Satellite tracking of minke whales (*Balaenoptera acutorostrata*) off the coast of northern Norway

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ABSTRACT

Two minke whales were tagged with satellite-linked radio transmitters off the coast of northern Norway in order to obtain data on daily locations, movements and swimming speed. One whale was tagged in September 1994, south of Lofoten at the entrance to the Vestfjorden, and one whale was tagged in August 1999 just north of Vesterålen. The whale tagged in 1994 was successfully tracked for 31 days (located 1.5 times/day on average). The whale tagged in 1999 was successfully tracked for 19 days (located 3.0 times/day on average), although the first locations were not obtained until 18 days after the instrumentation. The whale tagged in 1994 travelled between two apparent feeding areas on the west coast of northern Norway: one in the mouth of Vestfjorden and the other along the continental slope north of Vesterålen. The whale tagged in 1999 moved to an area inside Vestfjorden and remained there until early September, after which it began a southward movement out of Vestfjorden offshore to the edge of the continental shelf. Both whales were presumably feeding on herring (*Clupea harengus*), which is particularly abundant in these waters at this time of year. The two minke whales travelled 78 and 79 km/day when distances between all positions were used, and 66 and 53 km/day when the daily average positions (all qualities) were used. Both calculations illustrate that minke whales can move considerable distances on a daily basis.

KEYWORDS: MINKE WHALE; SATELLITE TRACKING; TELEMETRY; MOVEMENTS

INTRODUCTION

Information on the stock identity and seasonal segregation of North Atlantic minke whales (*Balaenoptera acutorostrata*) is fundamental to the development of sustainable harvest regimes. Observations and catch data show that minke whales are widely dispersed in the northeastern Atlantic during the summer (Horwood, 1990; Øien, 1990) but virtually nothing is known about the movements, site fidelity and dispersal patterns of minke whales in this area. Swimming speeds (vertical and horizontal speeds combined) have been measured directly for four minke whales for up to 24hrs (Folkow and Blix, 1991) although no information exists on daily movement rates.

Satellite telemetry is a powerful tool for collecting data on migration, winter distribution and key behavioural and physiological parameters for several cetacean species (e.g. Dietz *et al.*, 2001; Heide-Jørgensen *et al.*, 2001a). The insights obtained from free-ranging and undisturbed animals are substantial. The purpose of this study was to examine the feasibility of satellite tracking minke whales and to determine the seasonal movement patterns along the coast of northern Norway.

MATERIALS AND METHODS

Minke whale tagged in 1994

In September 1994, a minke whale was tagged off northern Norway using a 68kg *Panzer* crossbow (*Barnett Inc*., Wolverhampton, UK). The tag was launched from the vessel M/S *Jan Bjørn*, a 15m whaler. The satellite transmitter was a *Telonics* ST-10 RF-unit (*Telonics*, Arizona, USA) connected to a microprocessor and cast in epoxy by *Wildlife Computers* (Redmond, Washington, USA). The transmitter (4.1 × 11.2 × 2.2cm, 230g) was programmed to transmit for two 5hr periods per day (03:00-08:00 and 15:00-20:00 GMT) with a repetition interval of 40 seconds. The transmitter, attached to an anchor via a stainless steel wire, was equipped with a saltwater switch ensuring that transmissions only took place when the tag was above the surface. The anchor consisted of a 15cm long stainless steel needle (Ø = 0.35cm) with thin stainless steel barbs attached near the tip. The needle and barbs were rinsed in ethyl alcohol and smeared with antibiotic cream (basimycin) before deployment, in order to reduce the risk of infection. The anchor was designed to penetrate the whale's blubber layer and fasten within the underlying muscle layer. A polycarbonate stop ring (Ø = 4.0cm) prevented the anchor from penetrating deeper than 15cm into the whale. The crossbow arrow carrying the transmitter was attached to a monofilament nylon line, which allowed for easy retrieval if the transmitter missed the whale.

Minke whale tagged in 1999

In August 1999, a minke whale was tagged from the vessel K/V *Thorsteinson* with the Air Rocket Transmitter System (ARTS, specifically developed for remote deployment of satellite tags on baleen whales). The ARTS consists of a modified gun-shaped pneumatic line thrower that launches a rocket, containing the transmitter, which is equipped with tail feathers (Heide-Jørgensen *et al.*, 2001b). The rocket is designed to float, in case of misses. The ARTS was initially calibrated to a shooting distance of 20m at a pressure of 20 bar, using rockets of similar weight and length as those containing satellite transmitters. Test shooting showed that the ARTS was accurate to a distance of 50m. The transmitter was deployed on the whale from a distance of 15m, using a pressure of 15 bar. The cylindrical transmitter (22 × 2.5cm, 200g) was a modified *Telonics* ST-15 RF-unit with a 3cm steel dart with sharp edge. It was equipped with a stop plate

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(Ø = 3.8cm) that only allowed half of the transmitter to be buried into the blubber. The transmitter had a repetition interval of 45s, was not duty cycled, but was equipped with a saltwater switch, which only allowed transmissions when the whale was at the surface.

Analyses

Data on positions of the whales were retrieved from the Service Argos Data and Collection System. Service Argos operates with different location quality classes (LC) with decreasing precision in the following order: 3, 2, 1, 0, A and B. The LC 0, A and B are based on less than three successive uplinks and have no estimated location accuracy; LC 1, 2 and 3 have a presumed accuracy of < 1km (Fancy *et al.*, 1988; CLS/Service Argos, 1989). To reduce the noise introduced by the low-precision of the poor quality positions, a daily mean position (using all location qualities) was calculated to plot the movements of the whales in ESRI ArcView® and to calculate horizontal swimming speed.

RESULTS

Minke whale tagged in 1994

The minke whale tagged south of Lofoten (67°38'N, 13°21'E) on 5 September 1994 had an estimated body mass of about four tonnes and length of 7m. The tag penetrated the skin near the dorsal midline of the whale, about 1.5m in front of the dorsal fin. This position ensured that the antenna was exposed for approximately two seconds during each surfacing, allowing for successful transmissions. The tag was active for 31 days, during which 234 transmissions were received (on average 7.5 successful uplinks per day). This resulted in a total of 46 locations, or 1.5 locations per day. Locations were obtained on 71% of the days. Out of six possible location classes (A, B, 0, 1, 2 and 3), 0 was the best quality obtained. Most locations (68%) were of B quality (Table 1).

Table 1

The frequency distribution of locations belonging to four location classes (LC), as obtained from two satellite-linked radio transmitters that were deployed on minke whales in 1994 and 1999.

LC	1994 Percentage distribution *n*=46	1999 Percentage distribution *n*=58
0	4	0
A	28	17
B	68	83

The minke whale stayed in the outer Vestfjorden area for 10 days, later moving to the continental slope, and then moving 320km northeast in 52hrs. The whale then stayed off the coast of Vesterålen for about nine days, moving back and forth, along the continental slope. On September 27, the whale swam back to the Lofoten area, and stayed in the mouth of Vestfjorden for eight days until contact was lost on 5 October.

During the tracking period (5 September-5 October) the whale travelled 2,336km (straight line distance between all locations), corresponding to a daily average of 78km (SD = 48km, range 6.8-277km), or 3.2km/hr. As transmissions were not received at regular intervals, an average daily position was calculated for each day based on all transmissions received within that 24hr period. The 23 average daily positions gave a minimum travel distance of 1,450km in total and an average horizontal speed of 66km/day (SD = 64km, range 19.8-277.1) or 2.7km/hr.

Minke whale tagged in 1999

On 2 August 1999, a tag was deployed on a small minke whale, with an estimated body length of 5m, just north of Vesterålen (69°31'N, 15°52'E). The tag penetrated the skin in front of the dorsal fin, on the left dorso-lateral side of the whale. The rocket that accompanied the transmitter when the tag was launched did not instantly separate from the transmitter. No transmissions were received for 16 days and no locations were obtained until 18 days after instrumentation. The delayed release of the rocket may explain why transmissions were not initially received from the whale. A total of 407 transmissions, starting on day 16 after tagging, were received over the course of 19 days with transmissions. This resulted in a total of 58 locations, or 3.0 locations per day. Locations were obtained on 79% of the days. Out of six possible location classes, LC A was the best quality obtained. Most locations (83%) were of B quality (Table 1).

Eighteen days after tagging off the north coast of Vesterålen the whale had moved inshore to Vestfjorden, where it made localised movements in coastal waters until the end of the month (Fig. 1). In early September it started a southward movement along the coast, first inshore and later offshore out to the continental shelf edge where contact was lost on 8 September.

During the tracking period (20 August-8 September), the whale apparently travelled 1,530km at an average horizontal speed of 79km/day (SD = 22, range 2.4-87.3km) or 3.3km/hr. Sixteen average daily positions were calculated for days where locations were received from this whale. Using these data, the whale was found to have travelled at least 739km in total, at an average horizontal speed of 53km/day (SD = 27km, range 13.8-89.8) or 2.2km/hr.

DISCUSSION

The two minke whales stayed in the Vestfjorden and Vesterålen areas for more than a month in late summer and early autumn, indicating a preference for this area. The whale that was instrumented in August 1999 first utilised an inshore habitat in the Vestfjorden area and later moved south off the continental shelf. This pattern differs from that of the minke whale instrumented in September 1994, which first moved north to the Vesterålen area, and then returned south to the same area where it was tagged. This whale was still inshore in early October. Nevertheless, both whales explored habitats in the Vesterålen and Vestfjorden areas in August and September.

Minke whales that are found in Vestfjorden in early September could be either animals migrating south from feeding grounds in the far north or whales that are part of an aggregation that spends the summer in the Vestfjorden and Vesterålen areas (cf. Jonsgård, 1951). The northward trip of the minke whale in 1994 from the Vestfjorden area to the continental slope and back to Vestfjorden shows that whales are not necessarily limited to Vestfjorden - movements of their prey probably dictate their local occurrence. Since the whales have a preference for Vestfjorden and Vesterålen, they are probably feeding in these areas.

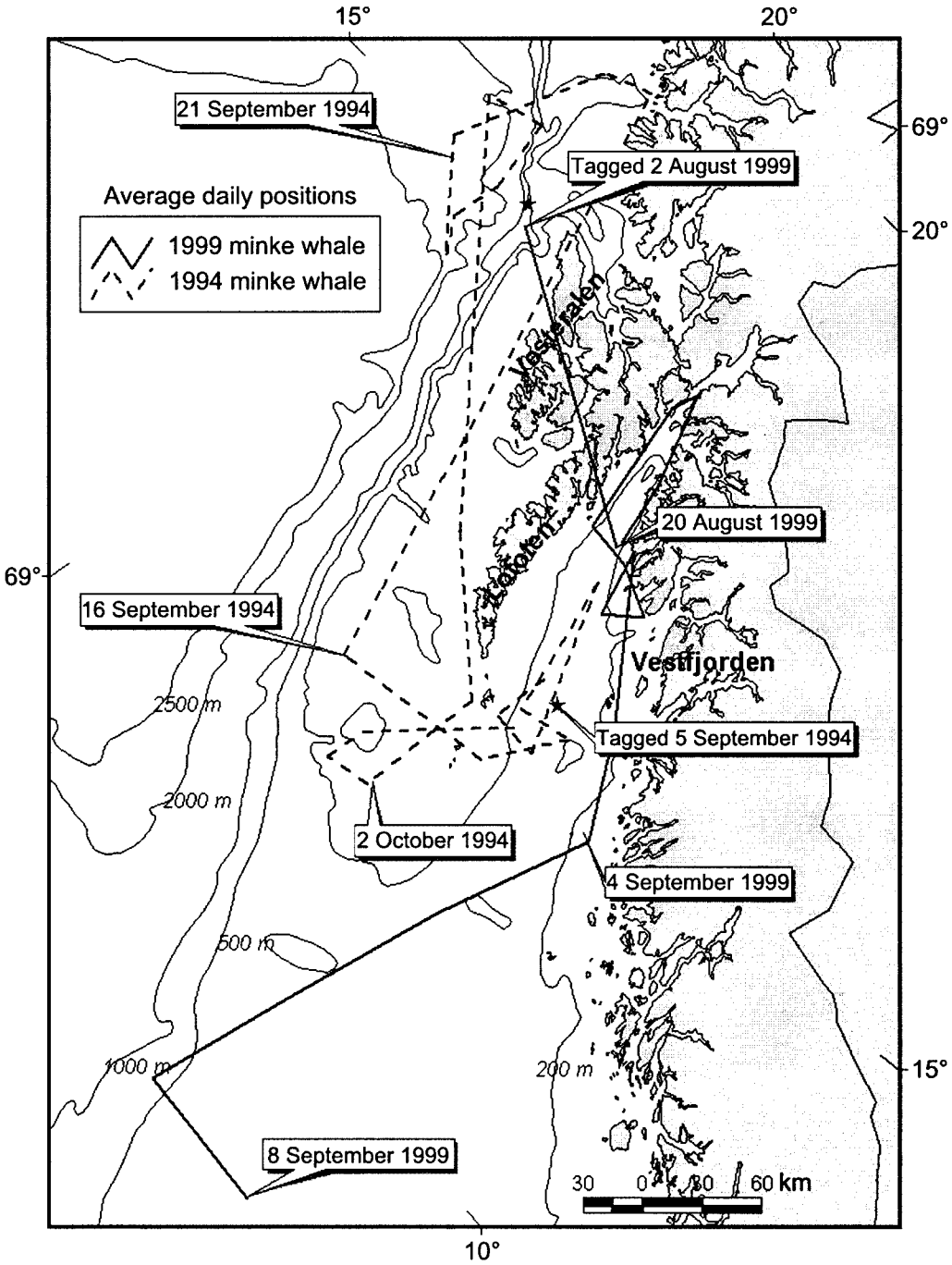

Fig. 1. Movements of two minke whales that were tagged with satellite-linked radio transmitters in 1994 and 1999. Dashed line: whale tagged on 5 September 1994. Solid line: whale tagged on 2 August 1994. Both whales were tagged off the coast of northern Norway, and were tracked for 31 days and 38 days, respectively.

The assumption that the Vestfjorden and Vesterålen areas are important feeding grounds for minke whales in August-September is supported by observations on the distribution of whales relative to herring (*Clupea harengus*), an important prey item of minke whales (e.g. Nordøy and Blix, 1992; Haug *et al.*, 1996). Lydersen *et al.* (1991) found that stomachs of 15 minke whales collected between 3 and 18 August 1988 in the Lofoten and Vesterålen areas all contained herring, which constituted an average of 92% of the total prey volume. Ten out of 15 stomachs analysed in that study were 100% full of herring.

The spawning stock of herring is reported to migrate east in early September from summer feeding grounds in the Norwegian Sea to the coast of Lofoten/Vesterålen, to spend the winter in the Vestfjorden-area (Anon., 1993; 1994). In September 1994, between 7 and 20 minke whales were observed on a daily basis in this area (Nordøy, pers. obs.). The presence of large shoals of herring at depths of 30-100m (concurrent with minke whale sightings) was confirmed by use of an echo sounder installed in the vessel (Folkow and Nordøy, pers. obs.). This same area is considered to be productive by the commercial herring fishery, which conducted intensive herring fishing in early September in 1994. Between September and December 1993, this fishery landed about 200,000 tonnes representing most of the 1993 quota of Norwegian spring-spawning herring in this region (Anon., 1994).

In 1994, the minke whale was in the Lofoten, Vesterålen and Vestfjorden areas at the peak abundance of herring. In 1999, the herring came close to the coast west of Lofoten in the last week of August and moved into Vestfjorden in the first two weeks of September (Institute of Marine Research

in litt.). The herring catches peaked in Vestfjorden in mid-October but remained high until mid-December. However, in 1999 the minke whale passed through the area earlier in the season (mid-August) before the high abundance of herring in September. The minke whales tagged in 1994 and 1999 were in the herring concentration areas approximately one month apart. Although the temporal shift may be dictated by annual variations in fish occurrence, this is not supported by the information on herring abundance.

The horizontal speeds calculated for the two whales were fairly consistent for both distances between all positions and distances between average daily positions. Speeds calculated using all quality positions might be biased by the unknown error in the poor quality positions. Calculations based on an average daily position are negatively biased because this method only captures the large-scale movement of the whales. In any case, both the calculated speeds and the distances travelled by the whales show that minke whales undertake considerable movements over short time periods, and that their horizontal swimming speeds appear to be well within the most cost-effective range determined by Blix and Folkow (1995).

In conclusion, this study demonstrates that satellite-linked radio transmitters are useful tools for tracking the movements of individual minke whales. The use of this technique to reveal wintering locations of these mammals requires improvement in tag longevity.

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REFERENCES

Anonymous. 1993. Ressursoversikt 1993. *Fisken Havet* (special issue 1):1-66. [In Norwegian].

Anonymous. 1994. Ressursoversikt 1994. *Fisken Havet* (special issue 1):1-104. [In Norwegian].

Blix, A.S. and Folkow, L.P. 1995. Daily energy expenditure in free living whales. *Acta Physiol. Scand.* 153:61-6.

CLS/Service Argos. 1989. *Guide to the Argos System*. Argos CLS, Toulouse. 152pp.

Dietz, R., Heide-Jørgensen, M.P., Richard, P. and Acquarone, M. 2001. Summer and fall movements of narwhals (*Monodon monoceros*) from Northeastern Baffin Island towards Northern Davis Strait. *Arctic*: In press.

Fancy, S.G., Pank, L.F., Douglas, D.C., Curby, C.H., Garner, G.W., Amstrup, S.C. and Regelin, W.L. 1988. Satellite telemetry: a new tool for wildlife research and management. *US Fish Wildl. Serv. Resour. Publ.* 172:1-54.

Folkow, L.P. and Blix, A.S. 1991. Norwegian whale sighting and acoustic surveys in the Atlantic Ocean during the winter of 1989/90. *Rep. int. Whal. Commn* 41:531-8.

Haug, T., Lindstrøm, U., Nilssen, K.T., Røttingen, I. and Skaug, H.J. 1996. Diet and food availability for northeast Atlantic minke whales, *Balaenoptera acutorostrata*. *Rep. int. Whal. Commn* 46:371-82.

Heide-Jørgensen, M.P., Hammeken, N., Dietz, R., Orr, J. and Richard, P. 2001a. Surface times and dive rates for narwhals (*Monodon monoceros*) and belugas (*Delphinapterus leucas*). *Arctic* 54(3):In press.

Heide-Jørgensen, M.P., Kleivane, L., Øien, N., Laidre, K.L. and Jensen, M.V. 2001b. A new technique for deploying satellite transmitters on baleen whales: Tracking a blue whale (*Balaenoptera musculus*) in the North Atlantic. *Mar. Mammal Sci.* 17(4):In press.

Horwood, J.W. 1990. *Biology and Exploitation of the Minke Whale*. CRC Press, Boca Raton. 238pp.

Jonsgård, Å. 1951. Studies on the little piked whale or minke whale (*Balaenoptera acuto-rostrata* Lacépède). Report on Norwegian investigations carried out in the years 1943-1950. *Norsk Hvalfangsttid.* 40:209-32.

Lydersen, C., Weslawski, J.M. and Oritsland, N.A. 1991. Stomach content analysis of minke whales (*Balaenoptera acutorostrata*) from the Lofoten and Vesterålen areas, Norway, August 1988. *Holarct. Ecol.* 14:219-22.

Nordøy, E.S. and Blix, A.S. 1992. Diet of minke whales in the northeastern Atlantic. *Rep. int. Whal. Commn* 42:393-8.

Øien, N. 1990. Sightings surveys in the northeast Atlantic in July 1988: distribution and abundance of cetaceans. *Rep. int. Whal. Commn* 40:499-511.