 21 August 1975, at least 1,150 belugas were present in and near Radstock Bay. However, none were seen along the entire south coast of Devon Island on 11-12 or 25-26 August 1976. We recorded only seven along the south coast east to Maxwell Bay on 11 August 1977.

Some belugas moved north and west from Barrow Strait in late summer. On 1 August 1975, small groups (totalling 44 whales) were dispersed along the southeast and east coasts of Cornwallis Island. Farther north, 348 were noted on 15 August 1977 in coastal waters along the south shore (about 76º 17' N) of Grinnell Peninsula, NW Devon Island. North of Grinnell Peninsula, 7 were seen about 25 km southeast of Cornwall Island on 14 August 1976. A group of 50 whales was noted off SE Bathurst Island on 18 August 1974 and a group of 169 swam west past Assistance Bay (S Cornwallis Island) on 24 August 1974. During intensive surveys of McDougall Sound and adjacent waters in 1977, our only sighting was of a herd of 30 along the west coast (75º 15' N) of Cornwallis Island on

19 August. It appears that no more than a few hundred belugas penetrated into waters north and northwest of eastern Barrow Strait in late summer in most years.

Peel Sound area

The area used most consistently by belugas in late summer appeared to be Peel Sound and northern Franklin Strait. In 1974, we saw about 150 belugas along the landfast ice edge across northern Peel Sound on 3 August, and 500 in Coningham Bay along SE Prince of Wales Island on 3 September. In 1975, a herd of 169 swam strongly west along the north coast of Somerset Island toward Peel Sound on 19 August. A reconnaissance survey of the northern half of Peel Sound on 23 August 1975 found 200 belugas in an area of extensive pan ice off

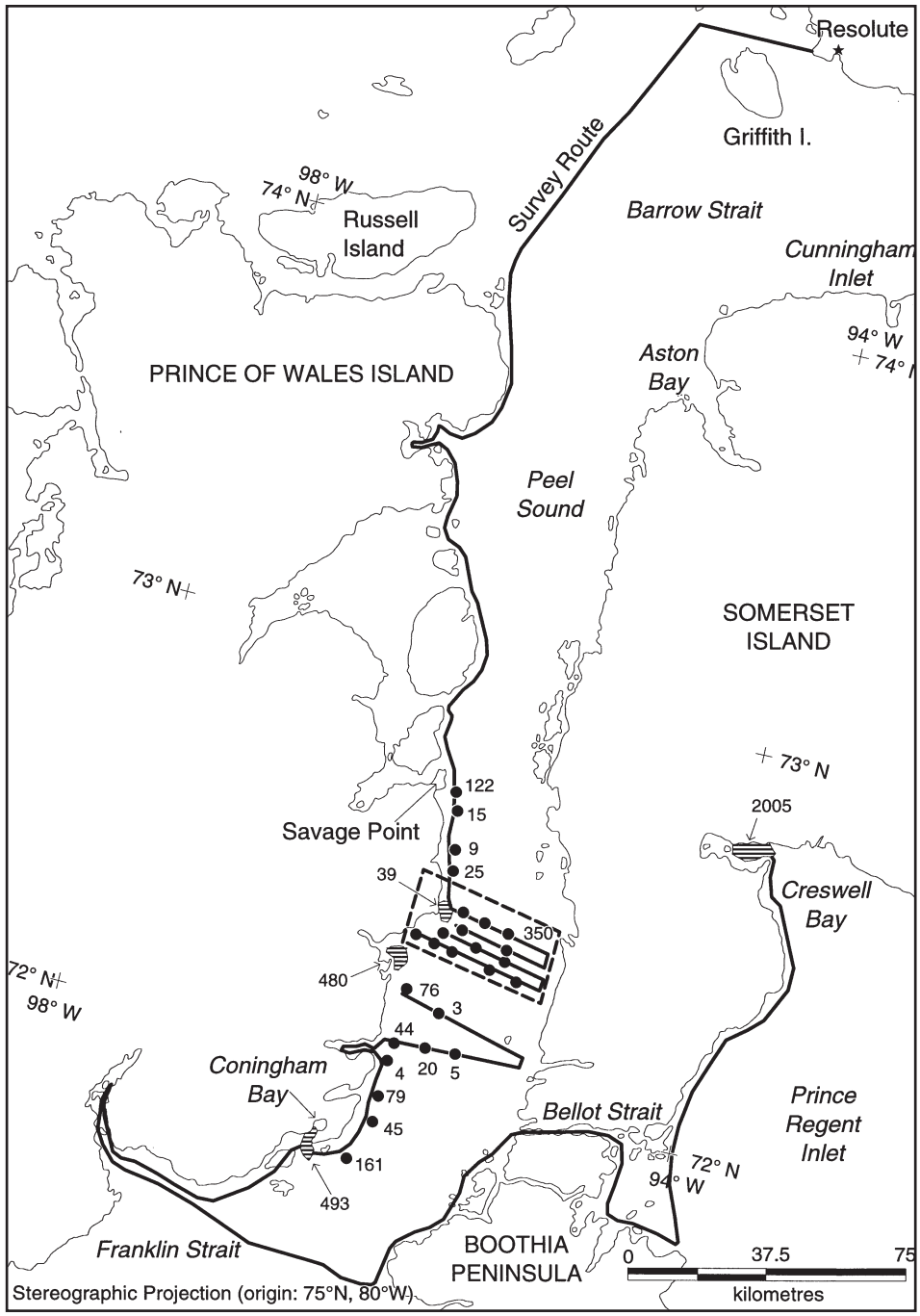


Fig. 9.
Sightings of belugas in Peel Sound and at Creswell Bay, 4 September 1976.

NE Prince of Wales Island. No surveys of southern Peel Sound and northern Franklin Strait were conducted in 1975.

Intensive surveys of Peel Sound and northern Franklin Strait were undertaken in 1976; 8 surveys were conducted from 11 August-24 September. Peel Sound was still covered with landfast ice on 11 August and no whales were seen.

The landfast ice in Peel Sound cleared in mid-August of 1976. On 28 August, 640 belugas were found in Coningham Bay and an additional 91 were dispersed among pan ice in northern Franklin Strait. The numbers of belugas in Peel Sound peaked on 4 September 1976 when an estimated 2,340 were present (Fig. 9). Ten herds (totalling 1,542 animals) were counted in coastal waters from Coningham Bay north to Savage Point. Many of these groups were moving strongly to the north, including a herd of 493 that was leaving Coningham Bay. An estimated 800 belugas were dispersed in small groups throughout a 1,300 km^2 area of pan ice in SW Peel Sound.

We found no belugas in Peel Sound on 10 September 1976 but a large herd of 1,668 was photographed about 10 km west of Griffith Island in northwestern Barrow Strait. When last seen, the herd was swimming strongly to the NE; some arrived at Allen Bay three hours later (A. Salluviniq, Resolute Bay, pers. comm.). This indicates an average speed of 12-14 km/h.

We surveyed Peel Sound again on 12 September and found only one small herd of belugas – 23 swimming north off Savage Point. A large (965) very dispersed herd was moving north about 25 km SW of Griffith Island. Few belugas remained in Peel Sound during our final three surveys; we saw only five on 15 September, four on 20 September, and none on 24 September. Ice had begun to form in Peel Sound and Barrow Strait on 20 September and covered 50-100% on 24 September.

In 1977, landfast ice in Peel Sound began to break up in mid-July, an unusually early date. An opportunistic survey along the west coast of Somerset Island on 20 July recorded 1,000-1,200 belugas in the entrance to Aston Bay and 50 in leads about 15 km farther south. The east coast of Prince of Wales Island was surveyed on 25 August; 4,072 belugas were recorded between Savage Point and Coningham Bay including 1,967 in the latter bay.

Our data from 1974-77 indicate that Peel Sound was consistently used by belugas in late summer. Landfast ice normally cleared from the sound in the first half of August and the whales penetrated into cracks along the east coast of Prince of Wales Island as breakup began. The return northbound migration was also along this coast. Coningham Bay, a shallow estuarine bay along SE Prince of Wales Island, was used by several hundred, or more, belugas in most years. This bay was occupied about a month later than were the estuaries used by summering belugas along northern and eastern Somerset Island.

Autumn migration

Read and Stephansson (1976) implied that belugas from Peel Sound circumnavigated Prince of Wales Island and migrated north along the western side of the island. Old Inuit hunters from Spence Bay have seen belugas on the western side of Prince of Wales Island in exceptionally open years. However, prevailing winds usually drive much multi-year pack ice onto this coast (Canadian Hydrographic Service 1970) and whales would probably rarely choose to migrate through this ice. We found that, at least in 1976 and 1977, belugas returned north along the western side of Peel Sound in September. They then crossed Barrow Strait to the south coast of Cornwallis Island, where Inuit from Resolute hunt belugas in September (Bissett 1968, this study). We frequently observed belugas near Resolute from 10 to 20 September in 1976, and 300 were in Allen Bay, just west of Resolute, on 7 September 1977.

1976

The eastward migration of belugas through Lancaster Sound was rapid and accomplished in large compact herds in 1976. Migrating belugas were first noted on 12-13 September when a herd of 300 swam out of Dundas Harbour, Devon Island. The major migration occurred during 19-22 September when 8,393 were

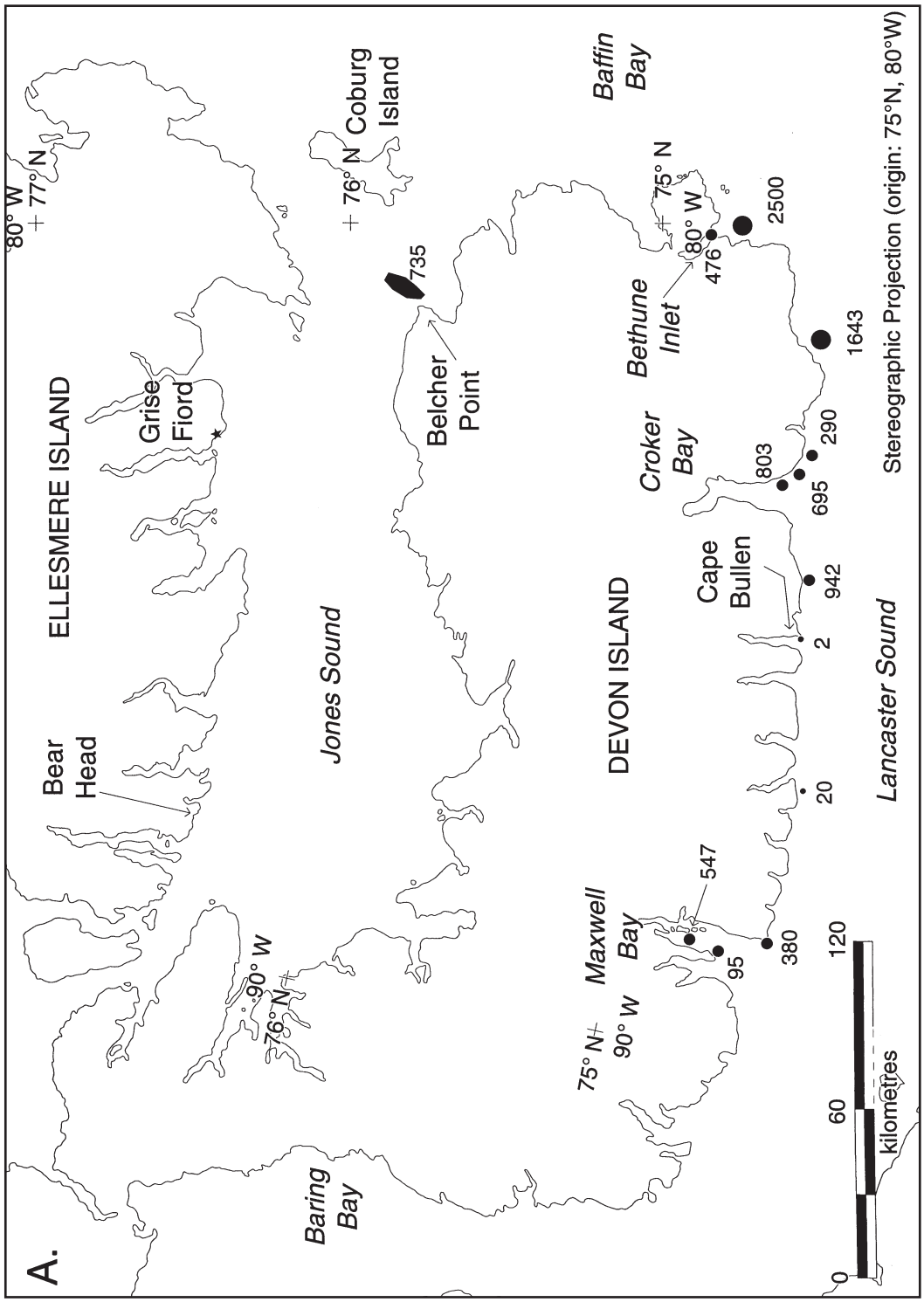
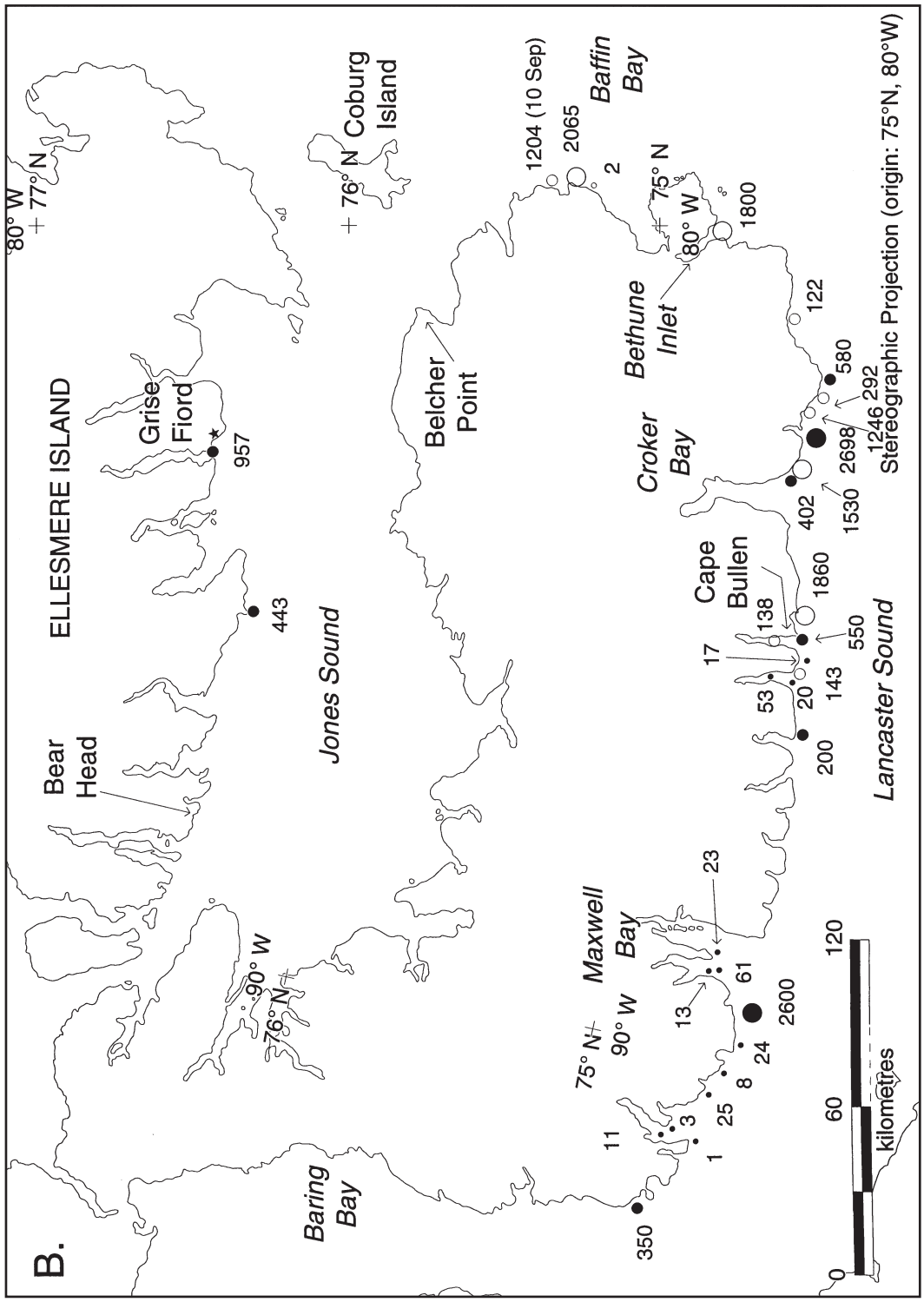


Fig. 10. *Distribution of belugas around Devon Island on (A) 19-22 September 1976 and (B) 13-15 September 1978. Open and closed symbols along Devon Island indicate sightings on 13 (closed) and 14 (open) September, respectively.*

counted along the south coast of Devon Island (Fig. 10A). None were recorded along the south coast of Devon Island west of Maxwell Bay, or along the south coast of Cornwallis Island, on 21 September. During our final survey of eastern Lancaster Sound on 26-28 September only 320 belugas were recorded.

The eastward migration was very rapid (a few days) compared to the spring westward migra-

Fig. 10B



tion (several weeks). The fall migration was almost exclusively along the northern margin of Lancaster Sound and within 0.4 km of shore; only two individuals were seen along the southern margin and none were observed in nearshore or offshore waters. Belugas stayed very close to the coast during fall migration. Of 1,017 seen when observers were present in rear seats on each side of the aircraft, 1,008 (99.1%) were within 200 m of shore and only 9 (0.9%)

Table 7. Summary of beluga sightings in the Canadian High Arctic during fall migration, 1978. See Fig. 10B for sighting locations.

Sighting	Date	Area	Number of belugas	Contribution to population estimate
1	29 Aug	SE Ellesmere Island	12	12
2	2 Sep	Croker Bay	400	400
3	9 Sep	Grise Fiord	450	same as 2
4	9 Sep	Bethune Inlet	435	435
5	10 Sep	E Devon Island	1,204	same as 11
6	12 Sep	Grise Fiord	450	same as 4
7	13 Sep	S Devon Island	7,170	7,170
8	14 Sep	S Devon Island	5,321	same as 7
9	14 Sep	SW Devon Island	469	469
10	15 Sep	E Devon Island	3,882	same as 7
11	15 Sep	S Ellesmere Island	1,400	1,400
12	29 Sep	Dundas Harbour	356	356
13	18 Sep - 10 Oct	E Devon Is./Jones Sound	372	same as 7
14	21 Sep - 9 Oct	Bethune Inlet	3,421	same as 7
Total			25,342	10,242

were 200 to 400 m from shore (observations by the front-seat observer are ignored here because of seat-related biases in detectability of whales).

In 1976, we did not follow the whales when they left Lancaster Sound. However, the facts that belugas were exclusively along the northern margin of the sound, and an opportunistic sighting of a herd of 735 moving north from NE Devon Island (Fig. 10A) on 27 September, suggest that they probably moved north along eastern Devon Island.

1978

Timing of migration

The 1978 eastward migration through Lancaster Sound was first detected on 2 September when 400 belugas were sighted in Croker Bay, southern Devon Island, by personnel from LGL Limited aboard the research vessel MV *Gulf Star*.

During the peak eastward migration we surveyed the entire south coast of Devon Island on both 13 and 14 September. On 15 September, we surveyed the west coast of Devon Island north to Baring Bay (100% ice cover from there north), ice-free parts of the north coast of Devon Island, the south coast of Ellesmere Island from Bear Head to Grise Fiord, and the east coast of Devon Island. We conservatively estimate that of the 18,227 belugas sighted during the three days of surveys, 9,039 represented different animals (Fig. 10B, Table 7). Most of those along the south coasts of Devon and Ellesmere islands were moving east; and those along the east coast of Devon Island were moving north, with the exception of those in Bethune Inlet, which were dispersed and appeared to be feeding along the extensive glacier fronts in this area.

The concentration of belugas in Bethune Inlet persisted (1,597 on 21 September, 1,440 on 24 September, 258 on 3 October, 99 on 7 and 9 October), but numbers elsewhere in the study area declined dramatically (15 seen along the rest of the regular survey route on 18-22 September, 42 on 23-27 September, 288 on 28 September-4 October, and 26 on 7-10 October).

Migration route from Lancaster Sound

As in 1976, virtually all belugas migrating along the south coast of Devon Island in September 1978 were within 400 m of shore and most were within 200 m; this was true even for animals seen in bays or inlets (Fig. 11). The few exceptions to this pattern were animals in Bethune Inlet and at the mouth of Grise Fiord where their behaviour and dispersed distributions suggested that they were feeding.

Very few belugas were seen far offshore or anywhere south of Lancaster Sound during the fall

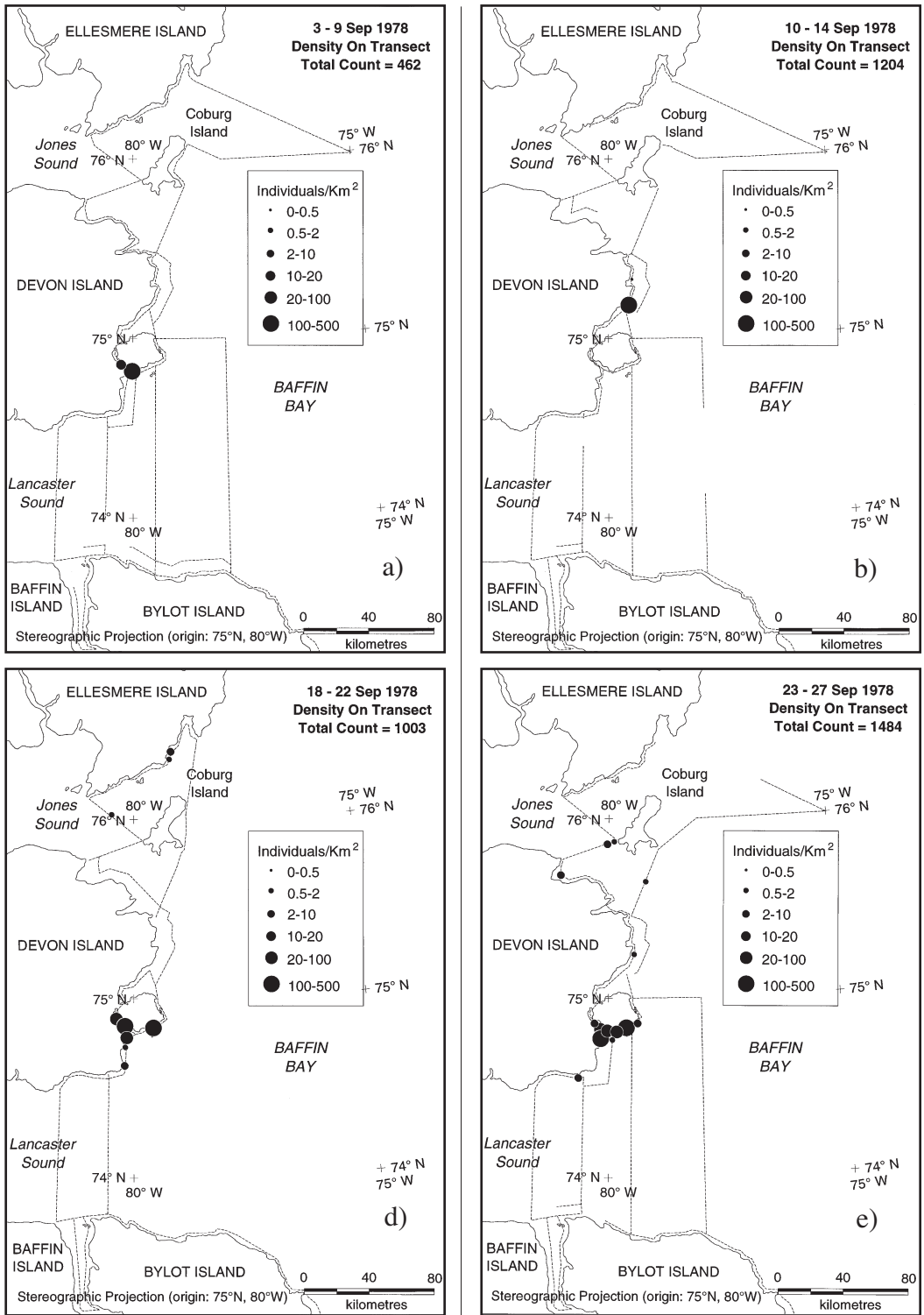
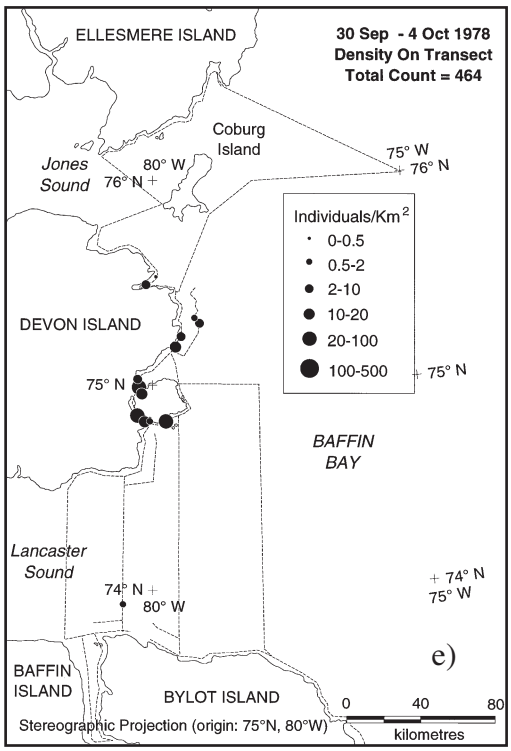


Fig. 11a-e. *(Continued on next page). Distribution of belugas sighted in eastern Lancaster Sound, along eastern Devon Island and along eastern Ellesmere Island, September and early October 1978. Plotted as in Fig. 4.*

survey period (3 September-10 October). Only three were recorded more than 3 km from shore; they were swimming SE about 15 km north of Bylot Island on 3 October. Only two belugas were recorded south of this location during this period; they were swimming west along the south coast of Bylot Island on 7 October. None were observed passing Cape Adair (NE Baffin Island) during a bowhead whale (*Balaena mysticetus*) migration study



consisting of 260 h of observations (13 September-7 October) from the top of a 220 m ASL cliff.

It appeared that in 1978 virtually all belugas from the central Canadian High Arctic migrated east along the south coast of Devon Island and then north along the east coast of Devon Island toward the mouth of Jones Sound (Fig. 10). Except for the feeding groups in Bethune Inlet, all belugas seen along eastern Devon Island were migrating north.

Migration pattern in Jones Sound

We saw a few small groups of belugas moving north across the mouth of Jones Sound just west of Coburg Island (21 September-9 October, Fig. 11). However, few were seen there despite intensive survey coverage. We believe that a substantial number moved west along the north coast of Devon Island into Jones Sound and crossed to the south coast of Ellesmere Island. These animals then moved east along the south coast of Ellesmere Island.

Our aerial surveys in 1978, plus satellite imagery from 1974-77, show that the landfast ice in Jones Sound began to break up at the end of July and in early August. We surveyed the Jones Sound ice edge on three occasions from 21 July-15 August 1978 and no belugas were observed. We conclude that insignificant numbers of belugas entered Jones Sound from the east in either July or August.

Ice conditions prevented entry of belugas into Jones Sound from the west in July and early August unless some wintered in the few polynias that persisted through the winter in the central Arctic (Fig. 3). We surveyed these polynias in April 1977 and March 1978 (Fig. 1) and found no belugas. We also found no whales in the large polynia at the western end of Jones Sound (Hell Gate and Cardigan Strait) during surveys in June 1974 or in June and July 1977. Our only record of belugas west or northwest of western Jones Sound is of 7 about 25 km SE of Cornwall Island on 14 August 1976. Thus, we conclude that few, if any, belugas entered Jones Sound from the west; we suspect that most of those that Riewe (1977) documented in Jones Sound originated in Lancaster Sound and entered Jones Sound from the southeast in September.

Rate of movement

The fall migration through Lancaster Sound was rapid in both 1976 and 1978. Our consecutive surveys along the south coast of Devon Island on 13 and 14 September 1978 allowed an estimate of the speed of migration. A herd of 2,600 belugas was recorded at Cape Hurd, just west of Maxwell Bay, on 13 September (Fig. 10B). On 14 September, slightly less than 24 h later, the nearest large herds were considerably farther east–1,860 at Cape Bullen and 1,530 between Croker Bay and Dundas Harbour (Fig. 10B). If the whales closely followed the coast and entered the various inlets between these areas, they travelled 320 km (13.5 km/h) to Cape Bullen and/or 430 km (18.5 km/h) to the area just east of Croker Bay. If they travelled the most direct route, they moved about 140 km (5.9 km/h) and/or 200 km (8.6 km/h). Since almost all whales seen in September were within 400 m of the coast, the actual speed was probably closer to the 13.5-18.5 km/h values.

1979

Aerial survey effort during the autumn migration period in 1979 was concentrated along NE

Baffin Island to document narwhal and bowhead migrations (Fig.2). Thus the survey route did not include eastern Devon Island and the mouth of Jones Sound as in 1978.

Six surveys of eastern Lancaster Sound included part of the south coast of Devon Island during September and October (Fig. 12). During all surveys except the last survey on 16 October, a few hundred belugas were seen feeding along the glacier fronts in Maxwell Bay and small numbers were detected elsewhere (Fig. 12). A survey of the south coast of Devon Island on 19 and 20 September detected 142 and 280, respectively, belugas moving eastward between Maxwell and Croker bays. No large groups of strongly migrating whales were encountered during any of the surveys in 1979 but three groups of 200-300 belugas were seen along SE Devon Island during 24-26 September. The last sightings of belugas were during the 4-5 October survey when 313 were sighted; 257 of these were in Croker Bay and the remaining whales were seen along the coast east of there.

The coasts of eastern Devon Island and all of Jones Sound were surveyed on 14 September. A group of 60 belugas was seen swimming westward near Belcher Point on NE Devon Island and groups of 14 and 90 were seen swimming eastward along southern Ellesmere Island. These observations support our hypothesis that belugas seen passing Grise Fiord in autumn entered Jones Sound along NE Devon Island and circumnavigated all or part of Jones Sound.

In summary, the main beluga migration out of Lancaster Sound was not detected during 1979, but it was likely during late September.

Calving

We did not observe calving during our extensive surveys. However, we recorded the proportions of calves among groups sighted from early May to mid-October. In 1978, belugas could not penetrate through Lancaster Sound until mid-July and the first neonates were seen along the ice edge across eastern Lancaster Sound: one on 26 June, four on 3 July, and two on 11 July. In 1979, belugas could not penetrate through Lancaster Sound until 2 August and the first neonates (3 individuals) were seen along the Lancaster Sound ice edge on 30 June. Totals of 943 and 919 belugas were classified to age during May and 1-29 June 1979, respectively, and no neonates were seen. During surveys on 30 June-2 July, 8-15 July, and 22 July 1979, 3 of 409 (0.7%), 10 of 240 (4.3%) and 13 of 95 belugas (13.7%), respectively, classified to age class were neonates.

In 1975, the first neonate was identified on 13 July in a herd of belugas swimming along the south coast of Devon Island. Two neonates were observed in offshore Barrow Strait on 18 July and considerable numbers were present in herds along the north coast of Somerset Island in late July. In 1977, a herd of 1,000+ was noted at the entrance to Aston Bay at the northern end of Peel Sound on 20 July; of 314 classified to age, 18 (5.7%) were neonates.

On 24 July 1975, 4% of 385 belugas in Creswell Bay that were classified to age were neonates (Table 5). The proportion of neonates varied from 3% to 6% from 24 July - 3 August; on the latter date most belugas moved out of Creswell Bay into offshore pan ice. When they returned on 5 August, the proportion of neonates was 10% (Table 5). By 14 August total numbers present had increased substantially, and about 12% were neonates. Despite careful observation, calving was not observed in Creswell Bay in 1975.

Age and sex composition

Data on the age composition of belugas were obtained during surveys along the ice edges during spring migration and during surveys of the estuaries during summer. A total of 2,596 belugas were classified during spring surveys in 1979: 76.3% were white adults, 1.0% were calves, 8.3% were yearlings and 14.4% were grey or brown subadults. The proportion of adults was relatively constant throughout the 9 complete surveys during the spring period (cv=2.8) but calves were not seen during the first 6 surveys.

Of the many belugas occupying summering areas in Creswell Bay in 1975, 64% of the post-neonates were white adults and 36% were grey or brown immatures. This ratio was fairly uniform throughout the mid-July to mid-August

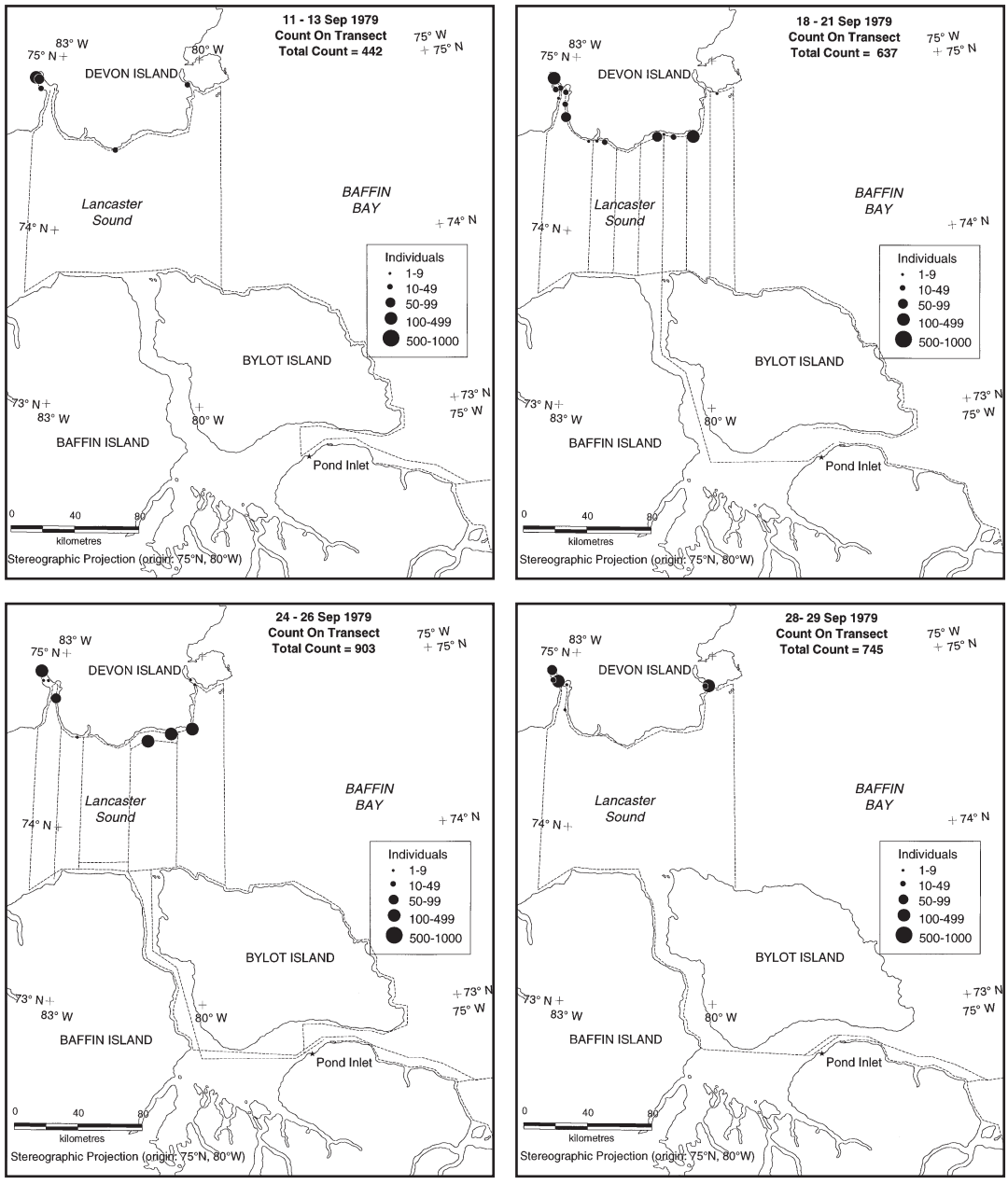


Fig. 12. *Distribution of belugas sighted in eastern Lancaster Sound and along eastern Devon Island, September 1979. Transect width was 0.8 km and density 0.2/km2 represents a sighting of a single whale; otherwise as plotted as in Fig. 4.*

period (Table 5). We suspect that some adult males were absent from the estuaries and the lower proportion of adult males in the estuaries accounted for the lower (64 vs 76) percentage of adults seen in Creswell Bay in summer vs in Baffin Bay in spring.

The proportion of neonates can vary among summering areas. On 3 August, a large herd (711) at Elwin Bay contained only 2% neonates while a herd at Creswell Bay contained 5% neonates.

Feeding

We examined the stomach contents of 22 hunter-killed belugas (Table 8). Polar cod was the principal food item, although smaller numbers of Arctic cod (*Arctogadus sp*.-presumably *A. glacialis*) were taken by whales near Grise Fiord in September 1978.

During their spring migration toward summering areas belugas concentrated along ice edges in Jones Sound, SE Devon Island and Lancaster Sound and fewer were seen along adjacent ice

Table 8. Diet of belugas in the Canadian High Arctic.

Food Items	Creswell Bay 10 August 1975 (*n*=13)			Allen Bay 9 August 1975, 30 July 1977 (*n*=3)			Grise Fiord 12 September 1978 (*n*=6)		
	F[a]	Mean[b]	Max.[c]	F	Mean	Max.	F	Mean	Max.
Fish (otoliths)[d]									
Boreogadus saida	77	190.5	958	100	2,275.0	3,500	100	1,226.2	1,771
Arctogadus sp.	0	0.0	0	0	0.0	0	100	63.8	115
Myoxocephalus sp.	8	0.1	1	0	0.0	0	33	1.0	5
Squid (upper and lower mandibles)	77	9.6	40	100	+[e]	8	83	1.7	3
Shrimps and Isopods	62	+	+	100	+	+	0	0.0	0
Gastropods	15	+	7	33	+	+	17	1.2	7
Bivalves	23	+	1	0	0.0	0	0	0.0	0
Polychaetes	15	2.5	30	0	0.0	0	50	+	+
Kelp	100	+	+	100	+	+	50	+	+
Maximum wt (kg) of stomach contents		<1			~10			10.1	

[a]Percent of stomachs containing item.
[b]Mean no. of items per stomach including empty stomachs.
[c]Maximum no. of items in a single stomach.
[d]Otoliths were used to identify fish; tabulated values are numbers of otoliths found (about twice the number of fish).
[e]Present in trace amount.

edges across Glacier Strait and along NE Devon Island. It is likely that some feeding occurred in these areas.

Belugas that arrived in the central Arctic before their estuarine summering areas became ice-free did not appear to concentrate or feed along ice edges. Few were seen along the ice edge across Barrow Strait in June 1975 (see **Spring Migration**). Intensive aerial and ice-based studies along the coasts and ice edges of northern Barrow Strait in June and early July 1976 showed that some belugas were present from 22 June onward, but they made no attempt to feed under the fast ice edge.

There appeared to be very little feeding during occupation of estuarine summering areas. The shallow foreshore area at Creswell Bay was a barren, ice-scoured environment with extremely few benthic animals or macrophytes (Sekerak *et al*. 1976). Significant benthic and macrophytic communities were first encountered in the deeper water at the edge of the foreshore area. Thus belugas could not have fed during high tide when they were in very shallow water; they did not appear to feed intensively at low tide when they were along the outer edge of the foreshore, although some dove among the kelp beds. The 13 stomachs from belugas killed by Inuit in Creswell Bay on 10 August 1975 indicated that little feeding had occurred recently (Table 8). The cod otoliths in these stomachs were very worn and had probably not been ingested recently. The possibility that the whales fed under pack ice when they left Creswell Bay on 4 August 1975 was discussed earlier (see **Summering**).

On several occasions during late summer we observed belugas feeding intensively in coastal areas and in offshore areas with pack ice. From mid-August to 4 September 1976, 1,500 to 2,000 belugas occupied inner Creswell Bay. They appeared to feed intensively and were accompanied by thousands of northern fulmars (*Fulmarus glacialis*) and black-legged kittiwakes (*Rissa tridactyla*) and by about 50 narwhals and 50 harp seals (*Phoca groenlandica*). The many predators forced shoals of polar cod into shallow waters, leaving thousands stranded when the tide receded (G. Eckalook, Resolute Bay, pers. comm.). In contrast, belugas were infrequently present in inner Creswell Bay in 1974, 1975 and 1977, and marine studies there in August 1975 did not find polar cod (A.D. Sekerak, LGL Limited, pers. comm.). Thus, in late summer belugas apparently concentrate in areas where food is abundant.

Belugas were observed diving, and presumably feeding, under offshore pack ice in southern Peel Sound and northern Franklin Strait in late August and early September 1976 (see *Late summer distribution*). They were accompanied by narwhals, harp seals and fulmars.

Feeding belugas were observed at Allen Bay, just west of Resolute, on 14 September 1976 (several hundred) and 6-7 September 1977 (300). Again the whales were accompanied by large numbers of fulmars and kittiwakes; the behaviour of the three species is aptly described as a "feeding frenzy". In 1976, the whales were diving beneath rotting landfast ice that remained in the bay. This activity forced many polar cod into shallow, ice-free water where they were taken by fulmars and kittiwakes. Thousands of cod were stranded in tide pools during low tide. On 6-7 September 1977, the 300 belugas were accompanied by about 65 harp seals, 10-20 ringed seals (*Phoca hispida*), two or three bearded seals (*Erignathus barbatus*) and several hundred fulmars and kittiwakes. The birds were observed catching polar cod, and we caught many cod in gill nets. No whale stomachs were available from either of the occasions described above, but all three stomachs from whales taken at Allen Bay on other occasions were full of polar cod (Table 8).

Feeding frenzies were also observed in Maxwell Bay on 21 September 1976; 500 belugas, 80 narwhals, 135 harp seals and many seabirds were present. A major feeding area along the glacier fronts in Bethune Inlet, SE Devon Island was heavily used in September of both 1976 and 1978. On 15 September 1978, 1,800 belugas were distributed throughout the inlet and appeared to be feeding; at least 30,000 kittiwakes were also present among the whales. Glacier fronts in Croker Bay were consistently used by several hundred belugas during mid-September to early October in 1979.

We observed a group of about 950 feeding belugas at the mouth of Grise Fiord on 15 September 1978. We could not determine what they were feeding on, but we obtained 6 stomachs from belugas that were killed by hunters near the same location three days earlier. All of those whales fed primarily on polar cod (Table 8).

Population size

Our estimate of the size of the Canadian High Arctic beluga population for the late 1970s comes from surveys during autumn 1978 as they migrated out of Lancaster Sound. During this period, movements were rapid and a large fraction of the population was counted during a 2 to 3 day period.

During our surveys on 13-15 September 1978, one observer (WRK) was present on all three days and RAD was present on 14 and 15 September. We circled (at 150-250 m ASL) each herd of belugas that was encountered. Both observers were on the same side of the aircraft; the aircraft circled until each observer was confident of his independent count of the animals. Most herds were compact and in clear, shallow water, and most animals did not disappear from sight during dives except when passing under ice pans. However, herds in Bethune Inlet were dispersed and disappeared during dives in the murky water off the glacier front; these groups were circled for about 22 minutes before observers were confident of their estimates. A total of 19 herds ranging in size from four to 2,156 animals were counted in this manner. The totals of the independent estimates by the two observers differed by only 1.6% (11,520 vs 11,340) and were not significantly different (Wilcoxon matched-pair signed rank test, T=55, n=15 unequal pairs, P>0.1). Six herds of 1,000+ whales were encountered. The independent estimates for these large herds differed by 1% to 14%. Thus, we believe that the estimates derived from the 13-15 September surveys were quite accurate.

We estimated that 9,039 different belugas were observed on 13-15 September. Other sightings made throughout the fall period were then assessed to determine whether they represented whales also seen on 13-15 September (Table 7). Using conservative assumptions, a minimum estimate of the numbers of belugas involved in the 1978 fall migration is 10,242 (Table 7). Some groups may have passed on days when we had no survey coverage and some of the groups assumed to have been repeats may actually have included different whales. Also, correction factors to account for the diving behaviour of belugas during fall migration have not been included, but this was not a significant factor in the clear shallow waters where most groups of belugas were counted.

DISCUSSION

Spring migration

Belugas that wintered in the "North Water" in 1978 and 1979 began to move south into Lancaster Sound in late March. Small numbers of belugas moved to the Lancaster Sound - eastern Devon Island - eastern Jones Sound area from late April to late June. The main westward migration into and through Lancaster Sound occurred from 20 June-15 July in 1976, 4-20 July in 1978 and during July in 1979. In 1975, arrival of the main migration in the central Canadian Arctic Archipelago occurred from 15-28 July. Thus, there seemed to be some variation in timing of spring migration into the Canadian Arctic.

The timing of migration along the W Greenland coast has been examined and summarised by Heide-Jørgensen (1994). The animals wintering off Western Greenland begin to leave the southernmost wintering areas (63º N) in February to early April and travel through Melville Bugt in June and early July. Thus, the early animals seen along coasts and ice edges of Lancaster and Jones sounds in April and early May of 1978-79 were probably whales that wintered in the "North Water". The movements into Lancaster Sound in late June-July appear to have followed the movements along Western Greenland.

Belugas probably followed leads between the landfast ice edge and the pack ice around Melville Bugt to northern Baffin Bay. This route differed from that used by bowhead whales which leave the Greenland coast at about 71º 30´ N and cross through the offshore pack ice (the "middle pack") to the Pond Inlet area (Brown 1868). Our data from extensive

offshore surveys in 1979 indicated that belugas did not cross the "middle pack", but probably followed the Greenland coast into northern Baffin Bay and then moved southwest into the Lancaster Sound area north of 74º 30´ N.

Summering

Sergeant (1973) thought that belugas occupied warm-water estuaries for the purpose of calving. Subsequent studies (Sergeant and Hay 1979, this study, Smith *et al*. 1994) have failed to confirm that calving occurs in estuaries. We have several observations of neonates in offshore waters before the adults had occupied estuaries; in fact, in 1979 most neonates were born in eastern Lancaster Sound or northwest of there because landfast ice persisted across Lancaster Sound until 2 August, which was late in the calving season. Our data from Creswell Bay in 1975, a year when belugas arrived at the estuaries before they had calved, suggested that belugas may have actually moved into deeper offshore waters to calve. It is now believed that belugas occupy shallow warm-water estuaries to facilitate skin moult (Finley 1982, St. Aubin *et al*. 1990, Smith *et al*. 1992).

The use of specific estuaries varied markedly among years, and there was much movement among areas in the same year. Creswell Bay was one of two summering areas in the central Canadian High Arctic that were used consistently by large numbers of belugas every year; the other was Cunningham Inlet (Hay and McClung 1974, this study, Smith *et al*. 1994). Studies in the 1990s indicate that belugas still occupy the same estuaries and follow the same sequence of occupation that we observed in the late 1970s (Martin *et al*. 1993, Smith and Martin 1994, Innes *et al*. 2002).

During any particular survey of estuaries in 1975-77, we were able to account for at most about half of the Canadian High Arctic population of belugas as estimated from surveys during the 1978 autumn migration period. Recent telemetry studies have confirmed that individual belugas do not remain in estuarine areas for extended periods of time and they spend much of the summer period feeding in deep offshore waters (Martin *et al*. 1993, Smith and Martin 1994, Richard *et al*. 1997).

Late summer

During late summer belugas moved into Peel Sound. They were found among offshore pack ice and in estuaries along the east coast of Prince of Wales Island. Feeding was seen on several occasions and was confirmed by feeding frenzies of birds and other marine mammals that accompanied the belugas. Movements out of Peel Sound appeared to follow the east coast of Prince of Wales Island.

Fall migration

The eastward fall migration of belugas through Lancaster Sound was exclusively along the south coast of Devon Island and was highly coordinated; most of the population moved through eastern Lancaster Sound in less than a week (19-22 September 1976, 13-15 September 1978), and some individual herds sustained high speeds. The proximate factors that triggered these mass movements are unknown but were presumably related to changes in weather systems that initiated the onset of ice formation in the central Canadian High Arctic channels.

From eastern Lancaster Sound, the animals moved north along the east coast of Devon Island. Some herds moved west into Jones Sound, crossed to the south coast of Ellesmere Island, and then moved east along that coast. Other herds crossed eastern Jones Sound to SE Ellesmere Island. It is not known how far north along the east coast of Ellesmere Island the whales travelled before crossing over to Greenland waters. Vibe (1967) recorded herds moving south past Neqe, on the Greenland coast at the southern end of Smith Sound, in September and October. It is not known whether these animals were migrants from the central Canadian Arctic or animals that summered in Smith Sound and Kane Basin.

Recent telemetry studies indicate that the fall migration patterns and behaviour of Canadian High Arctic belugas are similar to those observed during the 1970s (Martin *et al*. 1993, Smith and Martin 1994, Richard *et al*. 1998a). Belugas still migrate rapidly from summering areas, stop to feed in traditional feeding areas such as Croker Bay and along SE Devon Island, and follow the south and then east coasts of Devon Island toward Jones Sound.

Rates of movement during migration along Devon Island were extremely high (5.9-18.5 km/h), but are similar to the 12-14 km/h over a 3-h period estimated for belugas approaching Cornwallis Island on 10 September 1976 (see *Late summer distribution*). Martin *et al*. (1993) recorded a "straight-line" speed of 5.8 km/h for an adult female beluga during her easterly migration through Lancaster Sound. Allowing for the whale to have followed the coastline, the speed of this whale was in the middle to upper range of the speeds calculated by us. Richard *et al*. (1998a) used satellite transmitters to track six belugas migrating out of Lancaster Sound during September 1995. All of their whales had periods when rates of movement exceeded 8 km/h and two whales had maximum speeds between 10 and 14 km/h (they excluded two additional whales with "outlier" speeds of 16.7 to 27.5 km/h). Vladykov (1944) stated that belugas can attain speeds of 14 to 18 km/h while being chased, but they can sustain such speeds for only short periods. Kleinenberg *et al*. (1964) gave a speed of 3 to 9 km/h for calmly migrating belugas. Thus, our observed speeds of belugas migrating along the south coast of Devon Island are within the range of previously observed speeds, but they are unique in the length of time that the speeds were sustained.

Calving

Our observations of neonates suggest that most calving occurred during early July to early August which was slightly earlier than narwhals in the same area (Koski and Davis 1994). Although beluga neonates have been reported as early as 31 May in the Canadian High Arctic (Cosens and Dueck 1990) and as early as late March off West Greenland (Heide-Jørgensen *et al*. 1993), births before late June appear to be relatively rare in the Canadian High Arctic population.

Age and sex composition

Excluding neonates, about 77% of belugas in the Canadian High Arctic population were adults and 8.4% were yearlings during the late 1970s. Adult males seem to have been underrepresented in the estuaries during our surveys as has been noted by Smith *et al*. (1994) in Cunningham Inlet and the Nastapoka River delta in southeastern Hudson Bay. Allowing for under-representation of adult males, the proportion of neonates seen at the end of the calving season is consistent with a triennial reproductive cycle as noted by Sergeant (1973), Burns and Seaman (1986) and Heide-Jørgensen and Teilmann (1994).

Feeding

Belugas were present in the central Canadian Arctic channels for about two months in the summer and feeding apparently occurred throughout this period. Their principal food appeared to be polar cod, which is an important component of the diets of most seabirds and marine mammals in the Canadian High Arctic (Bradstreet 1980, 1982, Bradstreet *et al*. 1986, Welch *et al*. 1992). Belugas consistently utilised specific coastal feeding sites in late summer and during fall migration (*e.g*. Allen Bay, Croker Bay, Bethune Inlet). Use of these same areas has been documented by later studies by Welch *et al*. (1992), Smith and Martin (1994) and Richard *et al*. (1998a). In addition, belugas fed opportunistically in areas where polar cod occurred irregularly such as in inner Creswell Bay in 1976.

Belugas also fed offshore either under pack ice, where polar cod may have concentrated as the pack ice melted (*e.g*. Prince Regent Inlet off Creswell Bay, Peel Sound), or in deep offshore waters where they may have fed on polar cod, Greenland halibut or invertebrates (Martin *et al*. 1993). Recent telemetry studies of beluga movements during summer indicate that this offshore deep-diving behaviour is more common than previously thought (Martin *et al*. 1993, Smith and Martin 1994, Richard *et al*. 1997).

The only published data on the diet of belugas in the Canadian High Arctic are observations by Freeman (1968) on animals trapped by ice in Jones Sound, by Sergeant and Brodie (1975) of belugas feeding along a disintegrating ice edge in Maxwell Bay in early August 1973, and by Welch *et al*. (1992) on belugas feeding on a concentration of Polar cod near Resolute Bay during August 1985. The Jones Sound whales maintained small breathing holes in the ice from 25 November 1966 to 1 April 1967 and may not be representative because the animals

were trapped by landfast ice. Of the 46 stomachs examined from hunter-killed whales, over half were empty and the rest contained only small amounts (about 0.5 l) of food, primarily polar cod and the mysid crustacean (*Boreomysis nobilis*). The belugas observed by Sergeant and Brodie (1975) were believed to be feeding on polar cod, although this could not be confirmed. The belugas of Welch *et al*. (1992) appeared to be feeding on dense schools of polar cod and returned to the same area to feed numerous times over a 4-day period.

Population size

Sergeant and Brodie (1975) conducted aerial surveys in early August 1973; these "showed at least 10,000 animals…" in the High Arctic. Sergeant and Hay (1979) present the data from these (8,990 belugas estimated) and other surveys; they state (p. 10) "the total in various years approaches but does not exceed 9,000 animals".

Our best estimate of the size of the High Arctic beluga population in the late 1970s comes from surveys conducted during the peak of fall migration when virtually all of the animals were present along the south and east coasts of Devon Island and the south coast of Ellesmere Island. Surveys of the east and south coasts of Devon Island on 19-22 September 1976 recorded 8,393 belugas (Fig. 10A). More complete surveys in 1978 found 9,039 animals on 13-15 September (Fig. 10B) and a total of at least 10,242 during the entire fall migration (Table 7). The latter estimate is negatively biased; we excluded many herds that might have been counted twice even though some were seen several days and up to 350 km apart. In addition, because of the high speed of fall migrants our weekly surveys probably missed some herds completely. Although correction factors to account for the diving behaviour of animals have not been incorporated into the estimate, we believe that any bias due to diving is small because of the behaviour of the animals during migration. We estimate that at least 10,250-12,000 belugas were involved in the fall migration out of the central Canadian Arctic in 1978. This estimate includes some, but probably not all, of the neonates born in July and early August of 1978.

R.R.C.S. (1977) estimated that 15,500 belugas were present in eastern Lancaster Sound on 22 September 1976; however, they warned that the underlying assumptions for their extrapolation procedure (*i.e*., either random or uniform distribution throughout the area) were not met. They recorded 2,736 whales within 0.8 km of the south coast of Devon Island but none in offshore waters or along the southern margin of the sound; therefore, it was not appropriate to extrapolate densities to those latter areas. R.R.C.S. (1977), correctly, did not take the estimate of 15,500 seriously and it is only discussed because it has been uncritically cited.

Smith *et al*. (1985) surveyed summering areas of the central Canadian High Arctic during July and August 1981. Their July estimate was 10,368 (6,264 to 18,564), which is essentially identical to our estimate from the 1978 fall migration period. Their August estimate was 8,802 (6,771 to 14,067). The Smith *et al*. (1985) estimates do not include corrections for whales missed by observers or for whales that were below the surface at the time of the survey.

Innes *et al*. (2002) conducted a survey of the central Canadian High Arctic summering areas in 1996. Their estimate of 21,213 (95% CI 10,985 to 32,619) is unbiased and accounts for whales missed by observers, and the diving behaviour of whales. Their estimate corrected for perception bias was 10,347 (cv=0.28), which is only slightly lower than the two estimates of 10,368 and 8,802 by Smith *et al*. (1985) for the summer of 1981.

Recent winter surveys of belugas along Western Greenland suggest that the population wintering there may have declined by as much as 62% (Heide-Jørgensen and Reeves 1996). However, surveys conducted in the summering areas in 1981 (Smith *et al*. 1985) and 1996 (Innes *et al*. 2002) suggest that the decline, if one has occurred, is smaller than the winter surveys suggest.

In order to manage the Canadian High Arctic beluga population managers need to know either the population size or whether the population is increasing or decreasing. Surveys like those conducted by Innes *et al*. (2002) provide

an unbiased estimate of population size but the confidence interval of the estimate is too broad to assess changes in population status over relatively short periods of time. For example, the 1981 aerial surveys conducted by Smith *et al*. (1985) give a similar point estimate of population size (10,400) as our 1978 surveys (10,242-12,000) but the CI of the Smith *et al*. (1985) estimate is 6,300-18,600. We are unable to place an upper limit on our estimate, but we counted at least 10,242 different whales during our survey so the lower limit is 10,242 (neither estimate includes correction factors to account for diving behaviour or for groups that might have been missed). Since the lower limit of population size is conservatively used for risk-averse management decisions, there is a need to repeat the census of the Canadian High Arctic beluga population using our methods. If the census were completed during a year when belugas from that population were radio tagged and had TDRs (time-depth-recorders), the estimate would benefit from greater certainty about the movements of specific groups between days and hence a better estimate of total numbers of animals in the census area. TDRs would provide data to correct counts for animals below the surface at the time of the counts and permit an estimate of population size and confidence intervals.

ACKNOWLEDGEMENTS

The studies reported in this paper were funded by several organizations (see Methods). We gratefully acknowledge the support of L.D. Doran, J. Riddick, B. Ross and the Polar Gas Project, Toronto; A. Rutgers, D. Daae and Norlands Petroleums Ltd., Calgary; G. Glazier, H. Hume, G. Koenig and Petro-Canada Explorations, Inc., Calgary; D. Bowie, D. Bruchet, P. Wood and the Arctic Pilot Project, Calgary; and D.E. Sergeant and the Arctic Biological Station, Ste Anne de Bellevue. In addition, we thank R. Brown and Norcor Engineering and Research Ltd., Yellowknife, and S. Mackenzie of Kenmac Consulting, Resolute, for assistance and support in the field. N.B. Snow of the Department of Indian Affairs and Northern Development, and later Petro-Canada, was instrumental in several of the studies.

We particularly thank Dr. W. John Richardson of LGL Limited for his instrumental role in all of the reports upon which this paper is based and Dr. M.P. Heide-Jørgensen for his comments and encouragement. Dr. S.R. Johnson of LGL Limited made major contributions to the results presented here. We thank the following biologists (in alphabetical order) at LGL Limited for their efforts in the field: W.G. Alliston, M.S.W. Bradstreet, M.A. Gollop, C. Holdsworth, P.D. Hollingdale, S.R. Johnson, W.G. Johnston, M.A. McLaren, P.L. McLaren. L.A. Patterson, W.E. Renaud and R.E. Salter. We also thank R.E. Elliot for producing the figures.

A.D. Sekerak, D. Thomson and H. Bain of LGL Limited provided unpublished information about the central Canadian High Arctic marine system. We also thank A. Clarke, D. Dowler, G. Ekalook, D. Heyland and T. Idlout for providing unpublished information and two anonymous reviewers who provided comments that greatly improved the paper.

The preparation of this paper was funded by LGL Limited.

REFERENCES

Bissett, D. 1968. Resolute. An area economic survey. A.E.S.R. 67/1. Dep. Indian Affairs and Northern Development, Ottawa. 175 pp.

Bradstreet, M.S.W. 1980. Thick-billed murres and black guillemots in the Barrow Strait area, N.W.T., during spring: diets and food availability along ice edges. *Can. J. Zool*. 58:2120-2140.

Bradstreet, M.S.W. 1982. Occurrence, habitat use, and behaviour of seabirds, marine mammals and arctic cod at the Pond Inlet ice edge. *Arctic* 35:28-40.

Bradstreet, M.S.W., Finley, K.J, Sekerak, A.D., Griffiths, W.B., Evans, C.R., Fabijan, M.F. and Stallard, H.E. 1986. Aspects of the biology of arctic cod (*Boreogadus saida*) and its importance in Arctic marine food chains. *Can. Tech. Rep. Fish. Aquat. Sci.* 1491. 193 pp.

Brown, R. 1868. Notes on the history and geographical relations of the cetacea frequenting Davis Strait and Baffin's Bay. *Proc. Zool. Soc. London* 1868:533-556.

Burns, J.J., and Seaman, G.A. 1986. Investigations of belukha whales in western and northern Alaska. II. Biology and ecology. Report by Alaska Department of Fish and Game, 1300 College Road, Fairbanks, Alaska. 99701. 129 pp.

Canadian Hydrographic Service. 1970. *Pilot of arctic Canada. Vol. I.* Dep. Energy, Mines and Resources, Ottawa. 247 pp.

Cosens, S.E. and Dueck, L.P. 1990. Spring sightings of narwhal and beluga calves in Lancaster Sound, NWT. *Arctic* 43:127-128.

Davis, R.A., Finley, K.J., Bradstreet, M.S.W., Holdsworth, C. and McLaren, M. 1975. Studies of the numbers and distribution of birds and marine mammals in the central Canadian Arctic - 1974. Report by LGL Limited for Polar Gas Project, Toronto. 205 pp.

Davis, R.A., Koski, W.R. and Finley, K.J. 1978a. Numbers and distribution of walruses in the central Canadian high arctic. Report by LGL Limited for Polar Gas Project, Toronto. 50 pp.

Davis, R.A., Richardson, W.J., Johnson, S.R. and Renaud, W.E. 1978b. Status of the Lancaster Sound narwhal population in 1976. *Rep. int. Whal. Comm.* 28:209-215.

Doidge, D.W. and Finley, K.J. 1993. Status of the Baffin Bay population of beluga, *Delphinapterus leucas*. *Can. Field-Nat.* 107:533-546.

Eberhardt, L.L. 1978. Transect methods for population studies. *J. Wildl. Manage.* 42:1-31.

Finley, K.J. 1976. Studies of the status of marine mammals in the central District of Franklin, N.W.T. June-August, 1975. Report by LGL Limited for Polar Gas Project, Toronto. 183 pp.

Finley, K.J. 1982. The estuarine habitat of the beluga or white whale *Delphinapterus leucas*. *Cetus* 4:4-5.

Finley, K.J., Davis, R.A. and Richardson, W.J. 1974. Preliminary studies of numbers and distribution of marine mammals in the central Canadian Arctic–1974. Report by LGL Limited for Polar Gas Project, Toronto. 68 pp.

Finley, K. J. and Johnston, W.G. 1977. An investigation of the distribution of marine mammals in the vicinity of Somerset Island with emphasis on Bellot Strait, August-September 1976. Report by LGL Limited for Polar Gas Project, Toronto. 91 pp

Finley, K.J. and Renaud, W.E. 1980. Marine mammals inhabiting the Baffin Bay North Water in winter. *Arctic* 33:724-738.

Freeman, M.M.R. 1968. Winter observations on beluga (*Delphinapterus leucas*) in Jones Sound, N.W.T. *Can. Field-Nat.* 82:276-286.

Hay, K. and McClung, R. 1974. Observations on beluga and narwhal in the Canadian High Arctic,

summer 1974. Fish. Res. Board Can. MS Rep. No. 1385. 55 pp.

Harwood, L.A., Innes, S., Norton, P. and Kingsley, M.C.S. 1996. Distribution and abundance of beluga whales in the Mackenzie estuary, southeast Beaufort Sea, and west Amundsen Gulf during late July 1992. *Can. J. Fish. Aquat. Sci.* 53:2262-2273

Heide-Jørgensen, M.P. 1994. Distribution, exploitation, and population status of white whales, (*Delphinapterus leucas*) and narwhals (*Monodon monoceros*) in West Greenland. *Medd. Grønland, Biosci.* 39:135-149.

Heide-Jørgensen, M.P. and Reeves, R.R. 1996. Evidence of a decline in beluga, (*Delphinapterus leucas*), abundance off West Greenland. *ICES J. Mar. Sci.* 53:61-72.

Heide-Jørgensen, M.P. and Teilmann, J. 1994. Growth, reproduction, age structure and feeding habits of white whales (*Delphinapterus leucas*) in West Greenland waters. *Medd. Grønland, Biosci.* 39:195-212.

Heide-Jørgensen, M.P., Lassen, A., Teilmann, J. and Davis, R.A. 1993. An index of the relative abundance of wintering belugas *Delphinapterus leucas,* and narwhals, *Monodon monoceros*, off West Greenland. *Can. J. Fish. Aquat. Sci.* 50:2323-2335.

Heide-Jørgensen, M.P., Richard, P., Ramsay, M. and Akeeagok, S. 2002. Three recent ice entrapments of Arctic cetaceans in West Greenland and the eastern Canadian High Arctic. *NAMMCO Sci. Publ.* 4:143-148.

Innes, S., Heide-Jørgensen, M.P., Laake, J.L., Laidre, K.L., Cleator, H., Richard, P. and Stewart, R.E.A. 2002. Surveys of belugas and narwhals in the Canadian High Arctic in 1996. *NAMMCO Sci. Publ.* 4:169-190.

Johnson, S.R., Renaud, W.E., Davis, R.A. and Richardson, W.J. 1976. Marine mammals recorded during aerial surveys of birds in eastern Lancaster Sound, 1976. Report by LGL Limited for Norlands Petroleums Ltd., Calgary. 180 pp.

Kleinenberg, S.E., Yablokov, A.V., Bel'kovich, B.M. and Tarasevich, M.N. 1964. Beluga (*Delphinapterus leucas*): investigation of the species. Akad. Nauk SSSR, Institut Morfologii Zhivotnykh Im. A.N. Severtsova, Moscow. 450 pp. (Translated into English, 1969, Israel Program for Scientific Trans., Jerusalem. 376 pp.)

Koski, W.R. 1980. Distribution and migration of marine mammals in Baffin Bay and eastern Lancaster Sound, May-July 1979. Report by LGL Limited for Petro-Canada Explorations Ltd., Calgary. 317 pp.

Koski, W.R. and Davis, R.A. 1979. Distribution and movements of marine mammals in NW Baffin Bay, 4 May-10 October 1978. Report by LGL Limited for Petro-Canada Explorations Ltd., Calgary. 305 pp.

Koski, W.R. and Davis, R.A. 1980. Studies of the late summer distribution and fall migration of marine mammals in NW Baffin Bay and E. Lancaster Sound, 1979. Report by LGL Limited for Petro-Canada Explorations Ltd., Calgary. 214 pp.

Koski, W.R. and Davis, R.A. 1994. Distribution and numbers of narwhals (*Monodon monoceros*) in Baffin Bay and Davis Strait. *Medd. Grønland, Biosci.* 39:15-40.

Martin, A.R. and Smith, T.G. 1992. Deep diving in wild, free-ranging beluga whales, *Delphinapterus leucas*. *Can. J. Fish. Aquat. Sci.* 49:462-466.

Martin, A.R., Smith, T.G. and Cox, O.P. 1993. Studying the behaviour and movements of high Arctic belugas with satellite telemetry. Pages 195-210. In: Boyd, I.L. (ed.). *Marine mammals: advances in behavioural and population ecology*. Clarendon Press, Oxford. U.K.

McLaren, M.A. and Renaud, W.E. 1977. Numbers and distribution of marine mammals along the coast of southeastern Melville Island, July-August 1977. Report by LGL Limited for Petro-Canada, Calgary. 18 pp.

Read, C.J., and Stephansson, S.E. 1976. Distribution and migration routes of marine mammals in the central arctic region. *Can. Fish. Mar. Serv. Tech. Rep.* No. 667. 13 pp.

Richard, P.R., Martin, A.R. and Orr, J.R. 1997. Study of summer and fall movements and dive behaviour of Beaufort Sea belugas, using satellite telemetry: 1992-1995. Environmental Studies Research Funds Report No. 134. Calgary. 26 pp + appendices.

Richard, P.R., Heide-Jørgensen, M.P. and St. Aubin, D. 1998a. Fall movements of belugas (*Delphinapterus leucas*) with satellite-linked transmitters in Lancaster Sound, Jones Sound, and northern Baffin Bay. *Arctic* 51:5-16.

Richard, P.R., Orr, J.R., Dietz, R. and Dueck, L. 1998b. Sightings of belugas and other marine mammals in the North Water, late March 1993. *Arctic* 51:1-4.

Riewe, R.R. 1977. The utilization of wildlife in the Jones Sound region by the Grise Fiord Inuit. Pages 623-644. In: L.C. Bliss (ed.). *Truelove Lowland, Devon Island Canada: A High Arctic Ecosystem*. Univ. Alberta Press, Edmonton.

[R.R.C.S.] Renewable Resources Consulting Services Ltd. 1977. Aerial surveys of marine mammals of Lancaster Sound, 1975-1976. Report to Norlands Petroleums Ltd., Calgary. 110 pp.

Salter, R.E. 1979. Site utilization, activity budgets and disturbance responses of Atlantic walruses during terrestrial haul-out. *Can. J. Zool.* 57:1169-1180.

Sekerak, A.D., Thomson, D., Bain, H. and Acreman, J. 1976. Summer surveys of the marine ecology of Creswell Bay, Somerset Island and Assistance Bay, Cornwallis Island, N.W.T. 1975. Report by LGL Limited for Polar Gas Project, Toronto. 215 pp.

Sergeant, D.E. 1973. Biology of White Whales (*Delphinapterus leucas*) in western Hudson Bay. *J. Fish. Res. Board Can.* 30:1065-1090.

Sergeant, D.E. and Brodie, P.F. 1975. Identity, abundance, and present status of populations of white whales, *(Delphinapterus leucas*), in North America. *J. Fish Res. Board Can.* 32:1047-1054.

Sergeant, D.E. and Hay, K. 1979. Migratory sea mammal populations in Lancaster Sound. Arctic Islands Pipeline Project Report. 1978, Environmental-Social Program, Northern Pipelines, Ottawa. 31 pp.

Smith, T.G. and Martin, A.R. 1994. Distribution and movements of belugas, *Delphinapterus leucas*, in the Canadian High Arctic. *Can. J. Fish. Aquat. Sci.* 51:1653-1663.

Smith, T.G., Hammill, M.O., Burrage, D.J. and Sleno, G.A. 1985. Distribution and abundance of belugas, *Delphinapterus leucas*, and narwhals, *Monodon monoceros*, in the Canadian High Arctic. *Can. J. Fish. Aquat. Sci.* 42:676-684.

Smith, T.G., St. Aubin, D.J. and Hammill, M.O. 1992. Rubbing behaviour of belugas, *(Delphinapterus leucas)*, in a high Arctic estuary. *Can. J. Zool.* 70:2405-2409.

Smith, T.G., Hammill, M.O. and Martin, A.R. 1994. Herd composition and behaviour of white whales *(Delphinapterus leucas)* in two Canadian Arctic estuaries. *Medd. Grønland, Biosci.* 39:175-184.

St. Aubin, D.J., Smith, T.G. and Geraci, J.R. 1990. Seasonal epidermal moult in beluga whales, *Delphinapterus leucas*. *Can. J. Zool.* 68:359-367.

Vibe, C. 1967. Arctic animals in relation to climatic fluctuations. *Medd. Grønland* 170(5):1-227.

Vladykov, V.D. 1944. Études sur les mammifères aquatiques. III. Chasse, biologie et valeur économique du marsouin blanc ou béluga (*Delphinapterus leucas*) du fleuve et du Golfe St. Laurent. (Studies of marine mammals. III. Hunt, biology and economic value of the beluga of the Gulf of St Lawrence) Dépt. Pécheries, Quebec. 194 pp. In French.

Welch, H.E., Bergmann, M.A., Siferd, T.D., Martin, K.A., Curtis, M.F., Crawford, R.E., Conover, R.J. and Hop, H. 1992. Energy flow though the marine ecosystem of the Lancaster Sound region, Arctic Canada. *Arctic* 45:343-357.