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# Fin whale *(Balaenoptera physalus)* tracked by radio in the Irminger Sea

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ABSTRACT

A fin whale *(Balaenoptera physalus)* was radio tagged 155 km southwest of Iceland and tracked continuously for 9½ days, 25 June to 5 July, 1980. It travelled more than 1700 km and passed within 110 km of Greenland. Detailed analysis of surfacing patterns, swimming speeds, association with other whales, and diel behavioural changes were made possible by the radio tag signals, which were transmitted when the whale surfaced. The whale fed on krill off Iceland and schooled fish off Greenland. The average interval between surfacings was 1.98 min including the shortened intervals in clustered blowing. The average speed over the entire track was 7.4 km/hr. There were diel changes in activity in spite of less than total darkness at night. The tagged whale's crossing of the Irminger Sea, often in close association with conspecifics, is the first direct proof of an east-west movement of a fin whale between Iceland and East-Greenland, and an additional proof of mixing of whales between the two areas.

## INTRODUCTION

A fin whale *(Balaenoptera physalus)* tagged with radio transmitters was tracked from near Iceland to Greenland waters from 25 June to 5 July 1980. Details of the preparation for this open-sea radio tagging experiment and a preliminary field report were given by Watkins (1981a, 1981c).

During the past 20 years the distribution and movements of the fin whale population harvested west of Iceland has been studied by Discovery-marking (Jónsson 1965; Jonsgård and Christensen 1968; Rörvik et al. 1976; Brown 1979; Sigurjónsson 1983). Fin whales marked off western Iceland have been recovered in the same area where they were marked. Three fin whales marked off East-Greenland in 1968 (Rörvik et al. 1976; Brown 1979) and one in 1973 (unpublished data), all recovered on the whaling grounds of Iceland, indicate some mixing of fin whales across the Irminger Sea. A recent analysis (Sigurjónsson and Gunnlaugsson, in press) has shown that there does not appear to be a free mixing of whales between the two areas, although the fin whale population in the Irminger Sea has been considered a single stock for management purposes (IWC 1977). The general understanding, supported by short-term mark recoveries (Rörvik et al. 1976; Sigurjónsson 1983) was, however, that fin whales harvested west of

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Iceland remain within the whaling area (approximately 62° 30′ to 66°N, 24° to 30°W) for some weeks at least. Consequently, the logistics of our radio tracking experiment were planned to follow tagged whales in the whaling area and to gather information about movements, distribution, and behaviour of the "Icelandic" fin whales.

The whale was tagged and tracked with the WHOI/OAR (Woods Hole Oceanographic Institution, Woods Hole, Massachusetts, and Ocean Applied Research Corporation, San Diego, California) radio tag designed for remote implantation at sea on large unrestrained whales (Watkins et al. 1980). Previous tests of the tag during development had been conducted on fin whales in relatively protected waters in the Gulf of St. Lawrence (Ray et al. 1978) and in Alaska (NMFS 1977; Watkins et al. 1981). These and previous tests on humpback whales *(Megaptera novaeangliae)* and Bryde's whales *(Balaenoptera edeni)* demonstrated that the radio tags were well tolerated, and that the behaviour of tagged whales appeared to be normal (Watkins 1981b).

## METHODS

Four fin whales were tagged to test the radio tagging system in the open ocean, and the last of these was retagged and tracked continuously as long as logistics permitted. The 46-m Icelandic whaling vessel, *Hvalur 6,* was used to approach the whales for tagging, and a 40.5-m Icelandic capelin fishing vessel, *Ljósfari,* was used for tracking. The Icelandic whaling company Hvalur, Ltd., and the Marine Research Institute, Reykjavík, participated directly in the tagging and tracking activities.

The radio tags were 29 cm long and 1.9 cm in diameter (Watkins et al. 1980) with a point developed for blubber penetration (Watkins 1979). Folding toggles and "hula skirt" projections (Watkins et al. 1979), were used to insure retention after penetration. The tags were disinfected with benzalkonium (zephiran) chloride and then fired from shoulder guns. The tags were implanted at an angle with only the flexible antenna (45 cm long and 0.9 cm in diameter at the base) protruding from the whale's skin. The tags on the double-tagged whale had separate radio frequencies (27.420 and 27.520 MHz). Signals were transmitted only when the tag antennas were out of water (two 50 msec pulses per sec at 200 mwatts). Each tag also carried an external coloured plastic streamer (5×60 cm) to facilitate visual recognition (NMFS 1977).

Iceland time was used during the tracking and the analyses. This was approximately two hours ahead of local sun time.

Tracking of the two radio signals was achieved by means of separate automatic direction-finding receivers (OAR) with antenna mounted on the forward mast of the *Ljósfari.* Direction for each signal was indicated accurately, but because of the whale's variable surfacing behaviour and orientation of the tag antennas, the signal levels could not reliably indicate distance. Signal occurrence was recorded on a timed strip chart. To avoid chasing or disturbing the whale, the tracking vessel travelled on a parallel course rather than following behind, usually keeping the whale at a 45° angle on either side of the bow, at a distance of 1 to 5 km. Close approaches were attempted daily at different times for observation and photography of behaviour and the implant sites. Figure 1 indicates the track of the vessel from Loran C positions (usually taken hourly). Although this track generally minimized the actual swimming distance and smoothed small-scale excursions by the whale, sometimes the ship also may have outrun the whale. Overall the Loran track closely matched the whale's track.

Travel speeds were calculated from the Loran positions, and represent averages. Distances were measured in nautical miles from the charted positions. The short-term deviations in the track and consequent variations in speed were averaged over longer periods. During a portion of the track, the ship's speed was limited to about 8 knots by engine problems, so it was sometimes difficult to keep up with the whale. The whale's track, therefore, was less accurately represented during periods of rapid movements, such as during the feeding and social activity of the last parts of the track, but it was probably well represented during the relatively constant-speed travel of the passage across the Irminger Sea.

Results are given in three ways: Table 1 lists daily positions, activities, approximate distances, and average speeds of the track; Figure 1 plots the ship's Loran C positions, beginning at the implantation of the first tag, at 2200 hrs on 25 June 1980, and ending at 0610 hrs on 5 July; and the narrative gives behavioural details, particularly of the beginning period of the track to show that the tag did not appear to affect the animal's activities. Times in the narrative are approximate.

Assessments of the whales' activities were based on our combined experience observing finbacks (Schevill et al. 1964; Ray et al. 1978; Watkins and Schevill 1979; Watkins 1981b, 1981c; Watkins et al. 1981). "Clustered" and "single" blowing were distinctive respiratory behaviours, demonstrated by the radio signal patterns. "Social" behaviour included periods when fin whales in close association surfaced slowly together, repeatedly, with no apparent feeding or other activity. Social activity sometimes included rolling onto the side and considerable non-feeding, near-surface commotion.

## RESULTS

The 21-m fin whale, nick-named Kristján ("K"), was radio tagged at 2200 hrs on 25 June 1980, at 63° 19′N, 25° 49′W, about 83 naut. miles (155 km) southwest of Iceland (Fig. 1). The signals from K were tracked

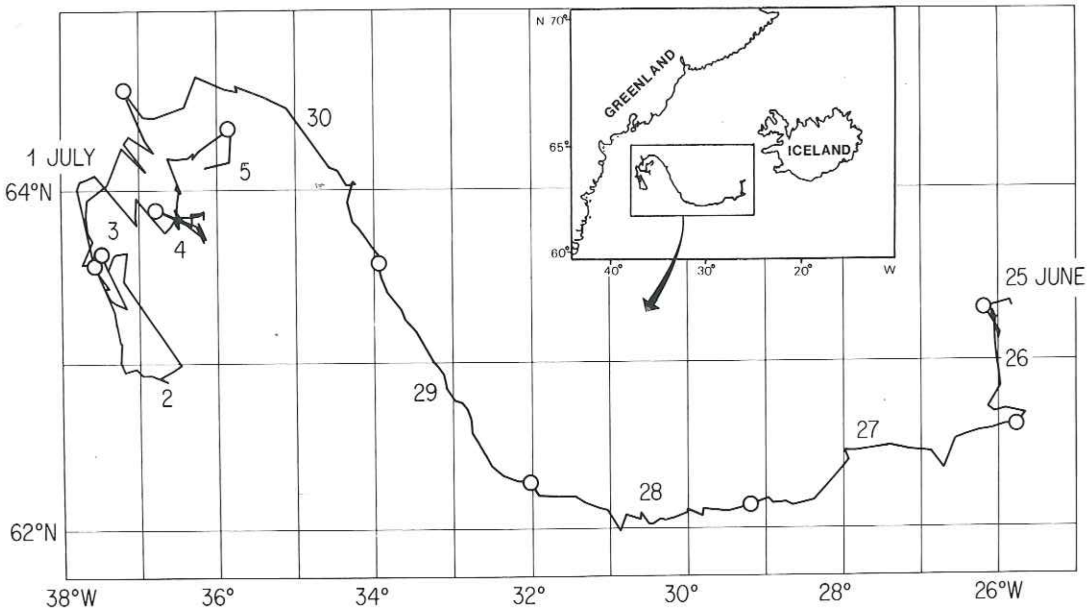


Figure 1. The approximate track of the radio tagged fin whale from 25 June to 5 July 1980 plotted from hourly Loran-C positions of the tracking vessel. The circles indicate midnight positions.

continuously for 9 days and 10 hours, ending at 0800 hrs on 5 July at 64° 07′N, 36° 09′W (the position where the ship stopped for repairs at 0610 hrs), about 86 naut. miles (160 km) southeast of Angmagssalik, Greenland. The closest approach to Greenland was within 59 naut. miles (110 km) at midnight on 30 June. The daily progress of the whale's track across the Irminger Sea is given in Table 1, with distances and speeds calculated on the basis of surfacing (dive time) data from the radio signals. The smoothed ship track was approximately 900 naut. miles (1700 km) long; the whale's track was considerably longer.

Approaches for inspection of the tags and observations of the whale's behaviour were accomplished without difficulty when K was accompanied by one or more other fin whales. However, K was difficult to approach when alone and not occupied with feeding near the surface, or during long-submergence routines. There were 22 close approaches made at irregular intervals, one to four each day except for 30 June, a stormy day. Except for one feeding blue whale *(Balaenoptera musculus)* on 25 June, all whales seen in close proximity to K were finbacks. Often it was difficult to be sure of the number of whales that should be considered as companions because other more distant whales may also have been associated with K. Of 37 close associations (within 200 meters), K was seen twice with six or more companions, once with four companions, four times with three, eight times with two, 15 times with one, and K appeared to be alone on seven occasions (no other whales observed within 2 km). These group associations generally remained stable over observation periods of 30 min or longer and did not include the 5 or 6 individual whales seen joining K for only short periods of one or two blow series. When the whales could be distinguished by size, fin shape, or markings, we recognized that K's companions changed at least daily.

## NARRATIVE

*25 June.* The first tag was implanted on K at the base of the fin on the left side (Fig. 2). Another tag fired simultaneously struck the water and startled the whales (tags implanted above the water line produced no obvious reaction; see Watkins 1981b). When approached for tagging, there were four 18- to 21-m finbacks in the area feeding on dense patches of krill, probably *Meganyctiphanes norvegica,* visible near the surface. With the maneuvering of the tagging vessel, the whales stopped feeding and separated temporarily, but remained in the area with the two vessels. Within 35 minutes after tagging, K was again feeding on krill, accompanied by three fin whales and one blue whale. The radio signals from the tag (at the base of the fin) were received only when the whale raised its back well out of water. Calm weather and the high-latitude long daylight allowed signals to be matched with observed behaviour.

*26 June.* Throughout the night K accompanied a slightly smaller fin whale, moving about 8.5 naut. miles (16 km) as they fed periodically. They were joined intermittently by other fin whales. No behavioural differences were observed between K and its non-tagged companions. The whales remained near the surface, with submergences of less than three minutes followed by one or two blows. The tag antenna was lifted partially out of water and transmitted during many of these surfacings. Then, at approximately 0430 hrs, the whale's dive periods lengthened, and blowing occurred in clusters of 5 to 7. The fin tag was now transmitting only during a "round-out" at the end of a blow series, as the whale began a new dive, as described by Watkins (1981c, Fig. 4, p. 93). The reduction in tag signals confirmed the need for a tag placed higher on the whale's back nearer the blowhole, so that the tag would transmit synchronously with respiration.

Figure 2. The "fin" radio tag implanted at 2200 hrs on 25 June on a finback whale. A coloured plastic streamer was used to make the tag more visible. This tag proved to be too far aft on the whale for antenna exposure except when the whale arched its back high out of water as in this photo (by Karen Moore).

The numbers of whales varied as they moved from one concentration of krill to the next, with new whales joining the group and others leaving. By mid-day K was keeping close company with a different fin whale and the two continued together, periodically meeting other whales as they fed.

A second tag was implanted at 1245 hrs, approximately 3 m behind K's blowhole and 25 cm to the right of the midline. There was no visible reaction to the tag implantation. K and its companions avoided the maneuvering tagging ship but returned to feed nearby within minutes of tagging. The higher forward position of the tag on the back resulted in signal transmission during most respiration surfacings, while the fin tag transmitted only when the whale lifted more of its body out of water. At 1500 hrs the *Hvalur 6* moved away and the whales were monitored from the *Ljósfari.*

Three hours after the second tagging, K and its companions stopped feeding and began to swim slowly in a southerly direction. Respiration was regular, often single blows at 2 to 3 min intervals. At about 1700 hrs the whales began to dive for longer periods (7 to 9 min) followed by 5 to 7 blows clustered within 2 to 3 min. K was again feeding on near-surface krill at 2000 hrs with three other fin whales, and as they approached the ship an attempt was made to place a third tag on K. The tag missed, striking the water, and all four whales startled and moved rapidly away. They returned within minutes, however, and resumed feeding. By 2200 hrs radio signals indicated shallow dives with one or two blows every 2 to 3 min. Signals were received from the forward tag at each blow but only occasionally from the fin tag.

*27 June.* Between 0130 and 1400 hrs the four whales swam near the surface on a relatively straight, westerly course, blowing once or twice every 1 to 3 min, with few signals from the fin tag (only one signal between 0701 and 1341 hrs). The weather deteriorated and seas increased in height to about 5 m, but the radio signals continued to allow reliable tracking.

K appeared to be alone and travelling such a straight course that we wondered if it were reacting to the vessel. To test this, the ship changed sides several times and crossed in front of the whale. There was no reaction to changes in ship's position, speed, or sharp turns (which create loud cavitation noise) unless the whale was within about 200 m; then K increased its submergence time to avoid the ship, sometimes diving to pass underneath. We had wanted to remain close to Iceland to test the tags and the tracking procedures conveniently near the base of operations (Watkins 1981a), and we would have been happy to find that K could be turned. However, throughout the morning K maintained a 5 knot speed and a westerly course.

At 1530 hrs K began longer submergences of 4 to 6 min with clustered blows. It was with another fin whale, and both maintained a westerly course. By 2300 hrs the whales' respiration pattern was one or two blows at intervals of 1 to 3 min as they swam near the surface.

*28 June.* At 0430 hrs the tag signal patterns showed lengthening dives with clustered blows. By 0900 hrs the submergences were 6 min or longer, and K was with two other (different) fin whales, and they continued to swim towards the west. For a short period around noon the swimming speed dropped and the direction varied. Other fin whales were seen at a distance in the afternoon as K resumed heading west with its companions. During the night, blows were mostly clustered in groups of three to five but at shortened intervals of 2 to 4 min.

*29 June.* Travel speed was less than 1 knot from midnight to 0300 hrs. Swimming slowly with one companion, at 0400 hrs K passed within 10 m of the tracking vessel, blowing several times without lifting either tag out of water (no radio signals). The whales turned gradually toward the northwest as they resumed their travel. We were able to observe clearly both tag sites at 1100 hrs and saw that they appeared unchanged, with no sign of tissue swelling. K was involved in social activities at 2000 hrs with two other fin whales, splashing and rolling. One remained belly-up at the surface for 15 sec, and another (not K) breached three times, after which the whales resumed travelling together. Many blows were not visible, and with little of the backs showing above water, it was only the radio signals that allowed the whales to be located and tracked.

*30 June.* After a night of mostly short (1 to 4 min) dives with periods of both clustered blowing and of one or two blows per series, at 0500 hrs the submergence times lengthened. Throughout the remainder of the day the signals indicated steady movement to the west. The weather deteriorated and seas increased so that we did not attempt a close approach. The whale was moving relatively slowly (3 knots), but the track (Fig. 1) indicates a higher speed, possibly due to the influence of the Irminger Current. By 2000 hrs K had passed onto the East Greenland shelf and was at the edge of the strong, southerly flowing East Greenland Current. For the remainder of the track the whales passed back and forth across the meandering current boundary which was visibly distinct, and at which fluctuations of as much as 4°C occurred in surface water temperature.

*1 July.* At 0310 hrs K shifted behaviour and began long series of clustered blows with dive sequences of up to 16 min. There were a number of fin whales in the area and K changed partners. Apparent social activity occurred periodically throughout the day. We also observed near-surface activity recognized as typical of fin whales feeding on schooled fish (rapid lunges, quick turns with the whale on its side, surfacing with mouth ajar and water pouring through the sides of baleen). This was very different from the steady, slow feeding passes through patches of krill observed earlier. The ship's crew were Icelandic capelin fishermen and their analysis of echo-sounder and sonar displays indicated an abundance of schooled capelin-like fish along the boundary of the East Greenland Current. Feeding and social activity were followed by a period in which K appeared to be alone and resting. Then in company with 5–6 other whales, K was actively social again. The whales fed for short periods (20 min) at a time.

*2 July.* The night (although light enough to see well above water) continued to be a time of relatively reduced activity: shorter submergences, blows sometimes without radio signals, and slower swimming with other whales near the surface. K changed companions during the night. Dive times lengthened beginning at 0400 hrs. Social activity and apparent feeding on fish near the surface occurred throughout the day with submergences up to 16 min. For a short period K was alone and difficult to approach closely, and then was joined by 4 or 5 fin whales. These whales remained active throughout the night (2–3 July), in contrast to the relative inactivity of previous nights.

*3 July.* The number of fin whales in groups that included K varied up to seven or eight at different times in the day. Other whales were often visible in the distance. The activities of the whales included variable periods of swimming close to the surface, social activity, periods of longer submergences, and feeding on schooled fish (sometimes visible from the surface). The whales crossed and recrossed the meandering edges of the East Greenland Current.

*4 July.* At 0430 hrs the whales changed their swimming behaviour from predominantly near-surface swimming with other whales (one or two blows at intervals of less than 3 min) to longer dives with clustered blowing. At 1100 hrs K was feeding with 3 other fin whales, and submergence times lengthened to 11 min. At 2000 hrs both radio tags were observed closely and photographed. They were still in good position with apparently no loosening in the tissues or changing orientation.

*5 July.* The activities of the whales varied throughout the night, with both short and longer submergences. By 0300 hrs K began to move westward at 5 knots, and maintained that heading for at least the next 5 hrs. The tracking ship stopped for engine repairs at 0610 hrs (final recorded position), while K continued to move to the west. The radio signals were monitored until 0800 hrs. Both the forward and fin tags were still transmitting well when tracking was terminated.

## TAG SIGNAL ANALYSIS

During the 9-day and 10-hr track, 6519 signals from the forward tag were recorded and 1603 from the fin tag. Each signal was comprised of a series of one to eight pulses transmitted at two per sec, when either or both tag antennas were lifted out of water during the whale's surfacing. Most respiration surfacings provided two to four pulses from the forward tag. During 24.6% of the recorded surfacings the fin tag also transmitted. Sometimes fin tag signals alone were received, and as noted above, occasionally K blew without exposing either tag antenna. A plot of 7.5-hr segment of time showing the relationship between signals from the forward and fin tags was given by Watkins (1981c, Fig. 4).

The two respiration patterns (clustered blowing and single blowing) were apparent

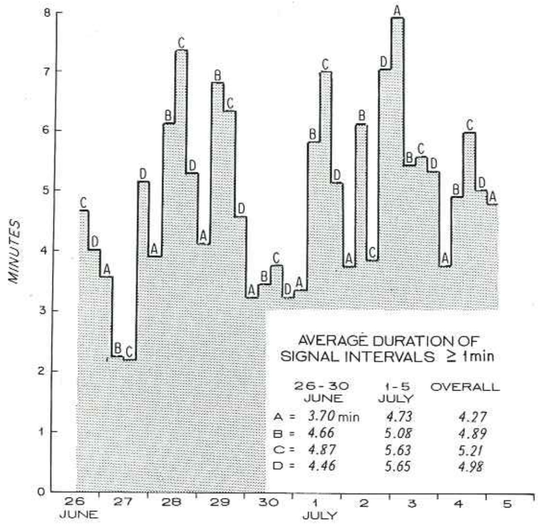


Figure 3. Average signal intervals (dive times) of 1 min or longer plotted for each of four 6-hr daily periods. Period A was 2200–0400 hrs, Iceland time, which was 2 hrs off local sun time; period B was 0400–1000 hrs; period C was 1000–1600 hrs, and period D was 1600–2200 hrs. The 1 min intervals in this figure exclude all of the short dives between blows during clustered blowing. The dive times were generally shorter during period A, the darkest period, and they were on the average longer during the lightest period, C.

in analyses of the radio signals. During clustered blowing there were 3 to 12 blows less than 1 min apart (usually 2 to 4 blows per min), occurring after submergences longer than 3 min. The average surfacing interval during clustered blowing was 0.48 min. Longer dives were generally followed by more blows. As an example of clustered blowing, on 1 July during 2 hrs and 58 min, there were 17 dives of 5 to 12 min (averaging 8 min 18 sec) with 133 blows in clusters averaging 3.4 blows per min during the blow sequences and 1.33 blows per min over the 3-hr period of diving and clustered blowing. There were 133 signals from the forward tag and 40 from the fin tag.

Single blowing (sometimes two blows) followed short submergences of 1 to 3 min when the whale apparently remained near the surface, and sometimes occurred over extended periods (10 hrs on 27 June, from 0330 to 1340 hrs). Single blows were often more difficult to see; the exhalation was less visible in air, and occurring singly they did not attract as much attention as did clustered blows. During single blows radio signals were usually transmitted only by the forward tag.

Submergence times indicated by the intervals between signals were analysed in three ways (Figs. 3, 4 and 5) to relate dive times to daily routines. Signal intervals from both tags were averaged over four 6-hr periods, beginning after the implantation of the forward tag. The times on the Figures were two hours ahead of local sun time in the Irminger Sea so that period A at 2200 to 0400 hrs was the darkest period, although never totally dark in midsummer at these latitudes.

Signal intervals of 1 min or longer were analyzed in Figure 3. This only excluded the shortest submergences, such as during clustered blowing. Without clustered blowing, the average signal interval (dive time) during all periods was 4.42 min during the first half of the track (26–30 June) which included feeding on krill near the surface and the travel across the Irminger Sea. During the second half (1–5 July) which included more

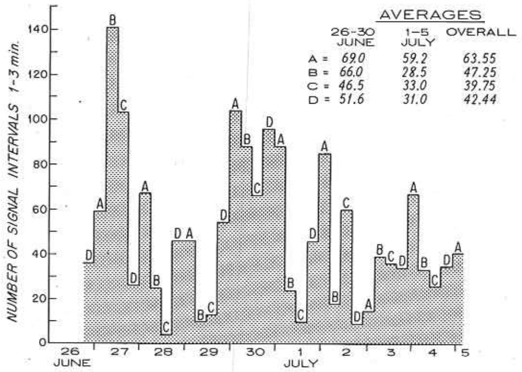


Figure 4. The number of signal intervals of 1 to 3 min duration are plotted in the four 6-hr daily periods. These shorter dives, indicating "single" blowing behaviour, occurred most often during the dark period A, in spite of differences in acitivity during the two halves of the track.

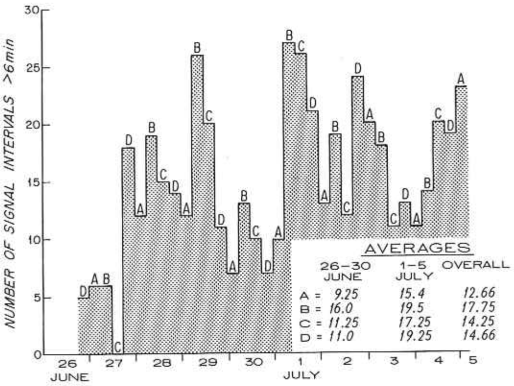


Figure 5. The number of signal intervals 6 min or longer is related to the four 6-hr daily periods. The long dives occurred least during the dark period A and most often in period B, which may be related to early morning feeding, although when considering all dives over 1 min (Fig. 3) average dive times were longer during period C.

long dives and feeding on schooled fish along the boundary of the East Greenland Current, the average dive time was 5.27 min. Over the entire track the dive times averaged 4.85 min. Including all submergences during clustered blowing, the average signal interval was 1.87 min during the first half of the track and 2.09 min during the second half, with an overall average of 1.98 min.

For each half of the track, the 6-hr averages of dive times longer than 1 min (Fig. 3) were generally shorter during period A, the darkest period, than during the other periods. Dive times of 1 to 3 min duration, which generally indicated single blowing behaviour, were analyzed (Fig. 4) and showed the same diel emphasis with more of these short dives on the average during the dark period A. In contrast, dive times longer than 6 min (Fig. 5) occurred least frequently during period A, but occurred most often during the early morning period B. However, when considering all dives greater than 1 min (Fig. 3), the total average dives were consistently longer by about 1 min during the mid-day period C.

The ocean currents encountered along the track may have had significant effects on travel distances and calculated speeds (Table 1), since a northerly drift of 1 knot or more was indicated by the ship's drift in the Irminger Current, and the ship was found to drift at a speed of more than 2 knots to the southwest in the East Greenland Current. The high rate of travel on 1 July of 138.3 naut. miles (255.1 km) was influenced by the whale's position in the East Greenland Current (Fig. 1).

The ship's speed during the track, calculated from hourly Loran C positions, ranged from 0.13 to 12 knots. Because the tracking ship had to compensate for unanticipated changes in the whale's speed and direction of movement, averages over several hours were more representative of the whale's speed (Tables 1–2). Daily averages of 3.5 to 6.5 knots are given in Table 1. K was always moving; even during resting periods there was some swimming. The average speed over the entire track (900 naut. miles over 224 hrs) was 4 knots. Highest speeds occurred during period B, averaging 5.2 knots over the whole track, 4.4 knots during the first half of the track while K was feeding on krill and travelling, and 6.2 knots during the second half while feeding on schooled fish and socializing. The slowest overall average speed of 3.8 knots occurred during period A, with a low of 2.9 knots during period A in the first half of the track.

## DISCUSSION

The WHOI/OAR radio tagging system worked well. Although the fin whales reacted to the maneuvering of the tagging vessel, neither the implantation of the tags nor their presence appeared to affect the behaviour of the tagged whale and its companions. This is consistent with our previous radio tagging experience and with conventional Discovery marking. The whales' startle reactions to missed tags and marks that strike the water has also been consistent (Ruud 1954; Watkins 1981b).

TABLE 1

*Daily 2400-hr (midnight) positions of the tracking vessel are listed. The ship was usually within 2.5 naut. miles (5 km) of the tagged whale. The predominant observed activity is given, and the travel distance, direction and average 24-hr speed is calculated from the positions. Nautical miles were used in measuring from the charted positions.*

| *1980-Date (ending 2400 hrs)* | *Ship's position* N. Lat. | W. Long. | *Whale's activity* | *Travel distance and direction (naut. miles)* | *Speed (average knots)* |
|---|---|---|---|---|---|
| 25 June ........ | 63° 19′ | 25° 49′ | 2200 hrs – 1st tag | | |
| – — ........ | 63° 19′ | 26° 03′ | feeding on krill | | |
| 26 — ........ | 63° 13′ | 26° 02′ | 1245 hrs – 2nd tag | | |
| – — ........ | 62° 37′ | 25° 46′ | feeding and travelling | 84.9 – S | 3.5 |
| 27 — ........ | 62° 08′ | 29° 11′ | travelling | 110.9 – W | 4.6 |
| 28 — ........ | 62° 16′ | 32° 01′ | — | 91.4 – W | 3.8 |
| 29 — ........ | 63° 34′ | 33° 56′ | — | 100.1 – NW | 4.2 |
| 30 — ........ | 64° 33′ | 37° 11′ | — | 114.9 – NW | 5.0 |
| 1 July ........ | 63° 38′ | 37° 29′ | feeding on fish, social | 138.3 – S | 6.0 |
| 2 — ......... | 63° 33′ | 37° 34′ | — – – — | 79.9 – SE, NW | 3.6 |
| 3 — ......... | 63° 53′ | 36° 47′ | — – – — | 70.3 – NE | 3.5 |
| 4 — ......... | 64° 13′ | 35° 52′ | social | 104.4 – E | 4.3 |
| 5 — ......... | 64° 07′ | 36° 09′ [1] | feeding on fish, social | 18.0 – N, NE | 3.6 |

[1]) Position at 0610 hours. Tracking terminated at 0800 hours.

Although the radio signals from the tags on K allowed good tracking even in periods of low visibility and rough weather, accurate assessments of the relative signal direction was required to maintain contact. Rapid changes in speed, meandering courses, and abruptly lengthened submergences that were typical of K's behaviour, made tracking demanding.

Long periods without signals from the fin tag emphasized the importance of proper tag placement for consistent tracking. If we had relied only on signals from the fin tag, with silent periods of up to 2½ hrs, the whale could have moved 40 km or more during that time. If the whale reversed course (as it sometimes did), the distance from it would have doubled, and tracking would have been impossible. The forward tag provided signals during most blows, at intervals of usually less than 15 min, during which time the whale was within a manageable tracking distance of about 2 naut. miles.

During short submergences K's dives were probably shallow because the length of time would not have allowed it to go deeper. Longer dives could have been deep, but our previous observations of fin whale activity have associated most long dives with particular activities such as subsurface feeding (Watkins 1981c). This was noted also by recent sonar tracking of fin and humpback whales (Watkins and Goebel, 1984) where both short and long dives were to about the same depths.

The frequency of long dives shown in Fig. 5 is worth noting here, since there appears to be a lower frequency of long dives during period A (night) than during each of the periods B and D (morning and evening). (Wilcoxon's two-sample test gives $p<0.1$ when A and B are compared, and $p<0.2$ for A and D). Nemoto (1957, 1959) observed increased stomach contents in North Pacific fin whales caught during morning and evening hours. He remarked that this tendency might be attributed partly to the clear diurnal migrations of the zooplankton as prey of the whale. *Meganyctiphanes norvegica,* the most common euphausiid species taken by fin whales caught west of Iceland (Rörvik et al. 1976; Lockyer and Brown 1978), generally occurs at 0–100 m depth during night and at 100–400 m depth during day (Mauchline 1980). In general capelin *(Mallotus villosus)* show similar diurnal vertical movements and are most commonly found at 0–100 m during night and at 200–300 m during daylight hours, although deviations from this may occur in summer (Vilhjálmsson, pers. comm.). It therefore appears that the most active feeding period of the fin whale is linked to the period when enough food is in the upper layer (not necessarily the greatest abundance) and some visual cues occur simultaneously, i.e. right after sunrise before the prey moves down, and during the upward movement of the prey in the evening. Thus K's long-dive rhythm, especially in the morning but also in the evening, may be related to more active subsurface feeding at these times. The same applies to the fast swimming behaviour (see Table 2), particularly during period B when the whale was actively feeding on schooled fish. It may be added that if the long dives denote active feeding as proposed, then K and his companions may have fed some during the passage across the Irminger Sea.

The diel differences in dive times match our previous radio-tagging results in which fin whales, humpbacks, and Bryde's whales made shorter dives at night, apparently resting and moving near the surface (Watkins et al. 1979; Watkins et al. 1981). It was interesting that there were these night-time speed and dive differences in the Irminger Sea although the sky was never really dark. The lack of darkness may account for the continuing activity during some nights and less marked diel differences. Although the differences were small, the lowest average speeds were generally at night, as was the greatest number of short dive sequences with single blows. With increasing morning light, the whales generally became more active, speeds increased, blows were clustered, and dives lengthened. Although the

TABLE 2

*Average speeds (in knots) over 6-hr periods, calculated from the ship's positions. Although the differences were small, the lowest (period A) agreed with diel differences in activity reflected by dive times. Note the differences between averages for the first half (feeding on krill and travelling) and the second half (feeding on fish and socializing).*

| | *2200–0400 hrs* *A* | *0400–1000* *B* | *1000–1600* *C* | *1600–2200* *D* |
|---|---|---|---|---|
| 25/26 June .............. | 2.5 | 2.1 | 4.2 | 4.3 |
| 27 — .............. | 4.0 | 7.5 | 4.1 | 4.1 |
| 28 — .............. | 2.1 | 3.4 | 4.5 | 3.7 |
| 29 — .............. | 2.5 | 4.9 | 3.8 | 5.4 |
| 30 — .............. | 3.0 | 4.1 | 5.1 | 6.8 |
| Track's 1st half average ... | *2.9* | *4.4* | *4.4* | *4.9* |
| 1 July .................. | 6.8 | 6.5 | 5.5 | 4.0 |
| 2 — .................. | 6.2 | 5.5 | 3.4 | 2.5 |
| 3 — .................. | 3.3 | 6.7 | 2.7 | 2.2 |
| 4 — .................. | 5.2 | 6.0 | 2.3 | 3.9 |
| 5 — .................. | 2.8 | | | |
| Track's 2nd half average .. | *4.9* | *6.2* | *3.5* | *3.1* |
| Average overall .......... | *3.8* | *5.2* | *4.0* | *4.1* |

longest dives occurred during period B, the overall dive time averages were longer in period C indicating consistently more activity during daylight.

Sudden shifts in K's activity from clustered blowing to single blowing were made obvious by the radio tracking. A surfacing behaviour characterized by readily visible blows, often at rates of 2 to 4 per min and high round-outs, could suddenly change to behaviour that was poorly visible, with faint blows 1 to 3 min apart with up to 0.5 km (at 10 km/hr) between surfacing and very little of the body showing. These behavioural shifts may explain why fin whales often seem to suddenly disappear or appear in an area.

The variations in behaviour throughout the different segments of the track were interesting. K changed from feeding with companions on an abundant supply of krill, travelled for four days with a variety of other fin whales, then again fed on schooled fish and was in social contact with more companions. The motivation for such travel may have been due to social factors rather than food abundance or preference. K is the first proof of east-west movement of a fin whale in the Irminger Sea and an additional indication of mixing of fin whales between Iceland and East-Greenland waters. Both K and one of the Discovery-marked fin whales off East-Greenland, that was captured off Iceland only one week after marking (Jonsgård and Christensen 1968), show that mixing may just as well take place by quick passages across the Irminger Sea as by gradual movement throughout the season.

Radio tracking is a promising means for studying the movements and local identity of whales as well as enabling accurate, detailed assessments of behaviour. Visual identifications even of the most easily identifiable cetaceans (as for humpbacks, see Katona et al. 1979) do not provide the continuous unequivocal identifications needed for monitoring whale activity. The radio tag allowed confident tracking over long periods and provided positive information about each surfacing. The ability to maintain contact and continue to obtain accurate details of the whale's behaviour was not confined just to close observations and times of good visibility, but the same information was obtainable when the tagged whale could not be seen at a distance, in rough seas, and during periods of low visibility. In addition to surfacing information, telemetry of environmental and physiological parameters could also be easily added to the radio beacons to provide much more complete pictures of whale activities. Our continuing development of more than 20 years (Schevill and Watkins 1966) has provided new information about whales with each tagging experiment. This Iceland to Greenland track of an open sea fin whale was especially productive, the track and continuous behavioural data could not have been obtained except by radio tagging.

## CONCLUSIONS

1) The fin whale "K" was not bothered by the tag.
2) Tagged and non-tagged fin whales behaved similarly.
3) The whale's movements were not influenced by the tracking ship.
4) K was difficult to approach when alone.
5) Fin whale associations were fluid, with much changing of companions.
6) Social activity may have been a primary interest: K stopped feeding, travelling, and resting to interact with other whales.
7) Diel changes in activity (speed and duration of dives) occurred in spite of less than total darkness at night.
8) Feeding methods varied with changes in prey.
9) Fin whales at sea were often difficult to see, especially during single blowing behaviours.
10) The mixing of fin whales across the Ir-

minger Sea may take place by quick passages between East-Greenland and Iceland, as well as by gradual movement throughout the season.

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