Inshore-offshore movements of two fin whales (*Balaenoptera physalus*) tracked by satellite off West Greenland

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ABSTRACT

Two fin whales (*Balaenoptera physalus*) were tagged with satellite linked radio transmitters in a costal area near Aasiaat in West Greenland and tracked for 76 and 32 days in 2000 and 2001 respectively. In 2000, one whale was tagged on 30 September; it stayed in the tagging area until at least 13 October. On 16 and 17 October it was found further south off the coast of West Greenland. On 20 October it had moved approximately 250km southeast to another inshore area. It moved another 100km south along the coast and up to 50km off the coast until 2 November, then appeared back in the area it was located on 20 October until contact was lost on 20 December. In 2001, one whale was tagged on 24 August, it stayed in the coastal area until mid September, where it travelled south along the coast to an area approximately 100km off the coast. From here it continued south to the same inshore area occupied by the whale in 2000. It remained in this area until the last position was received on 25 September. The tracking data suggest a connection between inshore and offshore (> 22km) fin whales and indicates the potential range of fin whales in West Greenland.

KEYWORDS: FIN WHALE; SATELLITE TRACKING; TELEMETRY; MOVEMENTS

INTRODUCTION

A main factor of uncertainty in recent assessments of fin whales (*Balaenoptera physalus*) in the North Atlantic (e.g. IWC, 1991; 1992; 1999; NAMMCO, 1998; 2000) is the question of stock identity. In relation to the aboriginal harvest that is conducted in the coastal areas (< 22km) of West Greenland, it is important to gain insight into the stock discreteness of fin whales found in coastal and offshore areas.

Berubé *et al.* (1998) found that genetic studies suggest more than one breeding stock of fin whales in the North Atlantic, but they were unable to distinguish between fin whales from West Greenland and adjacent areas. Although a considerable amount of data on the occurrence of fin whales off West Greenland have been collected during both the commercial and the aboriginal whaling operations (Kapel, 1984; Witting, 2000) as well as dedicated sighting surveys (e.g. Larsen *et al.*, 1989; Larsen, 1995), no data exist on the relationship between the inshore (< 22km) and offshore (> 22km) occurrences of fin whales in West Greenland. This study used satellite telemetry on tagged fin whales in West Greenland in the autumn, to examine the local movements within the West Greenland area.

In contrast to traditional tagging methods, satellite tracking of whales offers direct insight into the movements, travel speed and habitat utilisation of the whales. Satellite tracking also allows collection of information from areas and seasons where it is logistically difficult to locate whales. Finally, satellite tracking does not depend on recaptures of whales thus it can be conducted without a simultaneous harvest operation. Genetic studies provide additional information but depend again on sampling programmes restricted by logistics. The main problem with satellite tracking of baleen whales is that the longevity of the tags is either restricted by the ability to maintain them on the whales or by battery drainage. Recent results suggest however that it is possible under optimal conditions to maintain the tags on the whales for the entire period of the battery life and perhaps long after (Heide-Jørgensen *et al.*, 2003). Tags need to be small to be successful and battery power is restricted to what can be housed in small transmitter packages.

MATERIALS AND METHODS

The satellite transmitter used was a ST-15 (Telonics Inc.) transmitter unit equipped with two lithium thianyl batteries (M1) that was pre-programmed to be on for 24 hours and off for 72 hours. It had a salt water switch that only allowed transmission if the transmitter was out of the water for more than approximately 250ms. The repetition period of the transmissions was 45s. The transmitter was cast in epoxy in the shape of a cylinder 110mm in length and 28-35mm in diameter. The antenna extended from one end of the transmitter while the other end was glued to a stainless steel cup. In 2000, this cup was mounted on an 8mm diameter stainless steel dart 27cm in length equipped with two barbs (Fig. 1). In 2001, the cups were mounted on an 8mm diameter titanium dart 33cm in length equipped with three barbs (Fig. 1). The barbs act to anchor the dart in the blubber and muscle layers below the skin. The stainless steel cup acts as a flange that stops the transmitters from penetrating through the skin.

The transmitters were launched with the Air Rocket Transmitter System (see Heide-Jørgensen *et al.*, 2001a), a modified gun-shaped line-thrower powered by compressed air from a scuba tank. The 'rocket' consisted of the transmitter in combination with a finned tailpiece. The tailpiece provides stabilisation during flight as well as flotation, ensuring retrieval of the transmitter in case of a missed hit. The tailpiece is loosely attached to the transmitter so that it falls off after attachment to the whale. The pressure

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A

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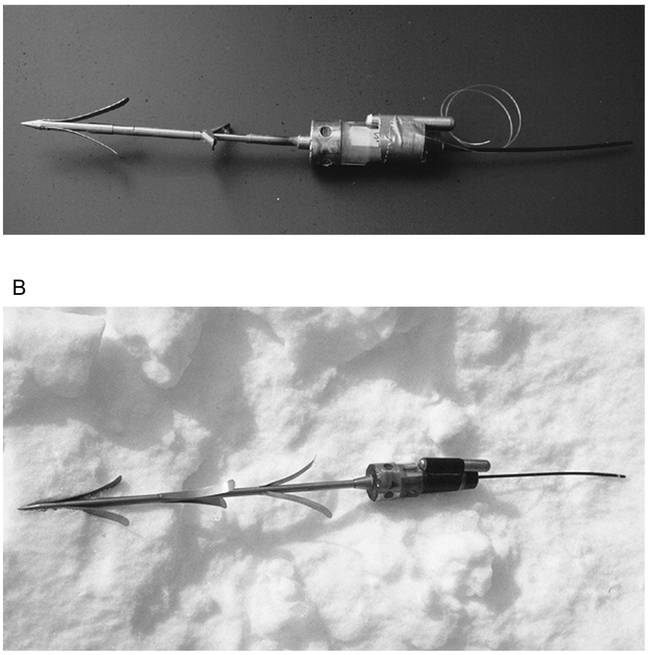

Fig. 1. Transmitter used for the fin whale tags in 2000 (above) and 2001 (below). The magnet attached with tape is removed before launching and the nylon line secures the tag in case of misses. The 2000 model had an adjustable stainless steel spear of 27cm with stainless steel barbs and the 2001 model had a fixed titanium spear of 33cm with stainless steel barbs.

(chosen in advance) and distance to the fin whale when the rocket was launched was 12 bars and 12m in 2000, and 14 bars and 15m in 2001.

The tagging operation in West Greenland was conducted from a 5.1m rigid hull inflatable (*Yonah*) with a 40hp outboard motor, a steering panel, and a maximum speed of 24 knots in 2000, and a 5m aluminium boat (*Arfivik*, model Buster L) with a 50hp outboard motor and a maximum speed of 34 knots in 2000 and 2001.

Positioning was facilitated through Service Argos Data Collection and Location Service. Location data were obtained from five classes of precision: 2, 1, 0, A and B. Positions of class 1-2 have an estimated precision (standard error) of <1km with class 2 being the best (Service Argos, *in litt.*). Experimental studies however indicate that for tracking of marine animals, slightly lower precision can be expected for all three location classes (Hays *et al.*, 2001; Vincent *et al.*, 2002). For tracking of marine mammals, it is important to note that the precision of class 0, A and B locations has not been specified by Service Argos. Precision of location class 0, A and B has been tested experimentally in two studies and apparently class A has a higher precision than both class 0 and class B and the precision of class A position may approach the precision of class 1 positions (Hays *et al.*, 2001; Vincent *et al.*, 2002). Hays *et al.* (2001) found that the distance of class 0 and B positions to the actual position was 10 and 7km on average, however, the longitudinal error is usually larger than the latitudinal (Vincent *et al.*, 2002). In any case all three classes of low precision positions contribute important information to the tracks of the whales and the errors seem insignificant relative to the scale of the movements.

In order to reduce the importance of the errors in the low-precision location data, an average position was calculated on the basis of all positions for each day (24hr periods) with data. These means deviated from the occasional positions of good precision (quality 1 and 2) by an average of 5km ($SD=0.8$, $n=6$) in 2000 and 7km ($SD=1.8$, $n=7$) in 2001.

The distribution of inshore catches (1988-1999) and offshore sightings of fin whales in Greenland (1980 and 1983) was plotted to show the known areas of concentrations of fin whales in West Greenland.

RESULTS

An approximately 18m long fin whale was tagged with a satellite transmitter (20685) on 30 September 2000 in the archipelago at Aasiaat (69°42’N, 52°50’W N, Fig. 2). A total of 200 positions covering 77 days were obtained from the whale (Table 1). Occasional signals were received until 20 December indicating that the instrument stayed on the whale for at least 81 days.

The fin whale appeared to stay in the coastal area where it was tagged until at least 13 October. On 16 and 17 October it was found about 225km south and about 130km off the coast of West Greenland based on an average of 1 quality 1 (67°N, 57°W), 2 quality 0, 7 quality A and 6 quality B positions. On 20 October it appeared approximately 250km southeast in another inshore area. It moved another 100km south along the coast and up to 50km off the coast until 2 November, then appeared back in the area where it was located on 20 October. It apparently stayed in that area until 16 December when the last position was obtained. Contact with the transmitter was lost on 20 December. During the period from 30 September through 16 December it travelled a minimum of 989km.

The average daily travel rates ($n=19$) between the average daily positions for the fin whale was 13km day^{-1} with a range from 1-66km day^{-1}. The fastest travel rates were observed when the whale was moving to and from its offshore position at approximately 56°30’W.

Another fin whale (20158) estimated to be 18m long was tagged on 24 August 2001 in the archipelago at Aasiaat (68°32’N, 53°16’W). A total of 71 positions covering 32 days were obtained from the whale (Table 1). The whale stayed in the coastal areas of Disko Bay where it visited the southeastern part of the bay on 9 September. On 13 September it was located further to the southwest in an area approximately 30km off the coast based on an average of 5 quality B and 1 quality A (67°52’N, 55°08’W) positions. From here it continued south to the same coastal area north of Nuuk that was used by the whale tracked in 2000 between 20 October and 16 December (Fig. 2). Here it stayed until the last positions were received on 25 September. During the period from 24 August through 25 September it travelled a minimum of 625km.

The average daily travel rates ($n=9$) between the average daily positions for the fin whale was 20km day^{-1} with a range from 1-70km day^{-1}. The fastest travel rate was observed when the whale was moving south from Disko Bay to the coastal area at 65°N between 13 and 17 September.

Fin whale catches in West Greenland were concentrated in two coastal areas during 1988-1999: the northern area is located in the archipelago of Aasiaat and the southern area is located between Nuuk and Maniitsoq (at 64°-65°N, Fig. 3). The fin whales tracked were initially sighted and tagged in the northern area and later moved into the southern area. Fin whales are frequently found in the central part of northern Davis Strait west of 57°W between 67°-68°N and approximately 400km off the Greenlandic coast (Fig. 3). The whale tracked in 2000 left the northern coastal area after 13 October and travelled to the offshore area and stayed there

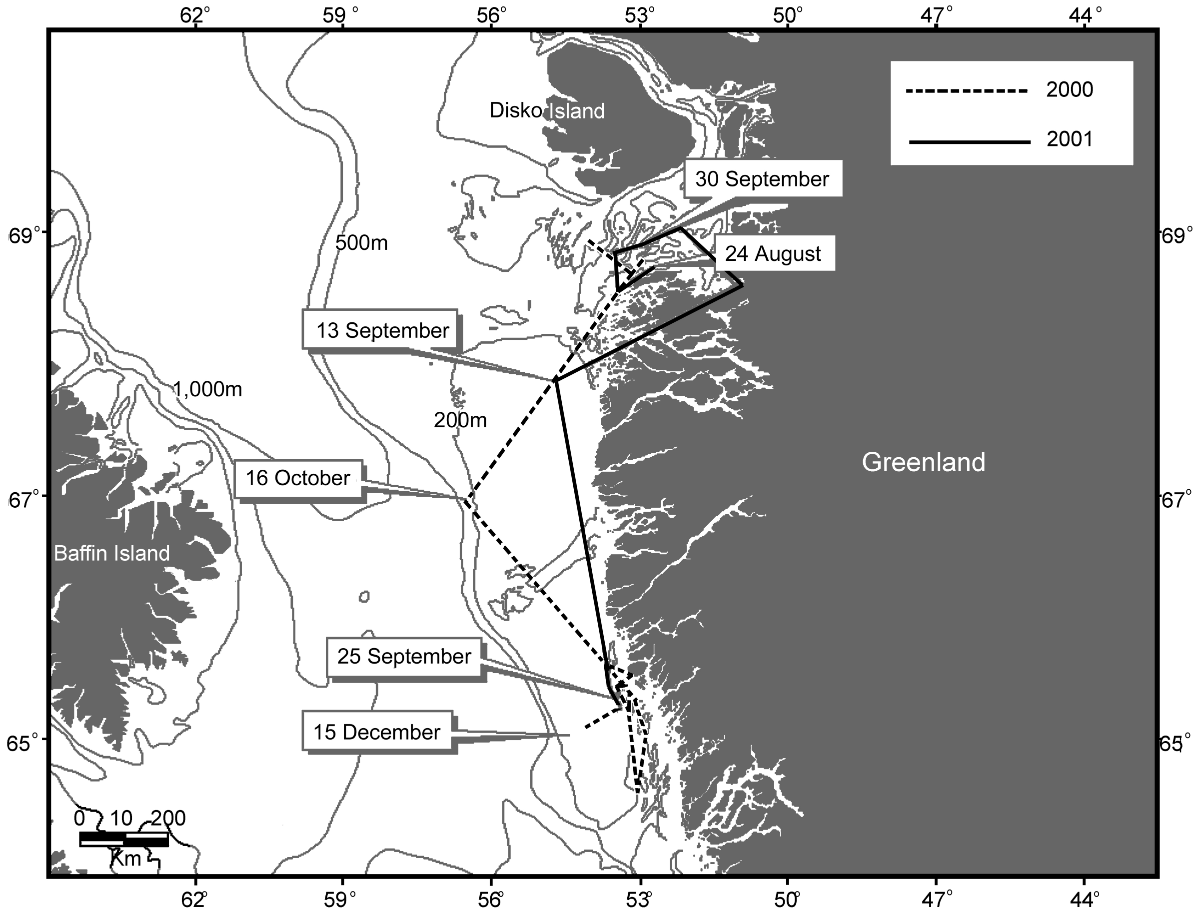

Fig. 2. Tracking of fin whales in West Greenland. Only the mean position for every 4 days is given. The track in 2000 (whale 20685) lasted from 30 September 2000 through 16 December. The track in 2001 (whale 20158) lasted from 24 August through 25 September.

Table 1

Details of instrumentations of two fin whales tagged with satellite transmitters in West Greenland in 2000 and 2001. Standard deviation given in parenthesis. For the locations precision classes 2 indicate positions with a nominal precision of 350m, 1 a precision of <1,000m and class 0, A and B has no assigned precision.

ID No.	Tracking period	No. of days	Position of tag	Total distance travelled	Daily horizontal speed	Number of positions	Distribution of positions on precision classes of locations (LC)				
							2	1	0	A	B
20685	30/09-16/12 2000	77	Midway between head and dorsal fin about 0.5-1 m to the right of the dorsal line.	989km	13km/day (17)	200		6	9	54	131
20158	24/08-25/09 2001	32	3m in front of dorsal fin, about 40cm to the left of the dorsal line.	625km	20km/day (24)	71	2	5	1	17	46

until 20 October, when it appeared at the southern coastal area where it remained until mid-December (compare Figs 2 and 3).

DISCUSSION

The ST15 transmitters equipped with two M1 batteries have a nominal longevity of 20-25 days with continuous transmissions. They were programmed only to transmit every four days and only when at the surface, thus the longevity should be at least four times the nominal capacity, i.e. around 80 to 100 days. The fin whale from West Greenland tagged in 2000 seems to have approached the expected transmitter longevity and it is thus likely that the ultimate failure of the tracking of this whale was due to exhaustion of batteries. For the other tag it seems plausible that the tags migrated out through the skin of the whale and eventually fell off.

In a study of bowhead whales (*Balaena mysticetus*), it was shown from voltage readings transmitted to the satellite that the batteries were drained when the transmitters ultimately failed after two months of operations (Heide-Jørgensen *et al.*, 2003). It thus seems possible that the present technique could be used for long-term tracking if sufficient battery capacity is supplied with the transmitter.

The large number of positions of low precision contributes some uncertainty about the exact location and routes of the whales; however, the uncertainty is reduced by the use of a daily average position. The overall movement pattern as estimated by the means of low precision positions is confirmed by the occasional positions of high precision.

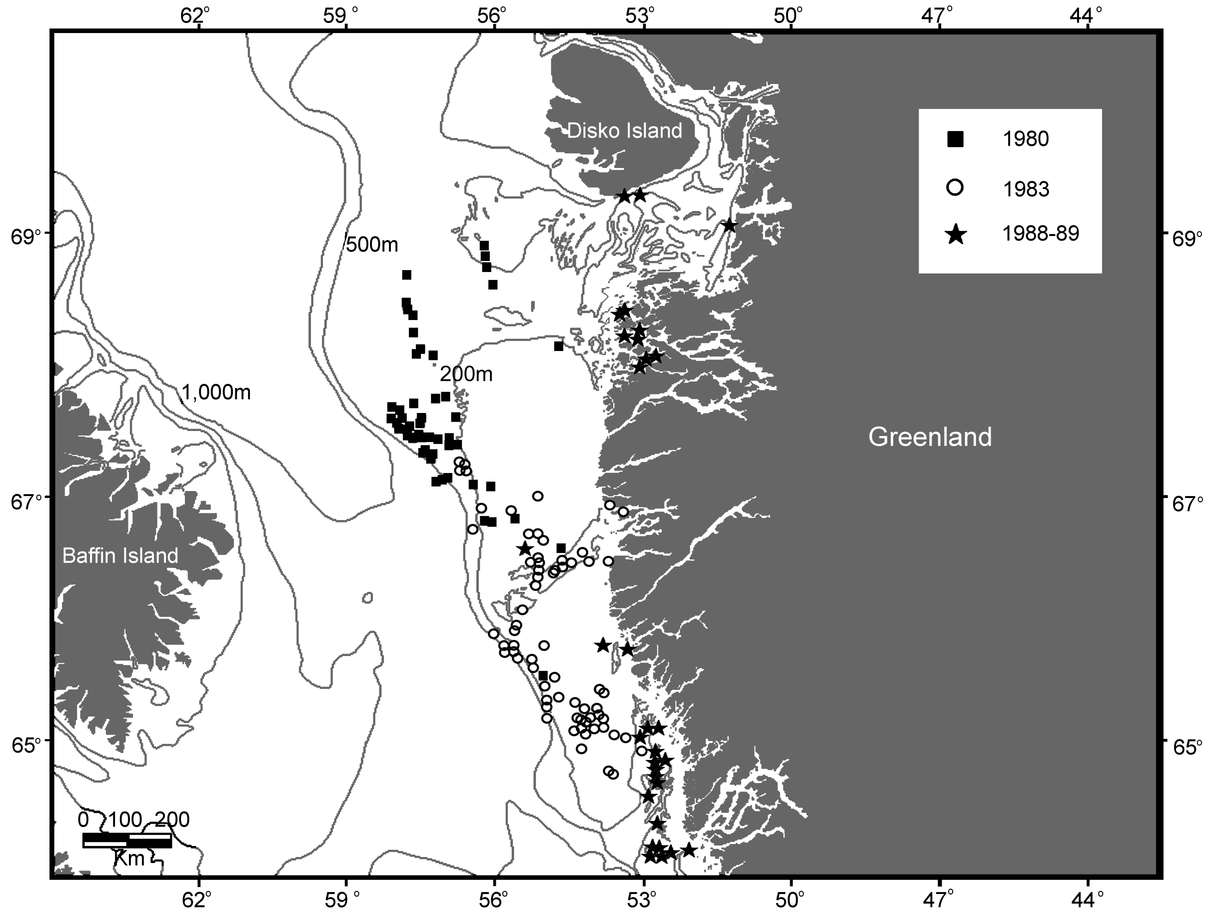

Fig. 3. Positions of offshore observations from *Kato* (squares and circles 1980 and 83) and inshore catches (stars 1988-99; Witting, 2000) of fin whales in West Greenland. The 200m depth contour is indicated.

Satellite tracking of a fin whale tagged in Iceland in 1994 provided location data for 43 days and, although not reported in detail, the frequency of good quality positions was generally better than that obtained in this study (Watkins *et al.*, 1984b). No details on signal strength or repetition rate for the tag are provided but it differed from this study by having a longer delay (550ms) before transmissions, which together with an implant closer to the dorsal ridge may have provided a better chance for precise positions.

The duration of the tags, the number of positions and their quality was better for the fin whales in this study compared to those obtained during satellite tracking of minke whales in 1994 and 1999 (Heide-Jørgensen *et al.*, 2001b). Some of the improved performance is due to the larger size of the fin whale which provides a better platform for transmissions because more of the body is exposed for a longer time during surfacing.

The tracking of a minke whale in 1994 used a transmitter attached to an anchoring dart with a wire and thus the transmitter was hanging more loosely on the skin of the whale. For the tracking in 1999, part of the transmitter was buried into the blubber (Heide-Jørgensen *et al.*, 2001b). A blue whale (*Balaenoptera musculus*) tracked in 1999 was also tagged with a transmitter intended to be partly buried into the blubber (Heide-Jørgensen *et al.*, 2001a); contact was lost after 22 days but the proportion of good quality positions (NQ > 0) obtained resembled that achieved in this study (Table 1). The transmitter design with an anchoring dart inside the whale and the transmitter unit with antenna and salt-water switch outside the skin pointing away from the whale may also have improved the tag performance.

Radio tracking (HF and UHF-satellite) experiments off Iceland have shown that fin whales are capable of moving rapidly between different areas. A whale tracked for 9.5 days in 1980 moved more than 1,700km at an average speed of 7.4km h^{-1} for the entire period (Watkins *et al.*, 1984a). Apparently the whale made a directional movement towards an area where it joined other fin whales. Another whale tracked for 43 days in August-September 1994 moved 1,546km at an average speed of 1.5km h^{-1} (Watkins *et al.*, 1984b). This whale apparently explored the waters along the 2,000m depth contour and it seemed more stationary during the tracking period. Both whales preferred areas with water depth in excess of 1,500m. The fin whales tracked in this study also indicate that fin whales can move at considerable speeds and cover considerable distances. Travel speeds of 13 and 20km on average per day and minimum distances of 989 and 625km covered during 76 and 32 days is below Watkins *et al.*'s (1984a) observations during 9.5 days but it resembles the values obtained from a 22-day track of a North Atlantic blue whale in 1999 (Heide-Jørgensen *et al.*, 2001a). However, the travel distances were measured in a relatively crude way in the present study and it is likely that larger distances would have been measured with more frequent locations of the whales.

The two fin whales tagged in Greenland mostly remained in coastal areas, but they also spent some time in offshore waters in the central Davis Strait. Observations from a commercial minke whaler documented offshore concentrations of fin whales from 1979 to 1983 as late as mid September (Larsen, 1981; Kapel and Larsen, 1982; 1983; Kapel, 1984). According to the whalers, the offshore areas are used during the northward migration of the fin whales (Larsen, 1981). The appearance of one of the tracked fin whales at the offshore area in October indicates that fin whales are still present in that area during autumn – at least for one day. Kapel (1984) also shows from observational data that rapid changes in the abundance of fin whales in the offshore area do occur.

The information presented here, although based on only two animals, suggests that the offshore and inshore aggregations of fin whales belong to the same stock. Any enumeration of fin whale abundance in West Greenland used for assessing the sustainability of the coastal harvest will thus gain from the inclusion of the offshore areas. Offshore fin whale distribution extends at least as far west as 58°W (Fig. 2) and possibly even further west. Little or no effort occurred to the west of 57°W in previous aerial surveys off West Greenland (Larsen *et al.*, 1989; Larsen, 1995).

The present study illustrates the potential for elucidating the movement patterns of baleen whales through satellite tracking. Future tagging should aim at longer duration of the trackings and better quality of the positions obtained. Tagging later in the season may also reveal more information on the whereabouts of the whales during winter (e.g. IWC, 2003).

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