

# Fall Movements of Belugas (*Delphinapterus leucas*) with Satellite-linked Transmitters in Lancaster Sound, Jones Sound, and Northern Baffin Bay

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**ABSTRACT.** Six adult belugas, *Delphinapterus leucas*, (2 males, 4 females) were instrumented with satellite-linked transmitters in Croker Bay, southeastern Devon Island in the Canadian High Arctic in mid-September 1995. Some days, the animals remained close to shore along the southeastern and eastern shoreline of Devon Island, presumably foraging for arctic cod (*Boreogadus saida*) and other prey. They spent the rest of the time in the deep waters of Lady Ann Strait, eastern Jones Sound, and the waters southeast of Coburg Island, presumably feeding on deepwater prey. Only males went farther north in waters off southeastern Ellesmere Island. The belugas' swimming speeds decreased in the later part of the study period. Their last transmissions came from the North Water, an area where belugas are known to winter. Results of this study were not sufficient to determine the extent of movement of belugas between the eastern Canadian Arctic and Greenland.

**Key words:** beluga, *Delphinapterus leucas*, High Arctic, North Water, satellite telemetry, swimming speed, fall migration

**RÉSUMÉ.** À la mi-septembre 1995, on a installé des émetteurs en liaison avec un satellite sur six bélugas adultes (*Delphinapterus leucas*) — 2 mâles, 4 femelles — dans la baie Croker, au sud-est de l'île Devon dans l'Extrême-Arctique canadien. Certains jours, les six bélugas se tenaient près des côtes sud-est et est de l'île Devon, probablement à la recherche de saïdas (*Boreogadus saida*) ou d'autres proies. Ils ont passé le reste du temps dans les eaux profondes du détroit de Lady Ann, de l'est du détroit de Jones, et dans les eaux du sud-est de l'île Coburg, se nourrissant probablement de proies habitant les grands fonds. Seuls les mâles se sont rendus plus au nord dans les eaux au large du sud-est de l'île Ellesmere. La vitesse de nage des bélugas a diminué durant la dernière portion de l'étude. Les derniers signaux provenaient de l'Eau du Nord, une région où l'on sait que les bélugas passent l'hiver. Les résultats de cette étude sont insuffisants pour évaluer l'ampleur des déplacements de bélugas entre l'est de l'Arctique canadien et le Groenland.

**Mots clés:** béluga, *Delphinapterus leucas*, Extrême-Arctique, télémétrie par satellite, vitesse de nage, migration automnale

## INTRODUCTION

Thousands of belugas (*Delphinapterus leucas*) spend July and August in the waters surrounding Somerset Island in the central Canadian Arctic (Koski and Davis, 1980; Smith and Martin, 1994). They later migrate eastward along the southern shore of Devon Island and north along its eastern shore during September (Fig. 1). Large numbers of belugas are also observed migrating south along the northwestern coast of Greenland, appearing first in the northernmost district (Avanersuaq) in September. Shortly after, in early October, they are usually seen farther south, in the district of Upernavik (Heide-Jørgensen, 1994). Some belugas are also known to winter in the North Water (northwest Baffin Bay and Smith Sound), but the large majority of Canadian Arctic belugas are thought to winter in West Greenland near Disko Bay (Doidge and Finley, 1993). The number of belugas wintering in West

Greenland has declined in the last two decades (Heide-Jørgensen et al., 1993; Heide-Jørgensen and Reeves, 1996).

Belugas from Grise Fiord (Canadian High Arctic) and central West Greenland attain similar size at physical maturity (Heide-Jørgensen and Teilmann, 1994; Stewart, 1994). The absence of morphological differences, however, does not prove conclusively that the two samples belong to the same stock. Satellite tracking of the movements of individuals can offer direct evidence of beluga stock relationships. The movements of belugas during summer and the early part of their fall migration in Barrow Strait and Lancaster Sound have been described by Smith and Martin (1994), who attached satellite-linked tags to 23 belugas. However, they were unable to determine whether those belugas moved between Canadian and West Greenland waters because the transmitters, which had been attached to the whales in summer, ceased transmitting in early autumn.

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This study was designed to test the hypothesis that animals tagged along the Devon Island coast in September would cross to Greenland and to gather data on their migration routes. Also, information on the horizontal and vertical movements of tagged belugas during the fall would contribute to our understanding of beluga ecology. Finally, beluga numbers are usually estimated by aerial surveys, which can count only animals at or near the surface. Because of the need to determine how many diving belugas may have been missed during surveys, measures of the proportion of time belugas spent near the surface and at depth would also help with the interpretation of survey results.

In this paper on six belugas tagged at Croker Bay, Devon Island, in September 1995, we give details of their movements, swimming speeds, and habitat use in relation to ice and depth over the following nine weeks. Other papers in this issue describe the dive activity of the same animals (Heide-Jørgensen et al., 1998) and the results of a winter aerial survey of the North Water beluga population (Richard et al., 1998).

## MATERIALS AND METHODS

### *Study Area*

The study area included Croker Bay, Devon Island, eastern Lancaster Sound, eastern Jones Sound, and north-western Baffin Bay north to Smith Bay, southeastern Ellesmere Island (Fig. 1). The waters in these areas are largely over 200 m deep. A deep trough, with depths over 400 m, runs along the east coast of Devon Island and then north and west into Jones Sound, where depths of more than 800 m occur in some parts. Waters along southeastern Ellesmere Island and east and southeast of Coburg Island are somewhat shallower, varying between 100 and 400 m in depth. Ice conditions in late September vary from year to year. Median ice cover calculated between 1959 and 1974 is medium (2/10 to 5/10) for Jones Sound and open water for the rest of the study area (Markham, 1981). The median time at which ice cover reaches 9/10 (i.e., winter ice) over the whole area is mid-October. By 21 September 1995, most of the study area had between 6/10 and 9/10 ice cover, and by 5 October, most of the area had 9/10 ice cover, including considerable multiyear ice (Weekly Composite Ice Charts, Canadian Ice Service, Environment Canada, 1995).

Aerial reconnaissance along the southeastern Devon Island coast on 10 and 11 September 1995 revealed that belugas were abundant in Croker Bay (Fig. 1) and that ice and weather conditions were suitable for a live capture operation. Croker Bay, a fjord approximately 40 km long and 15 km wide, varies in depth from 100 m to 400 m at its centre. It is forked at the northern end and has two active glaciers calving icebergs. A camp was set at the southeastern corner of the bay (approx. 74°33'N 82°55'W).

### *Live-capture and Tagging Methods*

From our capture camp, we observed belugas generally moving southeastward along the shore and out of the bay, in groups of one to several hundred. We captured six of those belugas (2 males, 4 females) between 12 and 16 September 1995 by immobilizing them along the shore using a 1.2 m diameter hoop with a 1.4 m pursing net. While we attempted to take animals from different pods, it is possible that some belonged to the same pod, since we observed tagged animals returning into the bay hours after being released. The four captured females were accompanied by large calves, presumed to be 1–3 years old because they were grey-coloured and approximately two-thirds to three-quarters the size of the adult females (Caron and Smith, 1990; Doidge, 1990).

Blood for hematological and plasma chemical analysis, skin samples for genetic analysis, and blubber for contaminant analysis were taken from each beluga. Each was then equipped with a satellite-linked time-depth recorder (SLTDR) or "tag" (Table 1), and identification bands (Orr and Hiatt-Saif, 1992) were put on both flippers. After a 40–55 minute handling period, the animals were released. The accompanying calves stayed around the capture site during these procedures and swam away with the females upon their release. On two occasions during the period we spent in Croker Bay, a tagged beluga was resighted in groups of belugas that included calves, its behaviour apparently unaffected by the live capture or the tag. This also indicates that the belugas' movements were not all southeasterly in direction, and that some pods reentered Croker Bay after having passed our camp.

The tags, model SDR-T6, were manufactured by Wildlife Computers Ltd. (Redmond, Washington). They contained a transmitter (model ST-6, Telonics, Mesa, Arizona), a pressure transducer, and a microprocessor, cast in epoxy. The transmitters were glued into a flexible rubber saddle (Ureol® polyurethane) 5 mm thick designed by the Greenland Institute of Natural Resources (Fig. 2). The transmitter housings measured 17.3 × 9.7 × 2.8 cm and the saddle-mounts 22 × 22 × 6 cm. The entire package weighed about 1 kg in air. The tags were attached to the belugas by three 8 mm polyethylene surgical pins (PEHD 1000) through the dorsal ridge. The animals showed no visible reaction to the surgical procedure. The saddles were secured to the pins and held in place with washers. The ends of the pins were melted to prevent the bolts from being torn off.

Each unit had a power output of 0.5 watts and was powered by four lithium C cells (3.5V), which were capable of 54 000 transmissions at 0°C. None of the transmitters were set on a duty cycle, and the only battery-saving features were a daily maximum of 1000 transmissions and a saltwater switch, which prevented transmissions after the switch was wet for more than 0.1 s. The minimum time between transmissions was 45 s. Each transmission contained 8 to 12 bytes of data in addition to its identifier number. Following every 15 transmissions, a status message relayed information about the total number of transmissions and the voltage of batteries. Data from the

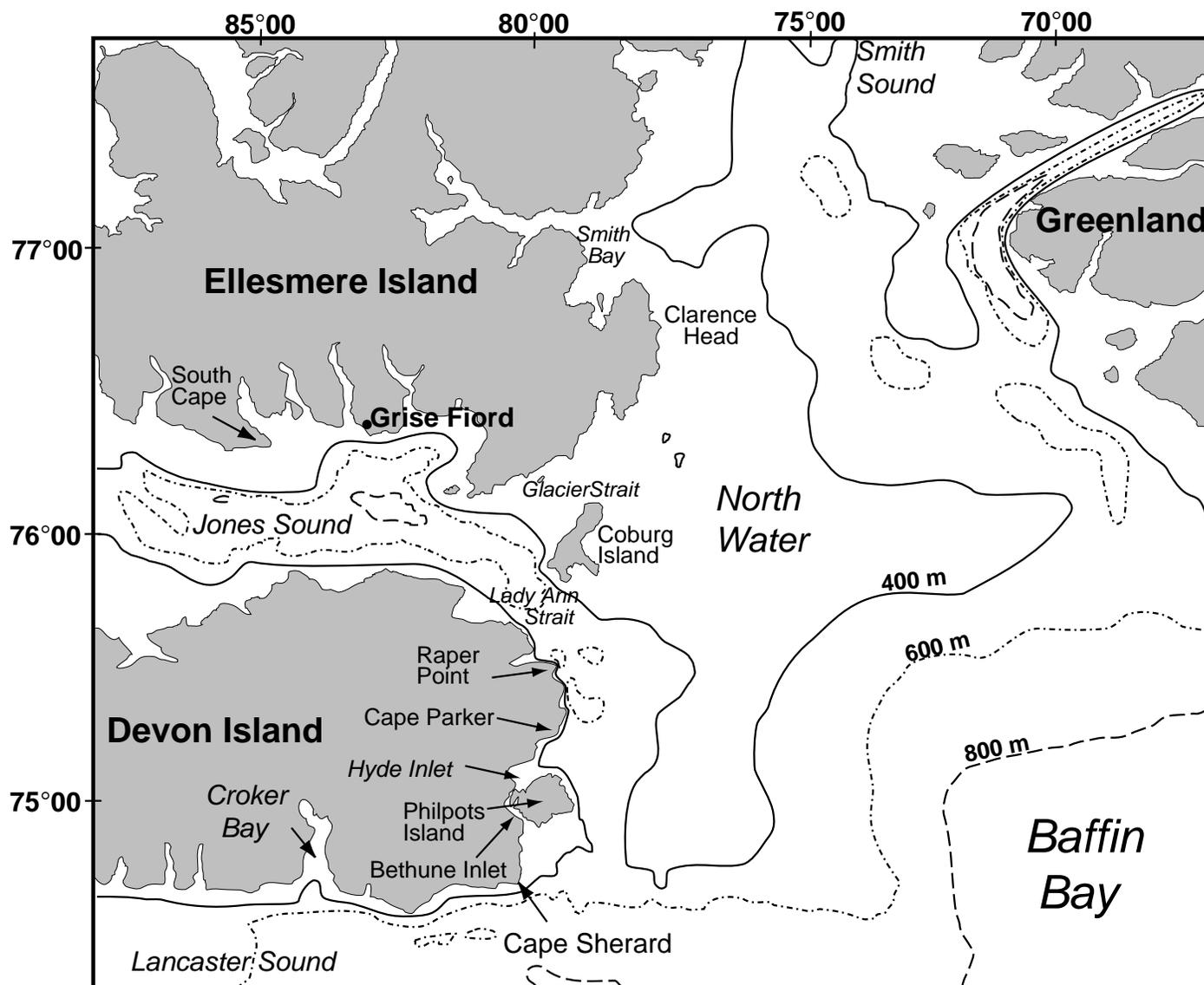


FIG. 1. Study area, with place names and bathymetric contours.

TABLE 1. Description of the belugas captured and duration of their tags' signals and locations. Quality locations (indices 1–3) are in error by 1 km or less.

Tag #	Sex	Length (cm)	Date of capture	Date of last location	Number of signals sent	Days till last signal	Days till last quality location
20688	M	465	14 Sept 95	16 Oct 95	18 350	37	33
20689	F	404	14 Sept 95	16 Oct 95	21 583	48	33
20690	F	368	12 Sept 95	17 Oct 95	21 200	37	34
20694	F	372	15 Sept 95	29 Oct 95	17 695	47	45
20695	F	392	16 Sept 95	4 Nov 95	26 089	52	50
20696	M	408	17 Sept 95	10 Nov 95	25 666	60	55

transmitters were received via the ARGOS Data Collection and Location System (DCLS) (ARGOS, 1988).

#### Analytical Methods

When sufficient numbers of signals were received during a satellite pass, the ARGOS DCLS estimated the position of the tag and assessed the quality of that estimate. We used only

good-quality locations (quality indices of 1–3) with predicted errors less than or equal to 1 km. Location and movement tracks were plotted on polar azimuthal base maps. Distances were calculated using great circle arcs on a spherical model of the globe 6371.11 km in diameter (Maling, 1989, 1993).

Swimming speed was estimated using the great circle distance and the elapsed time between consecutive locations. Two sources of bias affect the estimation of swimming

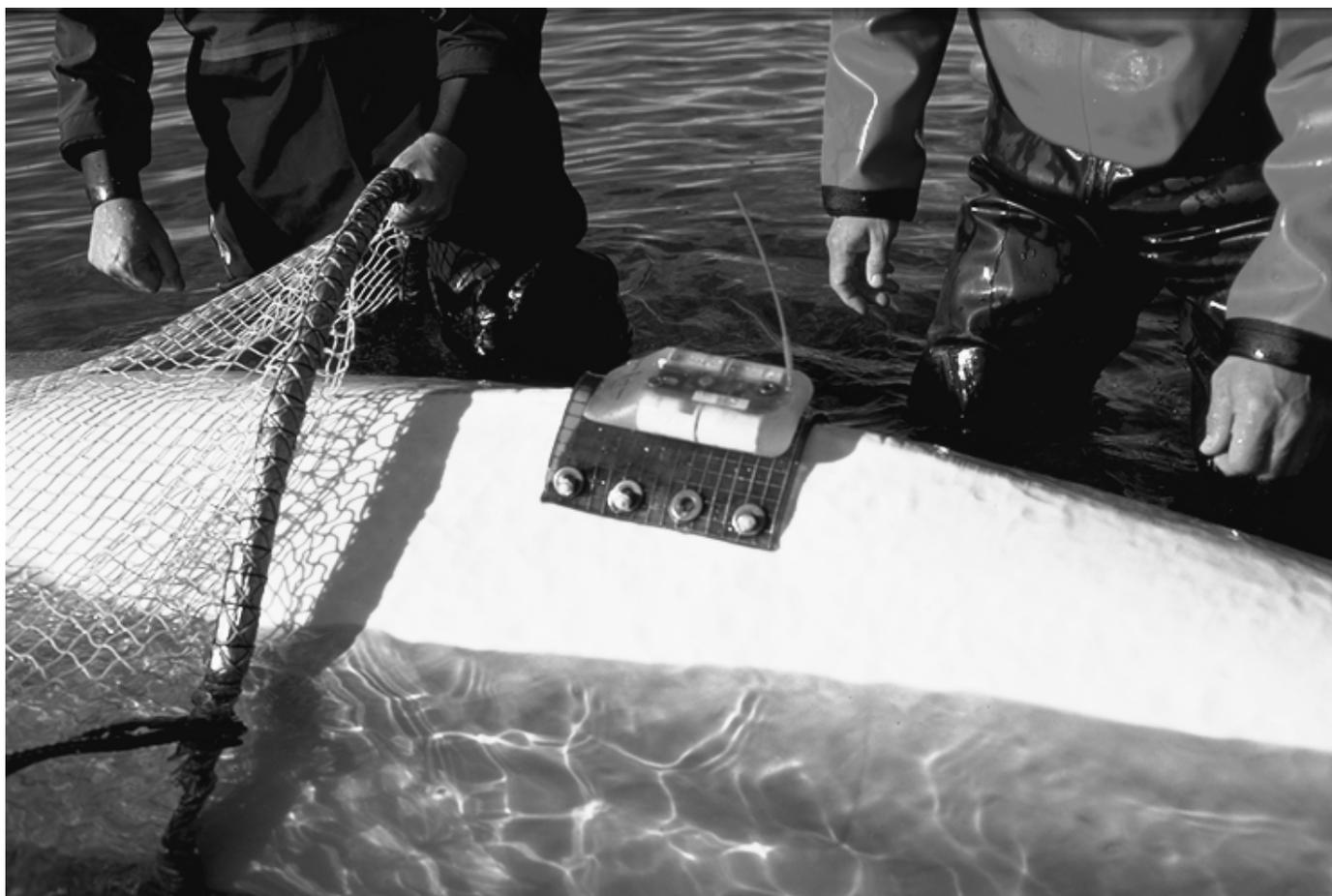


FIG. 2. Beluga equipped with a SLTDR tag pinned through the dorsal ridge. To the left is a hoop net used for live captures. (Photo: A. Rosing-Asvid)

speeds: a) for short time intervals (less than 0.5 hr), swimming speed estimates can be strongly biased downward or upward by errors in location; b) for intervals greater than 2 hr, estimates of swimming speed are biased downward when movements are not straight lines between the locations used to calculate travel distance. To reduce these biases, we calculated swimming speeds only for intervals between locations that were more than half an hour and less than two hours apart.

## RESULTS

### Tag Performance

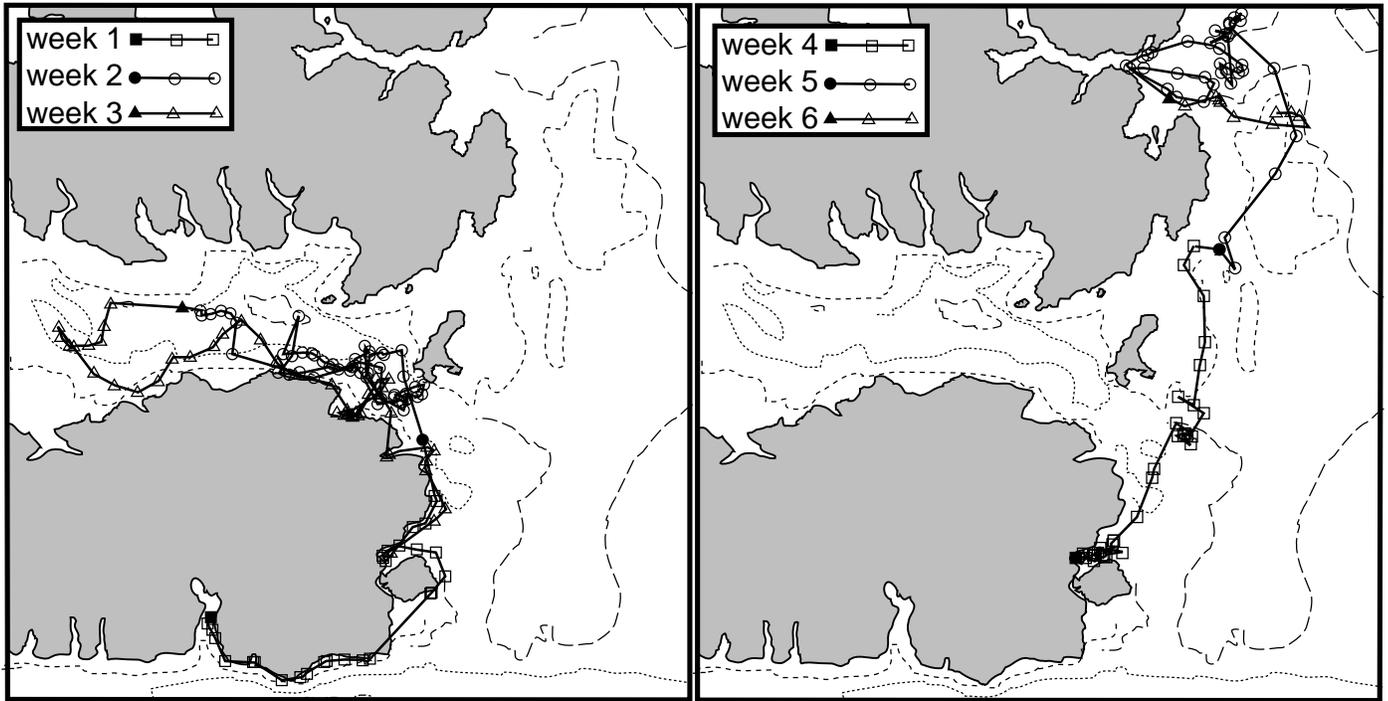
The six tags transmitted for 37–60 days, sending between 17 695 and 26 089 signals (or “uplinks”) to the satellites (Table 1). These signals produced good-quality locations (quality indices  $\geq 1$ ) for 33–55 days. The number of good quality locations varied among tags (Table 2) and declined with time in all six whales, resulting in fewer locations towards the end. Size or sex of the tagged animals did not appear to have influenced the longevity of transmissions since the two biggest animals, both males, had one of the longest and the shortest number of days of transmission (Table 1).

TABLE 2. Proportion of the quality 1–3 locations obtained from each tag.

Tag #	Total	Locations			
		Quality 1	Quality 2	Quality 3	Poor quality
20688 M	554	26.0%	14.6%	6.0%	53.4%
20689 F	567	18.0%	11.3%	4.8%	65.9%
20690 F	626	25.6%	15.5%	5.8%	53.1%
20694 F	526	18.3%	11.4%	3.2%	67.1%
20695 F	972	27.2%	16.7%	4.9%	51.2%
20696 M	1038	21.8%	10.2%	4.9%	63.1%

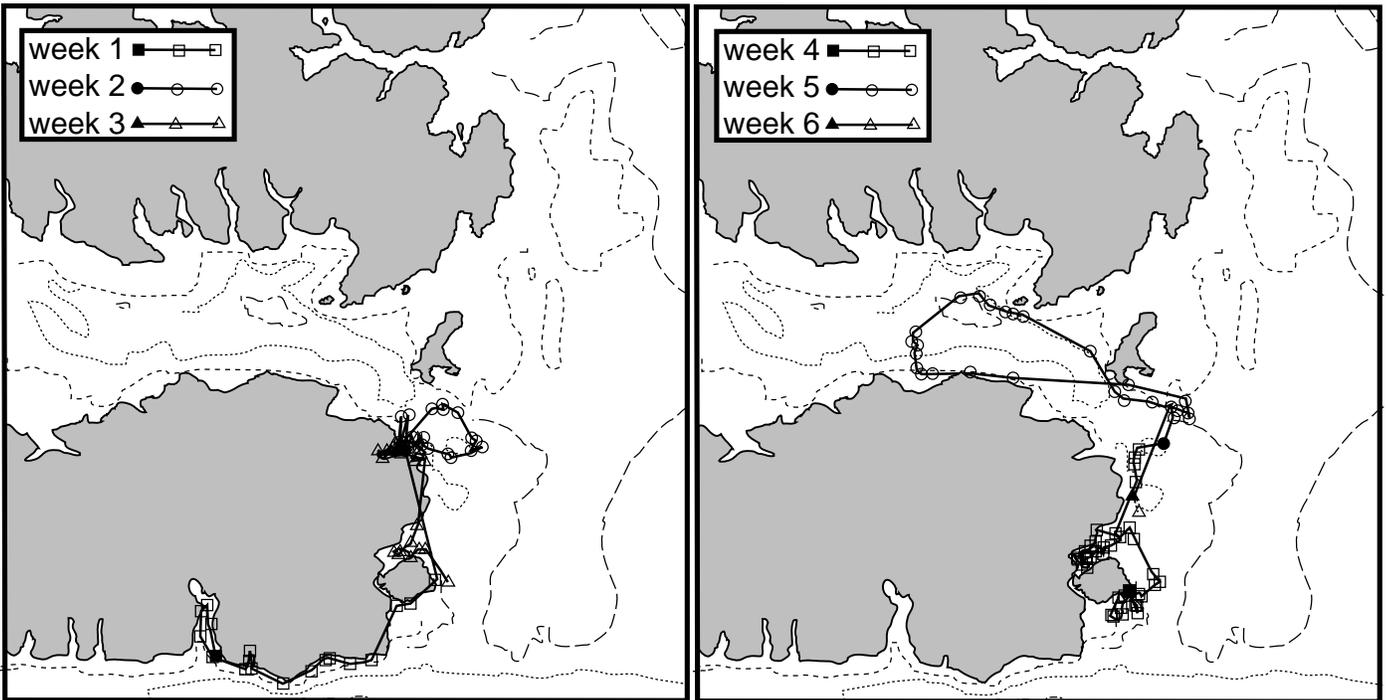
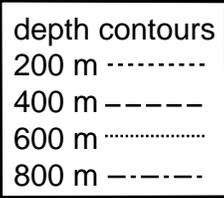
### Distribution and Movements

All but one animal left Croker Bay and traveled east within a day of their release (Fig. 3). Female 20694 remained in Croker Bay for five days after release before heading east. Once out of Croker Bay, they all traveled close to shore along the southern and eastern coasts of Devon Island, reaching Hyde Inlet northwest of Philpots Island or Lady Ann Strait, eastern Jones Sound, and waters to the south of Coburg Island. All six animals entered Jones Sound and spent some time there. The two males went as far north as waters east of Clarence Head or Smith Bay, Ellesmere Island, while the four females remained south of Glacier Strait (Fig. 3).



A) 20688 M weeks 1 to 3

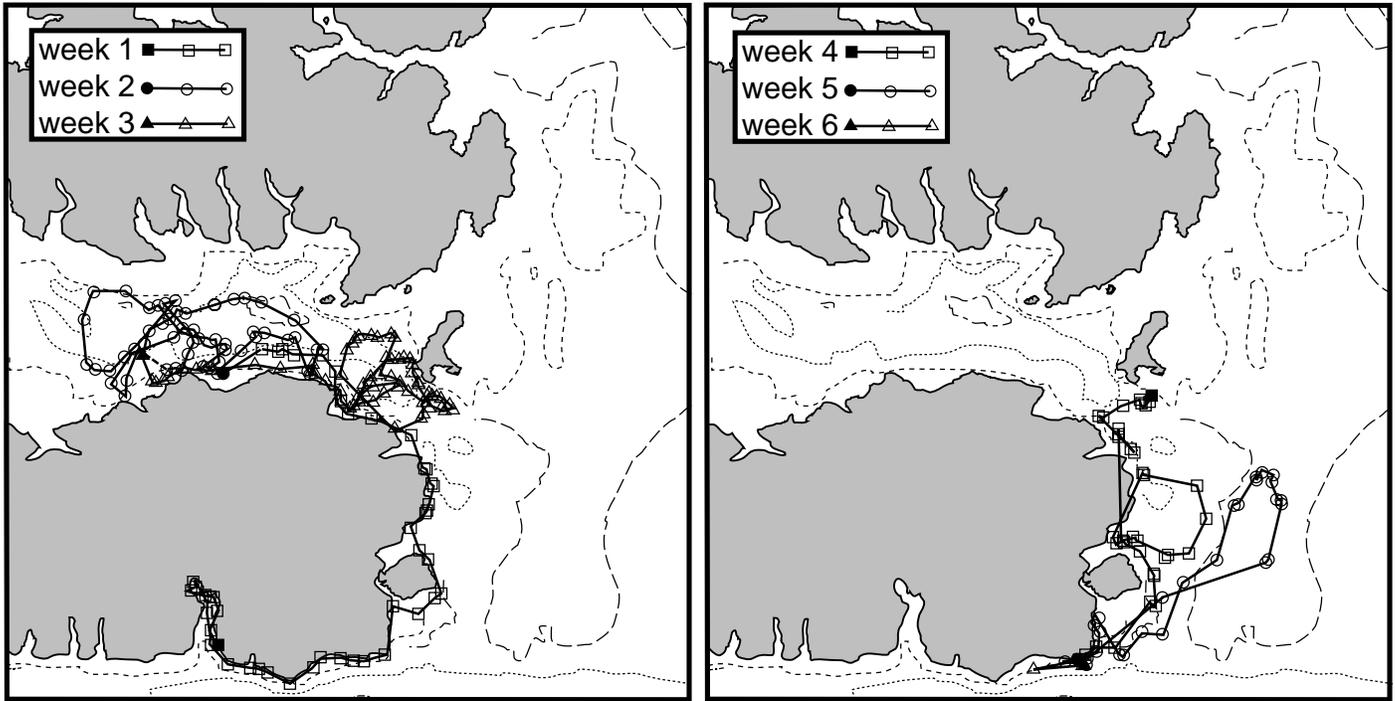
20688 M weeks 4 to 6



B) 20689 F weeks 1 to 3

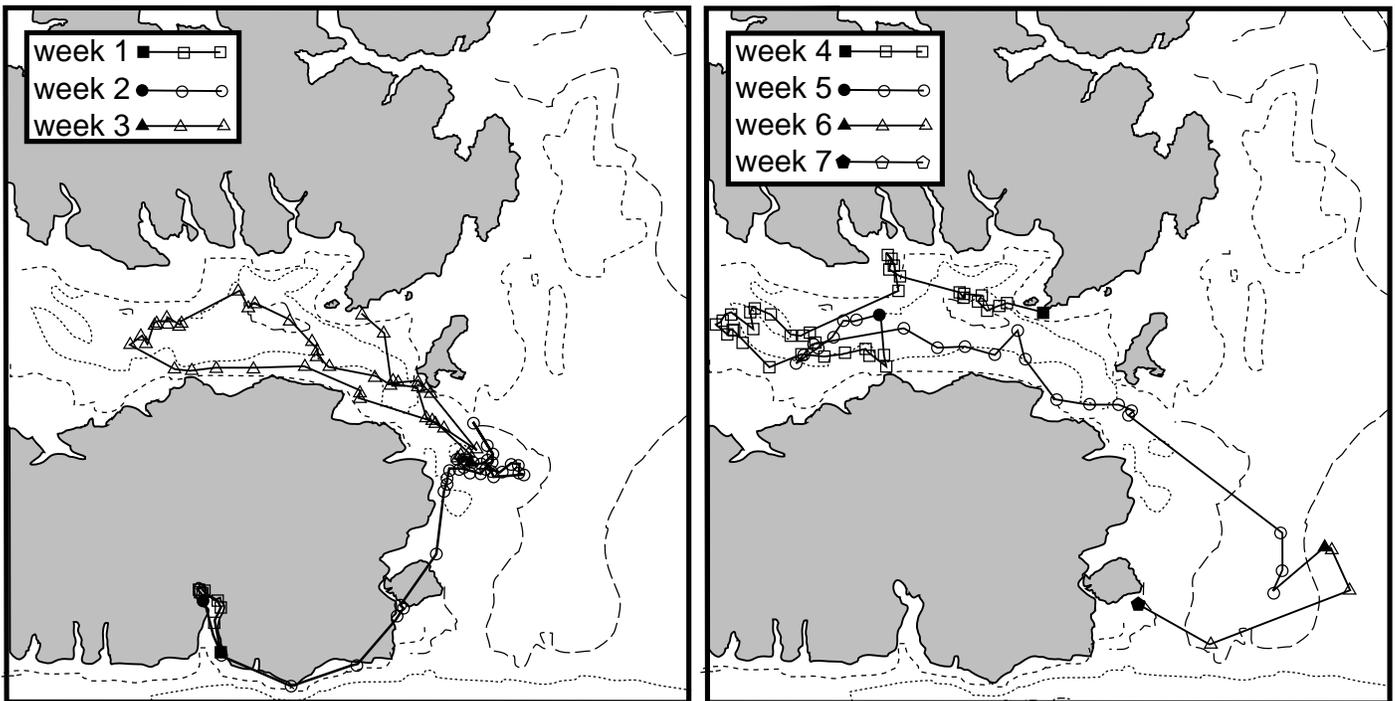
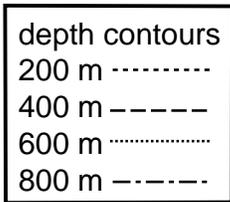
20689 F weeks 4 to 6

FIG. 3a and b. Weekly movements of the six tagged belugas, September to November 1995. The movement of each beluga is shown in two panels. Locations are plotted by calendar weeks (Sun-Sat). A different symbol is used to represent each calendar week. The first location in a calendar week is represented by a solid symbol; the remainder, by open symbols. Week 1 starts on 10 September 1995 and week 9 ends on 11 November.



C) 20690 F weeks 1 to 3

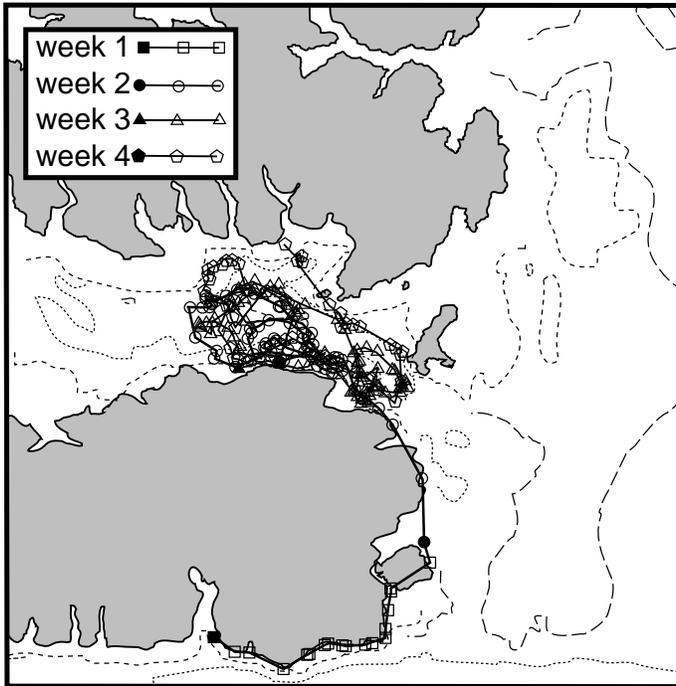
20690 F weeks 4 to 6



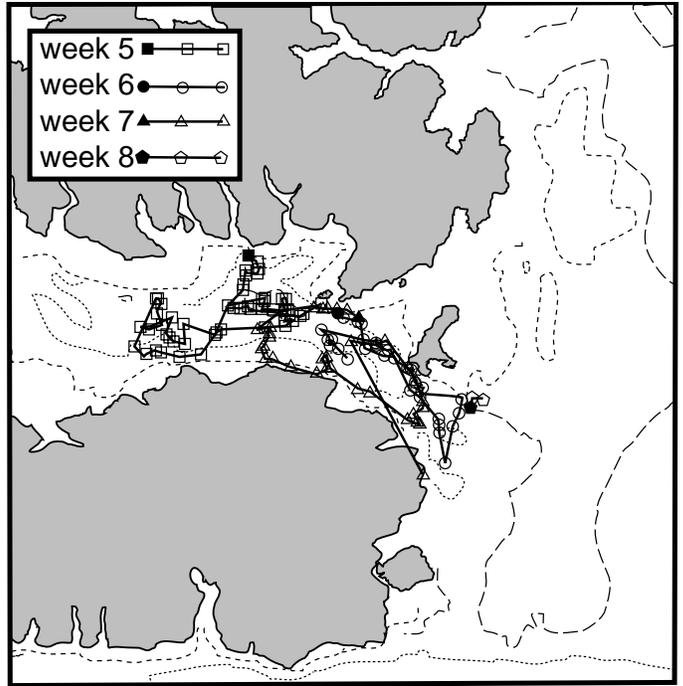
D) 20694 F weeks 1 to 3

20694 F weeks 4 to 7

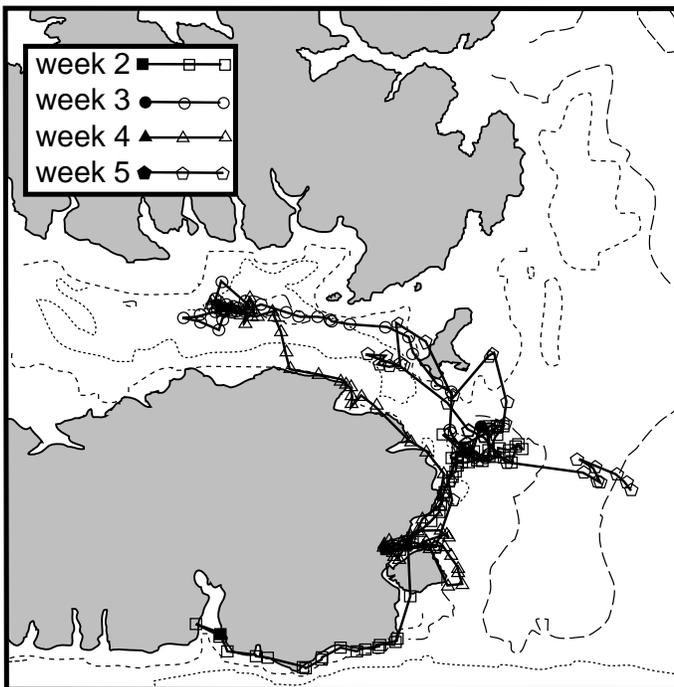
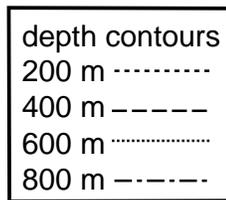
FIG. 3c and d. Weekly movements of the six tagged belugas, September to November 1995. The movement of each beluga is shown in two panels. Locations are plotted by calendar weeks (Sun-Sat). A different symbol is used to represent each calendar week. The first location in a calendar week is represented by a solid symbol; the remainder, by open symbols. Week 1 starts on 10 September 1995 and week 9 ends on 11 November.



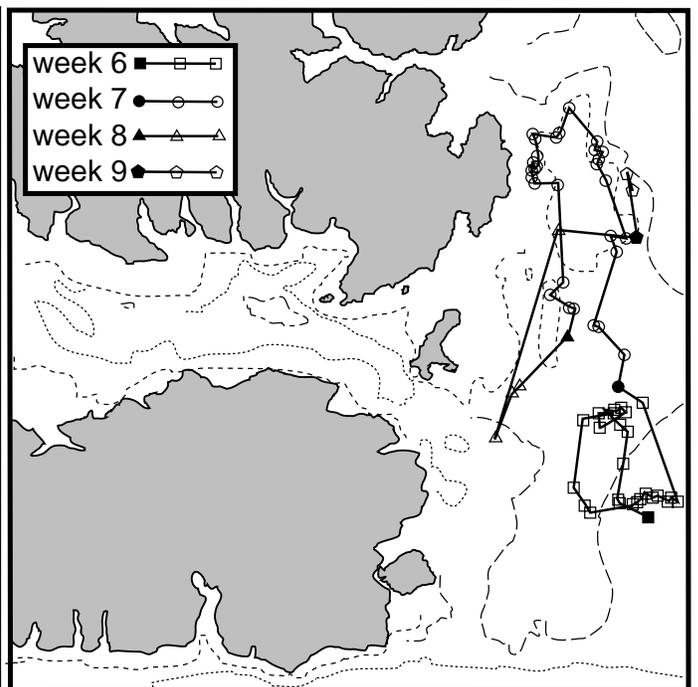
E) 20695 F weeks 1 to 4



20695 F weeks 5 to 8



F) 20696 M weeks 2 to 5



20696 M weeks 6 to 9

FIG. 3e and f. Weekly movements of the six tagged belugas, September to November 1995. The movement of each beluga is shown in two panels. Locations are plotted by calendar weeks (Sun-Sat). A different symbol is used to represent each calendar week. The first location in a calendar week is represented by a solid symbol; the remainder, by open symbols. Week 1 starts on 10 September 1995 and week 9 ends on 11 November.

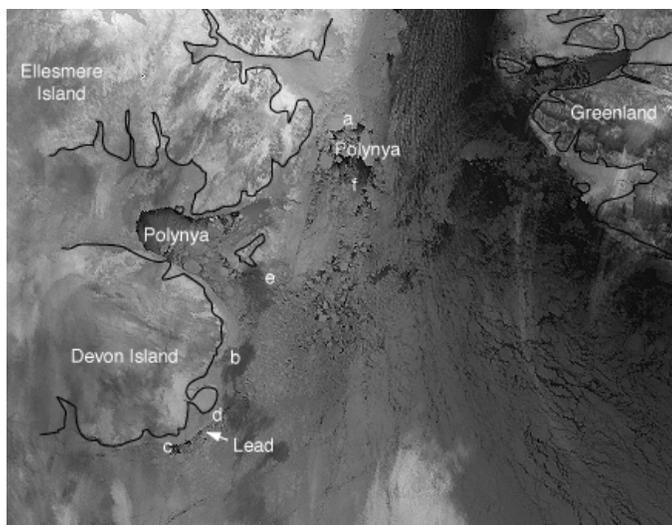


FIG. 4. NOAA satellite infrared image of the study area showing leads and polynyas of the North Water on 7 November 1995 (Source: Atmospheric Environment Service). Letters indicate the last recorded position of each animal: a) 20688M, b) 20689F, c) 20690F, d) 20694F, e) 20695F, f) 20696M.

Three areas were used by all six animals in the course of their movements: the southeastern shoreline of Devon Island, which all animals followed closely on their way east and north, and which was revisited by female 20690 in October; Lady Ann Strait and Jones Sound; and the waters southeast of Coburg Island. Two additional areas were used by some of the animals: Hyde Inlet, used by both males and female 20689; and the waters adjacent to Clarence Head, Ellesmere Island, used by both males.

Ice cover in the study area was greater than the median ice cover normally found at that time of year (Markham, 1981), and a lot of multiyear ice was mixed with newly formed ice. The tagged belugas traveled through ice cover varying between 2/10 and 9/10. Prior to ice consolidation (>9/10) in Jones Sound in early October, the whales moved to waters off eastern Devon Island, Coburg Island, and southeastern Ellesmere Island, where they could find ice leads and polynyas (Fig. 4).

None of the tagged belugas left Canadian waters during the period when the tags were operating, despite the fact that for all six whales transmissions lasted at least until mid-October, by which time belugas are typically seen migrating south along the West Greenland coast. Final recorded locations for all six whales came from the area of recurring winter leads and polynyas known as the North Water (Fig. 4).

### Swimming Speeds

In most cases, estimated swimming speeds ranged from under 1 km/h to about 10 km/hr (Fig. 5). A few speeds ( $n = 7$ ) were estimated at between 11 and 27.5 km/h. The mean swimming speeds of all animals combined decreased significantly from week to week (ANOVA  $p = 0.002$ ). Four of the six animals (20688M, 20690F, 20695F, 20696M) showed a decline in weekly mean swimming speed over their period of

transmission (Table 3). No swimming speeds greater than 6.3 km/h were recorded after October 15.

There was a significant interaction ( $p = 0.0001$ ) in the ANOVA model between individual beluga and time (week) because two animals (20689F, 20694F) differed from the rest. Female 20689's weekly mean speeds showed no trend, and female 20694 stayed in Croker Bay during her first week, with resultant low swimming speeds. Her swimming speed increased in week 2 during her migration along the coast of Devon Island and declined thereafter in weeks 3 and 4 (Table 3). The sample size for 20694 was too small in weeks 5 and 6 to allow useful comparisons.

## DISCUSSION

Soon after release, all but one of the tagged belugas moved to the eastern side of Devon Island, staying close to shore while migrating (Fig. 3). They occupied several bays of eastern Devon Island, such as Croker Bay, Bethune Inlet, Hyde Inlet, and unnamed bays opposite Lady Ann Strait, and later returned to these coastal areas after visiting Jones Sound. This coastal distribution pattern had previously been described by Koski and Davis (1979, 1980), who reported observing herds of hundreds and, in some cases, thousands of belugas along those shorelines and inside those bays. The fall concentrations of belugas in coastal areas of Devon Island may be related to the presence of arctic cod (*Boreogadus saida*), an important prey of belugas that occurs in large schools near shores in the Canadian High Arctic (Bradstreet et al., 1986). When discovered, such schools attract intense predation from birds and marine mammals, including belugas (Welch et al., 1993).

In deep fjords like Croker Bay, belugas may be foraging on other prey. Between 14 and 16 September, we observed hundreds of narwhals (*Monodon monoceros*) moving into Croker Bay. It is possible that both narwhals and belugas are attracted to Croker Bay by the same prey species. In addition to *Boreogadus saida*, narwhals are known to feed on Greenland halibut (*Reinhardtius hippoglossoides*) and on squid (*Gonatus fabricii*) in fjords of the Pond Inlet area (Finley and Gibb, 1982) and in Inglefield Bay, Greenland (Heide-Jørgensen et al., 1994).

All six tagged belugas spent between two and five weeks moving about eastern Jones Sound, Lady Ann Strait, and over the deep gully southeast of Coburg Island. The time-depth information shows that, while in those areas, the whales often dove to depths of 400–800 m or more, probably close to the seabed (Heide-Jørgensen et al., 1998). During those dives, it is probable that they were foraging for Greenland halibut, which usually occur at depths greater than 450 m (Scott and Scott, 1988). Greenland halibut remains have been observed by Grise Fiord hunters in ringed seal (*Phoca hispida*) holes and in the stomachs of hooded seals (*Cystophora cristata*) captured in Jones Sound (S. Akeagok, Grise Fiord, pers. comm. 1995). Other potential deepwater prey are the squid (*Gonatus fabricii*) and the octopus (*Bathypolypus arcticus*).

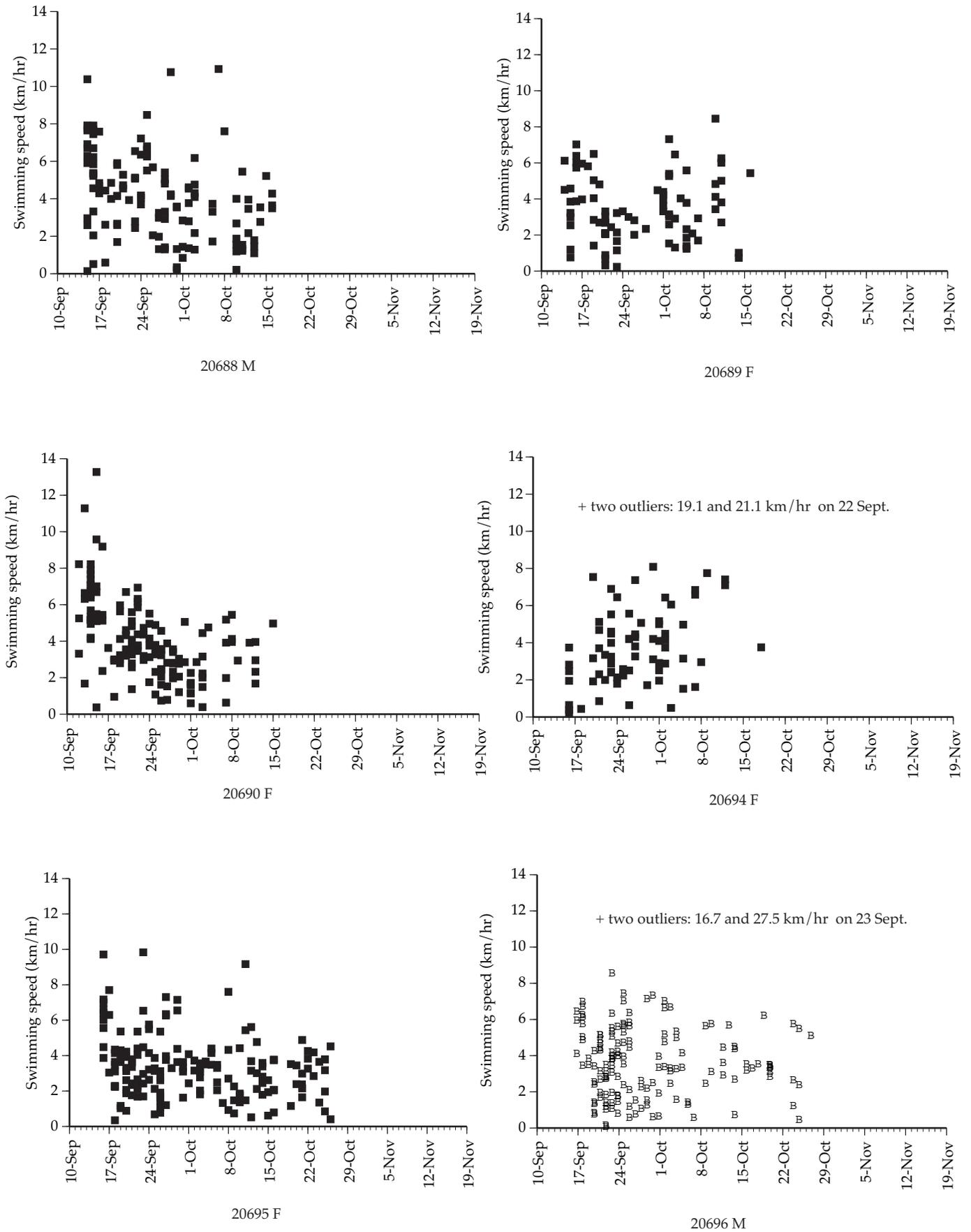


FIG. 5. Swimming speeds of tagged belugas over time.

TABLE 3. Mean weekly swimming speeds (km/h) of tagged belugas. Values are the mean, CV%, and (number of samples).

Beluga	WEEK							All weeks
	1 Sept 10–16	2 Sept 17–23	3 Sept 24–30	4 Oct 1–7	5 Oct 8–14	6 Oct 15–21	7 Oct 22–28	
M 20688 465 cm	5.3 47% (28)	4.9 34% (27)	2.9 53% (29)	4.6 65% (10)	2.7 55% (21)			4.1 21% (115)
F 20689 404 cm	4.4 42% (17)	2.5 56% (27)	3.7 39% (16)	2.9 57% (13)	4.3 51% (12)			3.4 20% (85)
F 20690 368 cm	5.6 42% (38)	4.0 33% (46)	2.4 45% (33)	3.1 52% (15)	3.3 37% (6)			4.0 17% (138)
F 20694 372 cm	1.6 85% (8)	4.7 102% (26)	4.1 41% (26)	4.2 61% (10)	7.3 3% (2)	3.8 0% (1)		4.1 39% (73)
F 20695 392 cm	4.7 48% (21)	3.4 49% (47)	3.5 53% (29)	3.0 49% (23)	3.0 62% (27)	3.1 34% (14)	2.6 57% (9)	3.4 14% (170)
M 20696 408 cm	5.7 20% (11)	4.0 94% (67)	3.5 65% (29)	3.4 52% (15)	3.8 36% (12)	3.7 27% (9)	3.4 64% (7)	3.9 24% (150)

All six tagged belugas left Jones Sound before week 6 (15–21 October), avoiding entrapment in the consolidating pack ice. Consolidated pack ice can form over all of Jones Sound as early as mid-October (Markham, 1981), and there are reports of past ice entrapments of belugas in Jones Sound which have resulted in mortality (Freeman, 1968; S. Akeagok, Grise Fiord, pers. comm. 1995).

The six tagged belugas remained in the waters east of Ellesmere, Coburg, and Devon Islands until their tags stopped transmitting. This area, known as the North Water (Smith and Rigby, 1981), has recurring leads and polynyas throughout winter where belugas are known to occur (Finley and Renaud, 1980; Richard et al., 1998). Therefore, in late October and November, the distribution of belugas was probably determined by the availability of open leads or cracks in the pack ice, as observed during winter aerial surveys of the North Water (Finley and Renaud, 1980; Richard et al., 1998). Both males traveled farther north along and off Clarence Head. This segregation between males and females could be due to the fact that all four females had calves with them and may have been less inclined than males to venture away from the predictable open leads off eastern Devon Island (Fig. 4).

Although we tracked animals only into October–November, we think that the tagged animals remained in the North Water for the winter, for two reasons. First, they stayed there well beyond the time when belugas are normally observed migrating along the West Greenland coast (Heide-Jørgensen, 1994; M.P. Heide-Jørgensen and A. Rosing-Asvid, Greenland Institute of Natural Resources, Copenhagen and Nuuk, unpubl. data). Second, the reduction in swimming speeds in October noted above and the decline in surface times and dive rates reported by Heide-Jørgensen et al. (1998) are what we expected to observe from belugas settling into their wintering area. Another possibility is that the belugas migrated to Greenland later in the winter, at a time when belugas would

go unnoticed by residents of northern West Greenland because of the darkness and heavy ice.

The timing of our live captures could have influenced the results if belugas that migrate to Greenland move along the southern coast of Devon Island earlier than those that winter in the North Water. We had timed our captures for early to mid-September to match the timing of migration of Somerset Island belugas in Lancaster Sound reported by other authors (Koski and Davis, 1979, 1980; Smith and Martin, 1994). However, two weeks before our expedition, on 28 August 1995, a pod of belugas was seen in Jones Sound by Grise Fiord residents, (D. Akeagok, Grise Fiord, pers. comm. 1995). Also, during the 10–11 September flights over Croker Bay (i.e., 3–4 days before we captured our first beluga there), we observed several thousand belugas in the bay. Therefore, the animals we sampled may not have been representative of all migrants. Thus our relatively small sample, which may have included some animals belonging to the same pods, is of limited value for describing the migratory behaviour of Baffin Bay belugas in the fall. There is a need to tag more animals to answer the question about movements to Greenland.

None of the beluga tags reached their full potential of 54000 transmissions at 0°C (Wildlife Computers, 1994). Furthermore, the diagnostics sent by the tags gave no indications that a drop in battery voltage was responsible for the cessation of transmissions. Therefore, we assume that transmissions ended because of tag loss. The longevity of our tags (mean number of days between first and last position = 42, Table 1) is comparable with longevity in other satellite-tagging projects on monodontids. For example, backpack transmitters of the same design put on five narwhals by Dietz and Heide-Jørgensen (1995) gave positions between 2 and 41 days (mean = 25 days). Tags with a different design used in the Beaufort Sea by Richard et al. (1997) gave positions between 7 and 91 days (mean = 41 days).

The declining trend in good-quality locations in our tags may not be the result of deteriorating tag performance, since the power diagnostic data sent by the tags did not show a sufficient decline in power output. This decline in locations could be due in part to the seasonal trend in the belugas' activity and in part to the progressive detachment of the tags, which would affect antenna orientation. In October and November, the average time belugas spent at the surface was about half as much as in September (Heide-Jørgensen et al., 1998). Signal interference by ice could also be a contributing factor.

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