Autumn space-use patterns of humpback whales (*Megaptera novaeangliae*) in West Greenland

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ABSTRACT

Five humpback whales were tagged with satellite transmitters on their summer feeding grounds in West Greenland in August between 2002 and 2005. Tracking durations lasted between 13 and 111 days and the locations obtained from the whales provided the first insight on the autumn distribution patterns of this species in West Greenland. Whales demonstrated a consistent pattern of rapid and long-distance movements along the West Greenland coast separated by longer-term, focal area use where feeding occurred. Humpback whales in West Greenland feed on capelin (*Mallotus villosus*), sand eels (*Ammodytes* sp.), and krill and these three prey species require different foraging strategies. Generally whales showed high affinity to the coast due to shallow aggregations of capelin. However some use of offshore regions was detected, likely due to concentrations of sand eels. One whale crossed Baffin Bay to Baffin Island, an area not known to support humpback whales. The rapid movements of humpback whales between feeding sites in Greenland and Canada may be a response to variable and dynamic prey resources throughout the summer and autumn seasons.

KEY WORDS: SATELLITE TAGGING, MOVEMENTS, HUMPBACK WHALES, GREENLAND; NORTHERN HEMISPHERE; FEEDING; FOOD/PREY; MOVEMENTS

INTRODUCTION

Humpback whales (*Megaptera novaeangliae*) are one of the characteristic species of baleen whales found in West Greenland. They arrive predictably from southern breeding grounds in May and remain in the area at least throughout autumn. Humpback whales occur seasonally in areas such as Disko Bay and Paamiut, yet may also occur year round at other coastal sites such as Nuuk Fjord. Resightings of individual whales indicate that the West Indies is the main breeding ground for whales that feed in West Greenland (e.g. Stevick *et al*., 2003). As discussed below, the abundance off West Greenland is estimated to be over 1,000 animals (e.g. see Heide-Jørgensen *et al*., 2007; IWC, In press).

Humpback whales utilise several different prey species in West Greenland, particularly sand eels (*Ammodytes* sp.), krill and capelin (*Mallotus villosus*). Between 1959 and 1976, 22% of stomachs sampled contained sand eels (Kapel, 1979), a species which occurs in large abundance on the banks off West Greenland at depths ranging between 50 and 200m. Additionally, 42% of the stomachs contained capelin, a small forage fish that moves inshore to spawn in the littoral zone in summer. Humpback whales have been observed to make bubble curtains and lunge feed around these surface schools of capelin. Few capelin are found offshore on the banks, as shown by an acoustic survey covering West Greenland from Kap Farvel to Disko Island in 2005 (GINR unpubl. data). Krill and plankton also form a significant part of the humpback whale diet in West Greenland, 28% of stomachs contained krill and 8% a mix of prey (Kapel, 1979). Northern krill (*Meganyctiphanes norvegica*) occur in high densities on coastal areas of the banks, peaking at 65°N (GINR unpublished data). Observations of bright orange defaecation from humpback whales in West Greenland during an aerial survey in September 2005 also confirm that this is an important prey item.

Little is known about the movements of humpback whales around Greenland or how whales move between foraging sites. Identifying focal areas where humpback whales frequently occur and forage in summer is important for both understanding how whales use the coast of West Greenland and for future work to identify critical prey species concentrations. Furthermore, large changes in physical oceanography have been identified along the banks of West Greenland. Sea surface temperatures (0-40m depth) have dramatically increased over the past 50 years, with maximum recorded value of 3.8°C in 2005 (Ribergaard *et al*., 2006). Thus, it is important to identify feeding grounds for humpback whales in order to more closely monitor changes in the local hydrology and how those changes might manifest themselves on prey species. This study reports on satellite tracking of humpback whales in West Greenland between 2002 and 2005 with the purpose of describing movement patterns and focal area use sites with respect to potential prey resources.

METHODS

Daily searches for whales were conducted from small boats in Nuuk Fjord between 20 August and 22 September 2002 and 17 and 31 August 2003, as well as near the town of Qeqertarsuaq, Disko Island, between 9 and 18 August 2005 (Fig. 1). When a whale was sighted the boat moved towards the whale until it dove. The process was repeated again until the whale was surfacing in a predictable manner, which usually took less than half an hour. Tags were deployed when the whale was positioned alongside the boat, 4-5m away and when the whale remained at the surface long enough to place the tag in a good position.

The humpback whales were tagged using two different configurations of satellite-linked radio transmitters. In one configuration, transmitters (SPOT2, Wildlife Computers,

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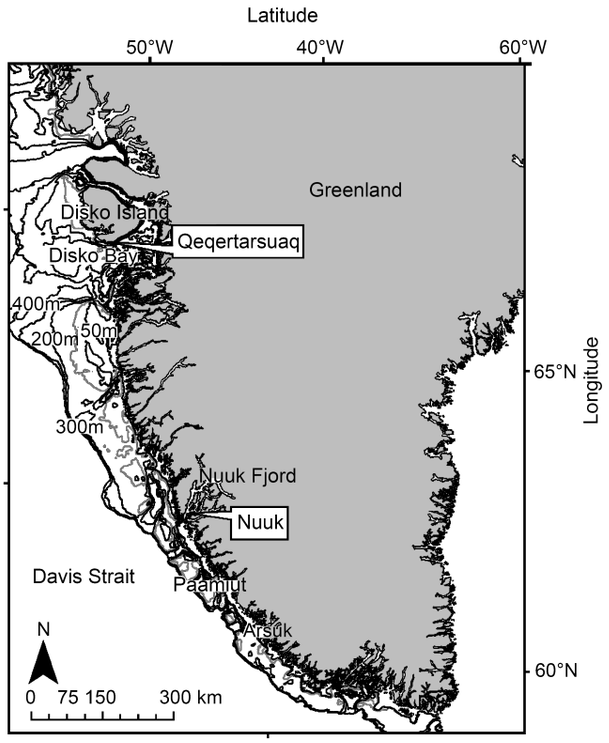

Fig. 1. Map of the West Greenland coast and localities mentioned in the text.

Redmond, Washington) were equipped with two M1 lithium thianyl batteries and glued to a cup-shaped stainless steel base (referred to as 'can tags'). The 'can' dimensions were 45×32mm. The anchor was a 33cm titanium spear (diameter 8mm) welded to the can and equipped with three foldable leaf-like barbs and a sharp pointed tip. The can tags had an expected battery longevity of 20,000 transmissions and were programmed to provide 250 transmissions every other day. A second configuration had the transmitter (SPOT3 and 5) and a single AA-cell mounted in a 10cm long and 2cm wide stainless steel cylinder (referred to as 'implant tags') connected to a 13cm spear with one set of barbs and a triangular double-edged blade. This tag provided 50,000 transmissions.

All tags in 2002 and 2003 were deployed using an 8m fibreglass pole. The tag was mounted on the tip of the pole and secured by a nylon line in case of failed deployments. The titanium spear was pushed through the skin and into the blubber and once the tag was implanted the nylon line was cut by a sharp edge on the pole. The tags in 2005 were deployed with the 'ARTS' (Air Rocket Transmitter System), a pneumatic air gun (see detailed description in Heide-Jørgensen *et al.,* 2001). All satellite tags were positioned high on the whales' back so that transmissions could be received by the satellite.

Locations were collected using the Argos System (see Harris *et al*., 1990). Location qualities were provided by Service Argos and coded based on predicted accuracy. Location codes were LC B, A and 0-3 in order of increasing accuracy of position. All location qualities received on a particular day were used to calculate an average daily position for each whale over the entire tracking period. Average daily positions were mapped and tracklines were created for individuals whales.

RESULTS

Ten humpback whales were tagged with satellite transmitters in August 2002-05 in West Greenland. Five of the instruments provided only short-term data or lasted for less than five days and thus are not reported here. Of the remaining five, three tags provided data for <20 days (Table 1) whereas two tags provided information on movements for up to 111 days.

All whales demonstrated the typical movement pattern of rapid and long-distance movements between specific foraging sites, either coastal or offshore. Whales remained localised at these foraging sites for anywhere between one week to one month before again rapidly moving to another site along the coast. Focal sites were Disko Bay and Nuuk Fjord.

In 2002, two humpback whales were tagged in the Nuuk Fjord. Contact was lost with both whales within three weeks, however both animals had moved quickly out of the Nuuk Fjord and headed south, with some residency time in the outer part of the Nuuk archipelago (Fig. 2).

In 2003, two whales were also tagged in the Nuuk Fjord area. One whale tagged on 17 August (no. 20690-03) moved immediately from West Greenland across Baffin Bay, northwest to Exeter Sound on the east coast of Baffin Island (Fig. 3). It spent about a week at this site before heading northwest back to Greenland into Disko Bay. When it returned to Greenland, it travelled to Green Island (Grønne Ejland) in eastern Disko Bay before moving to the south coast of Disko Island. The whale spent almost three weeks within a few kilometres of the shore, where dense schools of capelin occur on the coast each year (Fig. 4). It departed Disko Bay and took a direct offshore route to the Arsuk area. The whale returned to the Nuuk Fjord around mid-November and remained at this site until contact was lost.

The second whale tagged on 25 August 2003 in Nuuk Fjord (no. 20692) went south along the coast and reached the same area in south Greenland (around Arsuk) in early September as visited by whale no. 20690 in 2003 (Fig. 5). In early October this animal returned north to Nuuk Fjord and remained at this site until 11 November, when contact was lost.

Table 1

Humpback whales tagged with satellite transmitters in August in West Greenland between 2002 and 2005. Position of the satellite transmitter on the whale is indicated by L and R (left or right), F, M, or B (forward of midline, midline, or behind midline) and H or L (high or low).

ID number	Day	Year	Estimated length	Tagging position	Transmitter type	Deployment	Position on whale	Duration of contact	Average speed km day^{-1}
20690-02	24	2002	~13m	64°03,780 51°40,230	Can	Pole	RHM	18	10.5
20689	29	2002	~14m + calf	3nm north of Nuuk	Can	Pole	RHM, 30cm under dorsal fin	13	27.2
20690-03	17	2003	~12-14m	64°10,113 51°50,860	Implant	Pole	RBH	111	30.1
20692	25	2003	~14m	64°12,720 51°42,339	Implant	Pole	LMH	75	23.3
21810	11	2005		69°14,350 53°40,222	Implant	ARTS		14	54.9

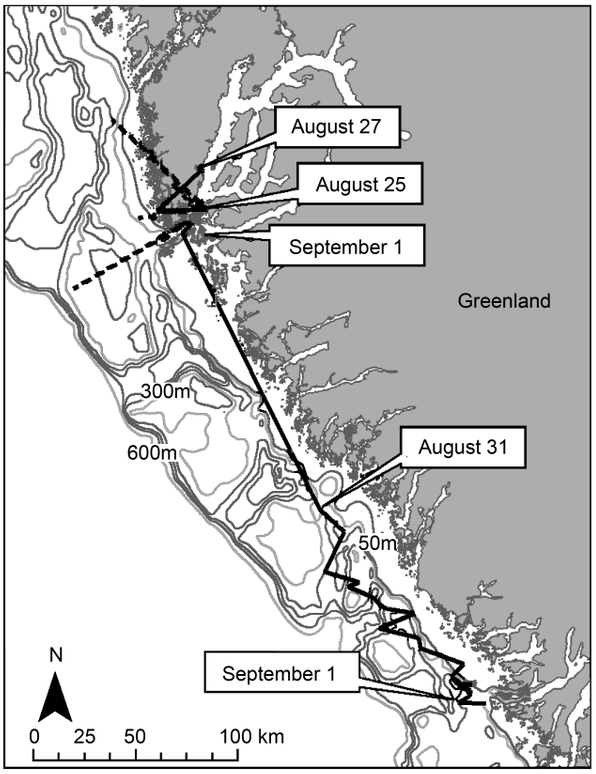

Fig. 2. Movement patterns of humpback whale no. 20689 (solid line) and no. 20690-02 (dashed line) on 29 and 24 August 2002 in Nuuk Fjord, West Greenland.

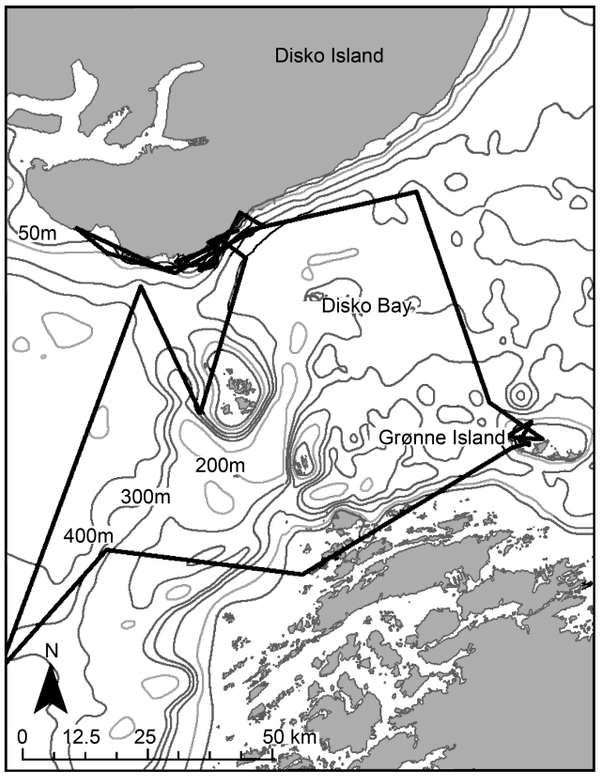

Fig. 4. Coastal area use of a humpback whale (no. 20690-03) in Disko Bay, West Greenand (see Fig. 3 for full track).

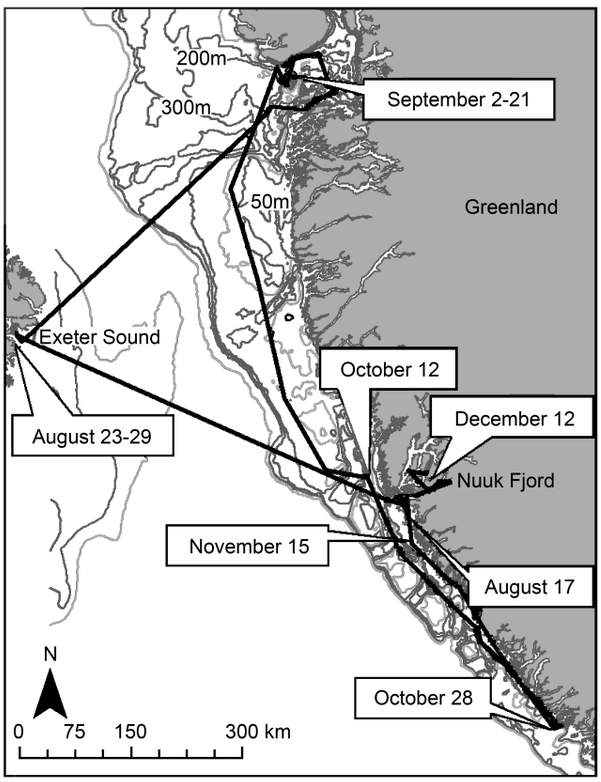

Fig. 3. Movement patterns of humpback whale no. 20690-03 tagged on 17 August 2003 in Nuuk Fjord, West Greenland.

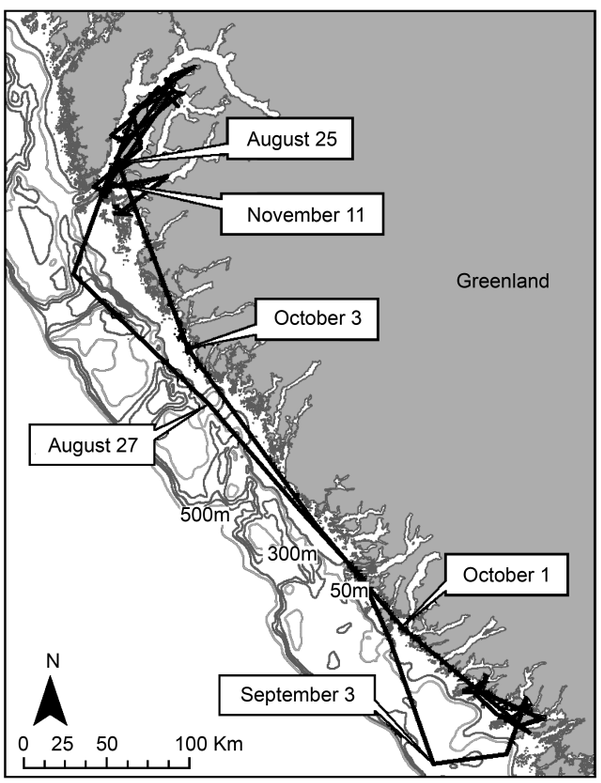

Fig. 5. Movement patterns of humpback whale no. 20692 tagged on 25 August 2003 in Nuuk Fjord, West Greenland.

In 2005, one whale was tagged on 11 August 2005 near Disko Island (no. 21810). This whale immediately travelled south across the West Greenland banks and stopped at Nuuk (around 19 August), before continuing south until contact was lost on 25 August (Fig. 6).

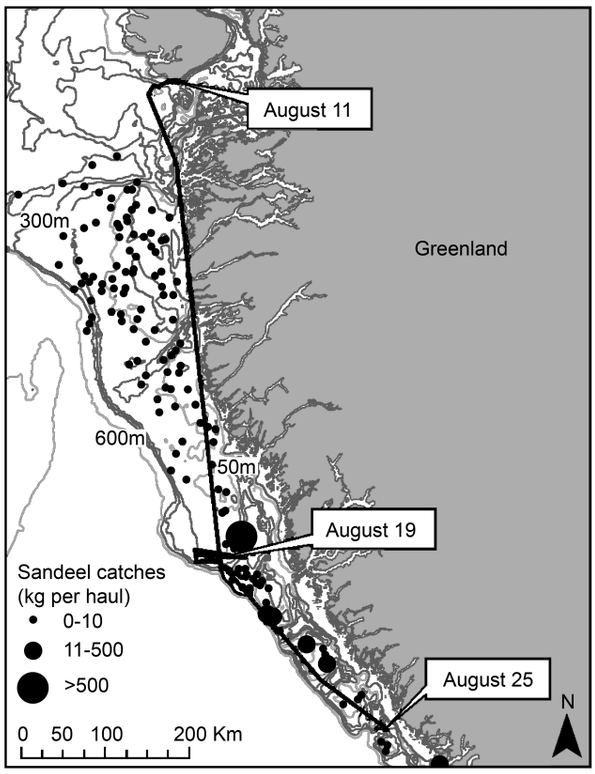

Fig. 6. Movement patterns of humpback whale no. 21810 tagged on 11 August 2005 near Disko Island, West Greenland. Concentrations of sand eels (*Ammodytes* sp.) estimated from bycatches from standardised scientific trawl (30min hauls) samples for northern shrimp (*Pandalus borealis*) are indicated by dots (GINR unpublished data).

All whales covered long distances (>200km) over the relatively short tracking periods and made rapid shifts between focal areas, where they were then stationary for several days to weeks at a time. With the exception of one animal tracked in 2005 (no. 21810) whales used areas very close to the shore (e.g. Fig. 4). Whale no. 21810 made a brief stop on the banks off Nuuk, a site where high concentrations of sand eels occur, as demonstrated from bycatches during standardised scientific trawl samples for northern shrimp (*Pandalus borealis*) (GINR unpubl. data).

The average daily speed of each whale, determined from the distance between daily average positions, varied between 10 to 55km^{-1} day (Table 1). Speeds were as high as 200km^{-1} day for long-distance travel (i.e. across Baffin Bay) and for offshore movements along West Greenland (see Fig. 7, no. 20690-03). Travel in coastal areas was considerably slower, indicating these areas were either explored at a different spatial scale or used as feeding grounds. Offshore areas, with the exception of no. 21810, were only used for migrating between feeding sites.

DISCUSSION

Movements

Humpback whales evidently use a large range along the West Greenland coast for summer foraging activities and do not appear to be stationary in any particular area for more than a month. There are clearly some preferred sites for foraging, these include Disko Bay, Nuuk Fjord and the Arsuk area and all whales tracked rapidly shifted between preferred sites. Previous photo-identification population estimates were based on sampling in three areas in West Greenland: an area off Nuuk, an area at approximately 63°30'N; and an area off Paamiut (Larsen and Hammond, 2004). Abundance in these areas was estimated at 360 (95% CI=314-413) in 1988-93. None of the whales tracked in this study spent time in the vicinity of these three areas and, assuming no major changes in distribution over time, the population estimates from 1988-93 would inadequately cover the current range of humpback whales in West Greenland and thus be underestimates. More recent abundance estimates obtained on aerial (1,218; 95% CI=423-3,508) and ship-based surveys (1,306; 95% CI=570-2,989) in 2005 provide better total coverage of the area used by humpback whales in summer and this could, together with a population increase between the surveys, explain the higher abundance estimates in 2005 (Heide-Jørgensen *et al*., 2007).

Both humpback whales tagged in 2003 used nearly all of the Nuuk Fjord and movements extended into the far reaches of this site. The extensive travels in the complex fjord system at Nuuk in autumn are probably related to searching for schools of capelin. Whales have been observed lunge feeding at this site in summer and capelin are clearly the target prey species. This is also in agreement with the almost year-round observations of presumably young immature humpback whales in the fjord (GINR unpublished data).

The movement of one whale across Baffin Bay is the first evidence that humpback whales occur on the east coast of Baffin Island. This also demonstrates that West Greenland humpback whales may be connected to other less well defined humpback whale feeding concentrations in northeast Canada.

Relation to food resources

Many inshore areas in West Greenland are known for their conspicuous abundance of spawning capelin in the shallows during summer. The south coast of Disko Island, the area around Grønne Ejland, the Nuuk Fjord and the area at Arsuk in South Greenland are all particularly well known as capelin concentration areas with good feeding opportunities for humpback whales. Movements of whales in this study support the idea that humpback whales target these concentration sites. Scientific acoustic surveys for capelin have failed to find any major offshore concentrations of capelin in late summer of 2005 (GINR unpublishead data). Nearly all capelin detected on dedicated surveys have been found in coastal and shallow areas. However, bycatch data in scientific trawl studies have shown that some capelin are indeed present in the deep trenches between the banks and on the western slopes of the banks. However these capelin occur at >400m and are likely an inaccessible prey source for foraging humpback whales. Thus, it is likely that the movements and area use patterns of humpback whales in West Greenland are largely dictated by the coastal occurrence of capelin in surface waters of inshore shallow

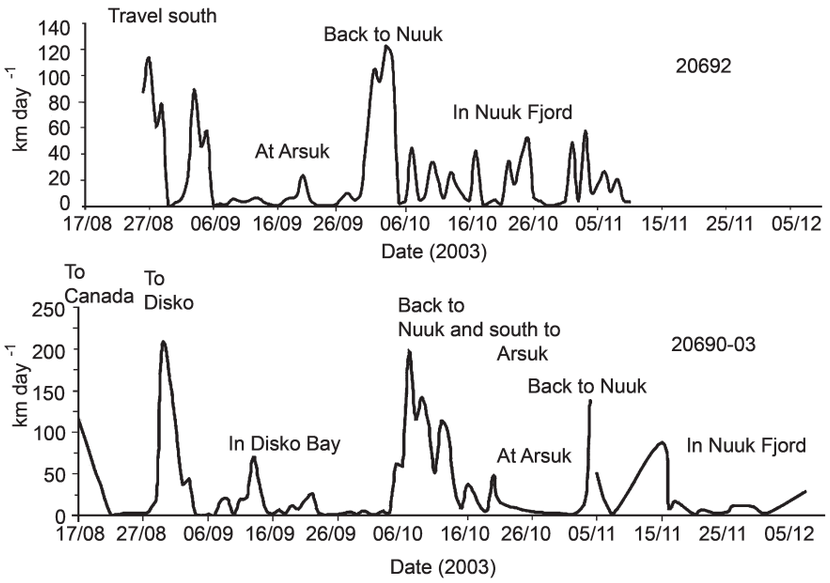

Fig. 7. Changes in daily speed (km day^{-1}) of two humpback whales calculated from differences in daily average positions.

(<100m) areas in summer. In the autumn, capelin schools are supposedly more dispersed and in deeper waters, thus humpback whales must search more actively.

Bottom dwelling sand eels are another likely food source for humpback whales in West Greenland. These fish occur in specific areas on the offshore banks, however are a less optimal prey species (with respect to capelin) because they do not occur in similarly dense schools. Furthermore, they are usually found at deeper depths (50-200m) and they never occur in spawning swarms on beaches. The trackline of a whale tagged in 2005 paused over an area with particularly high concentrations of sand eels, however, the extent to which humpback whales may prefer this prey item over capelin is unknown.

Sightings of humpback whales on Baffin Island have not previously been reported and it was unexpected that a whale tagged in Greenland immediately moved from the productive West Greenland shelf to the Baffin Island coast. It is possible some capelin resources occur in inshore areas of the east coast of Baffin Island, however the only other alternate prey sources available would be schools of polar cod or copepods and krill. A high abundance of capelin has not been documented along the coast of Baffin Island, however, capelin have been visually observed in Cumberland Sound on East Baffin (E.W. Born, pers. comm.). This area is about 200km south of where the whale tagged in Nuuk was located along the coast.

Satellite tracking of individual whales is an ideal technology for the quantification of space use patterns of cetaceans. This study, although limited in sample size, clearly demonstrates the potential of the technique. The whales moved quickly over large areas probably exploiting food resources both at specific coastal sites and offshore on the banks. The rapid and directional movements of the whales between specific sites suggest previous experience with localities with predictable food resources. Although humpback whales have three very different prey types available for summer feeding in West Greenland, they seem to be able to shift between habitats where one or more of these prey can be found. These shifts are probably in response to the fluctuating and somewhat unpredictable nature of the occurrence of these prey species in the dynamic West Greenland ecosystem. Unlike most other North Atlantic large marine ecosystems, the West Greenland ecosystem borders the high Arctic and the sub-Arctic and is highly susceptible to small changes in inflow of warm water from the Irminger current along southwest Greenland. Extensive changes in sea surface temperatures in this area likely impact recruitment and distribution of prey resources utilised by humpback whales. It is not known how these prey populations, and thus the whales, will respond to these changes.

This study reports on the first movement data collected from humpbacks on their summer feeding grounds in West Greenland. Humpback whales also feed at three other sites in the North Atlantic: the Gulf of Maine, eastern Canada, and the eastern North Atlantic (Stevick *et al*., 2001). Mark-recapture studies of movements of animals at these other sites also confirm high site fidelity to focal areas interspersed with long-distance movements. None of these other aggregations have been satellite-tracked therefore is it unknown to what extent their movements, travel speeds or travel distances are similar to the whales on their feeding grounds in West Greenland.

ACKNOWLEDGEMENTS

This study was funded by the Mineral Resources Administration in Greenland and the Greenland Institute of Natural Resources. Mikkel Villum Jensen, Anders Villum Jensen, Malene Simon and Hans Christian Schmidt conducted the tagging of the whales.

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Date received: October 2006
Date accepted: June 2007