Short-term movements of long-finned pilot whales Globicephala melas around the Faroe Islands

Authors: Bloch, Dorete, Heide-Jørgensen, Mads Peter, Stefansson, Eyðfinnur, Mikkelsen, Bjarni, Ofstad, Lise Helen, et al.

Source: Wildlife Biology, 9(1) : 47-58

Published By: Nordic Board for Wildlife Research

URL: https://doi.org/10.2981/wlb.2003.007

Short-term movements of long-finned pilot whales *Globicephala melas* around the Faroe Islands

Dorete Bloch, Mads Peter Heide-Jørgensen, Eyðfinnur Stefansson, Bjarni Mikkelsen, Lise Helen Ofstad, Rune Dietz & Liselotte Wesley Andersen

Bloch, D., Heide-Jørgensen, M.P., Stefansson, E., Mikkelsen, B., Ofstad, L.H., Dietz, R. & Andersen, L.W. 2003: Short-term movements of long-finned pilot whales *Globicephala melas* around the Faroe Islands. - Wildl. Biol. 9: 47-58.

On 15 July 2000, a pod of about 80 long-finned pilot whales *Globicephala melas* was driven to the coast at Sandavágur, the Faroe Islands (62.055°N, 7.157°W) for the purpose of tagging selected whales with satellite-linked radio transmitters. A transmitter was attached to the anterior flank of the dorsal fin of four beached whales. After the tagging, all four whales were reunited with their pod and the entire pod was driven to sea. The positions of three of the four whales were tracked (one for a period of 47 days) and the results show that the whales separated after a few days and eventually went in different directions. After 10 days, two of the whales were observed together in a pod, and after 19 days two of the whales were located at positions determined to be within 2.3 km of each other. The whales showed a strong affinity for the deep water off the continental shelf. The sex and relatedness of the four, tagged whales were determined from skin biopsies. The tagged whales comprised one adult female with one juvenile in puberty, possibly her male offspring, and two adult males, one of which could be the offspring or the sibling of the female. The swimming speed of the whales was estimated at 0.2-14.5 km/hour, and they travelled average distances of 70-111 km/24 hours with a maximum of 200 km in 24 hours. Considering the mobility of the whales, it seems likely that the catches that occur at the Faroe Islands are recruited from a larger area in the North Atlantic than previously presumed. This suggests that the whales are taken from a larger population than that estimated from coastal areas around the Faroe Islands, hence increasing the probability that the harvest is sustainable.

Key words: the Faroe Islands, Globicephala melas, long-finned pilot whale, movements, satellite telemetry

Dorete Bloch, Eyðfinnur Stefansson & Bjarni Mikkelsen, Museum of Natural History, FO-100 Tórshavn, Faroe Islands - e-mail addresses: doreteb@ngs.fo (Dorete Bloch); eydfinns@ngs.fo (Eyðfinnur Stefansson); bjarnim@ngs.fo (Bjarni Mikkelsen)
Mads Peter Heide-Jørgensen, Greenland Institute of Natural Resources, c/o National Marine Mammal Laboratory, 7600 Sand Point Way NE, Seattle, WA 98115, USA - e-mail: madspeter.heide-joergensen@noaa.gov
Lise Helen Ofstad, Faroese Fisheries Laboratory, FO-100 Tórshavn, Faroe Islands - liseo@frs.fo
Rune Dietz, National Environmental Research Institute, Frederiksborgvej 399, Boks 358, DK-4000 Roskilde, Denmark - e-mail: rdi@dmu.dk
Liselotte Wesley Andersen, National Environmental Research Institute, Kalø, Grenåvej 12, DK-8410 Rønde, Denmark - e-mail: lwa@dmu.dk

Corresponding author: Dorete Bloch

Received 19 October 2001, accepted 13 June 2002

Associate Editor: Sigurður Snorrason

The long-finned pilot whale *Globicephala melas* is an abundant odontocete in the Northeast Atlantic with an estimated population size of around 778,000 animals (C.V. = 0.30; Buckland, Bloch, Cattanach, Gunnlaugsson, Hoydal, Lens & Sigurjónsson 1993). In the Northwest Atlantic, surveys with partial coverage have revealed abundance estimates of 10,000-12,000 long-finned pilot whales from the Gulf of Maine to Cape Hatteras (Winn 1982, Payne & Heinemann 1993) and 13,167 off Labrador and Newfoundland (Hay 1982). The biology of long-finned pilot whales has been studied in Newfoundland by Sergeant (1962) and through an intensive sampling programme of 'grinds' (we use the Faroese word grind for a pod of long-finned pilot whales that has been stranded on the beach) harvested in the Faroe Islands during 1984-1986 (Donovan, Lockyer & Martin 1993, Desportes, Bloch, Andersen & Mouritsen 1994b).

Long-finned pilot whales have been harvested since the Norse settlement more than one thousand years ago on the Faroe Islands, as well as in all the old Norse area (Dahl 1971). Long-finned pilot whaling has also been conducted in Normandy (France), Shetland, the Orkney Islands, the Hebrides, and in Ireland from the beginning of the 17th century and for at least one century in Greenland (Bloch 1994a, Smith 1993, Heide-Jørgensen & Bunch 1991). Today, long-finned pilot whales are taken in drive fisheries at the Faroe Islands and in Greenland. By far the largest and most frequent catches are taken at the Faroe Islands with an average of 6.1 grinds/year and 846.8 whales/year during 1709-2001 (Bloch 2001). Although the estimate of the total abundance of long-finned pilot whales in the Northeast Atlantic is high relative to the catch abundance, nothing is known about the extent of the area from which the harvested whales are recruited. This has important bearing on the evaluation of the sustainability of the exploitation.

Studies of stomach content and burdens of heavy metals, organochlorines and parasites in long-finned pilot whales show a heterogeneity that indicate that the whales for the main part of their life occupy different areas in the Northeast Atlantic (Borrel & Aguilar 1993, Caurant, Amiard-Triquet & Amiard 1993, Desportes & Mouritsen 1993, Desportes, Andersen, Aspholm, Bloch & Mouritsen 1994a, Caurant & Amiard-Triquet 1995, Dam & Bloch 2000, Dam 2001).

Generally, direct observation does not provide information on the movement patterns, feeding habits, dive capacity, swimming speed or dispersal of individual whales. Specifically for long-finned pilot whales, direct observation does not provide information on how long individuals from a pod stay within the same pod. The structure of the landed grinds at the Faroe Islands was found to be composed of related females and their offspring of both sexes (Andersen 1988, 1993, Amos, Bloch, Desportes, Majerus, Bancroft, Barrett & Dover 1993). It was found that the size of a grind varied between seasons and years, that grinds sometimes were composed of more than one pod, or alternatively that only a part of a larger pod was landed (Bloch, Desportes, Mouritsen, Skaaning & Stefansson 1993a, Bloch 1994b). It is still unknown, however, how many whales compose a pod and how new pods are established.

Tracking of whales equipped with satellite-linked radio transmitters offers new opportunities to gain insight into the migratory behaviour of odontocetes in offshore areas. The technique provides unique opportunities for following the whales in areas and during seasons in which direct observation is difficult, if not impossible (Dietz, Heide-Jørgensen, Richard & Acquarone 2001). Furthermore, tracking by satellite offers opportunities for collecting sensor data (e.g. depth) that describes the behaviour of the whales (e.g. Heide-Jørgensen, Hammeken, Dietz, Orr & Richard 2001). Stranded long-finned pilot whales have occasionally been rehabilitated, tagged with satellite transmitters, released and followed at other places in the North Atlantic (Mate 1987). Two juvenile pilot whales that initially stranded in Connecticut, USA were rehabilitated after a stay at Mystic Aquarium, tagged with satellite transmitters at the northeast coast of the USA and tracked for 132 days during the winter. They moved over Georges Bank and Georges Basin. They were swimming together and three dives to the bottom at 320 m exceeded 26 minutes (Nawojchik & Aubin 2003).

Since the pod structure seems to be fundamental to the social behaviour of long-finned pilot whales, we knew that it was critically important that the pod structure should remain undisturbed during the capturing and tagging operation. It seemed both practically and financially impossible to tag all whales in a pod since the average pod size is 138.7 ± 3.08 (N = 1,828 grinds; 253,531 whales) and with a range of 1-1,200 in the Faroese harvest (time period: 1584-2001; Bloch (2001), Archive of the Faroese Museum of Natural History). On the other hand, if the pod structure is as stable as the genetic studies indicate, one entire pod could be followed by tagging a few individuals from the pod. This, however, requires that the entire pod is undisturbed by the tagging operation. No other studies have attempted to capture and hold large schools of odontocetes for tagging, but we found that the Faroese driving of long-finned pilot whales provided a unique opportunity in this respect. This opportunity is unique for several reasons: 1) the Faroe Islands has a number of good whaling bays that catch long-finned pilot whales frequently, and 2) very importantly, many local Faroese are very skilled in the techniques employed in the driving and holding of large pods of long-finned pilot whales.

In order to elucidate the spatial dispersal of long-finned pilot whales around the Faroe Islands, a tagging project involving tracking of whales by satellite was initiated. To maintain the integrity of the pod structure some selected whales were equipped with satellite transmitters and returned to their pod.

Methods

Tags

It was expected that long-finned pilot whales potentially could dive to great depths. Long-finned pilot whales are frequently found in waters with depths of more than 1,500 m, and it was therefore decided to develop a transmitter that could sustain pressures down to a depth of 2,000 m. The basic transmitter chosen was a ST-10 (Telonics, Mesa, Arizona) with 2 D-cell batteries, capable of 180,000 transmissions with a nominal output of 0.45 watt. The transmitters were modified by Wildlife Computers (Redmond, Washington) and equipped with a controller board that allowed collection of data on the diving behaviour. The saddles were constructed from fibre glass models of the dorsal fins of a small, medium and large long-finned pilot whale. Anchoring on the dorsal fin was facilitated by the use of three stainless steel bolts (8 mm in diameter) that penetrated the dorsal fin through holes that were made by cork borers. Different lengths of bolts were available for different thicknesses of the dorsal fin, which was measured in the field. The inside of the saddle was covered with neoprene. The triangular saddle was 26 × 22 × 13 cm, the tag was 19 cm long, and the whole unit weighed 1,100 g in air.

Software onboard the transmitters collected quantitative information on the diving of the whales, battery voltage and the number of transmissions. Initiation of a transmission was controlled by a conductivity switch that only permitted transmissions when the transmitter was out of the water. The delay caused by the conductivity switch was 0.25 seconds, and the minimum time between transmissions was 45 seconds.

Capturing of whales

From a review of the long-finned pilot whaling statistics over the last four centuries, it was evident that the villages of Miðvágur and Sandavágur (62.054°N, 7.154°W) on the southeastern side of the island of Vágoy (Fig. 1) have the most frequently used whaling bays with 16% of all grinds and 19% of all whales landed in the Faroe Islands (Bloch 2001). The bays of Miðvágur and Sandavágur were also chosen because they have wide and sandy beaches, a relatively flat slope towards the beach and easy access from most areas in the Faroe Islands. Therefore, an agreement was made with the local sheriff, who is the government official in charge of long-finned pilot whaling on Vágoy, and the local chairmen of the whaling operations association. They were assigned the tasks of driving, holding, beaching and releasing the whales.

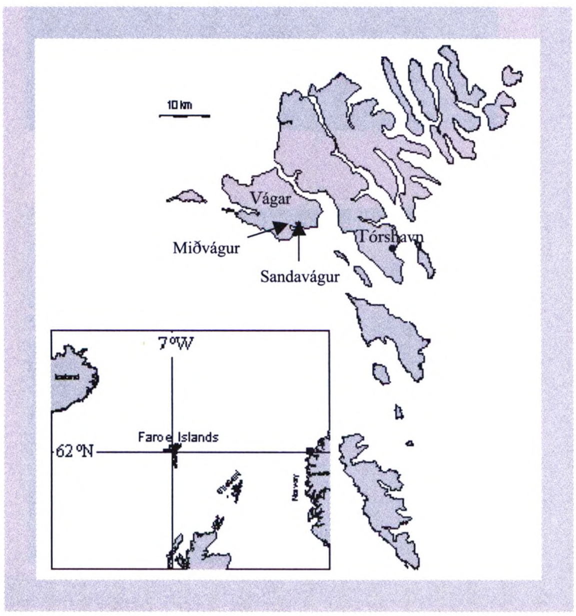

Figure 1. Location of the capturing locality Sandavágur in the Faroe Islands where four long-finned pilot whales were tagged on 15 July 2000.

The project started in 1997. After an unsuccessful attempt in September 1997, the next chance came on 15 July 2000 when a grind estimated to number 80 whales was driven to Sandavágur for tagging.

The grind was driven towards the shore in the traditional way. The boats were positioned in a half circle behind the pod, driving the pod slowly towards the whaling bay (Bloch 2001). As soon as the first 20-30 whales were stranded on their bellies, the boats pulled back to prevent additional, unnecessary strandings. The boats then maintained their position about 500 m from the shore with the rest of the whales. In the beginning, the whales were kept between the boats and the beach. They stayed close together and did not attempt to escape even when they later moved outside the boats.

Wearing dry suits, 2-4 people walked out to each of the four whales that had been chosen for tagging. The people were standing on each side of the whale and kept it belly-down by holding on to the dorsal fin and thereby preventing the animal from rolling around. It is worth noting that the whales have to be moved gently from side to side to prevent them from losing their balance. Should they roll over, they can have severe difficulties swimming away again from the beach and can easily drown. During the tagging of the whales, additional locals turned the remaining beached whales so they headed away from the beach and pushed them out again by pulling carefully on the dorsal fin, flippers and fluke. These whales, as well as the tagged whales, swam directly to the rest of the pod, which they joined in waiting for the last, tagged whale. As soon as the last whale was tagged it swam out to the others and the whole pod swam away again. The whole process of driving the pod ashore, tagging and releasing the pod lasted 50 minutes in all.

Attachment of the tags

During the tagging operation, two people kept the whale on its belly while three others mounted the tags. The saddle was attached to the proximal anterior aspect of the dorsal fin. The dorsal fin was penetrated with a sharp, hollow cork borer 8 mm in diameter from the side

Figure 2. Tagging of pilot whales in Sandavágur on 15 July 2000, showing attachment of the tag to the dorsal fin (A-B), the attached tag (C), and the grind being driven to sea again after tagging (D). Pictures are from www.ngs.fo.

Table 1. Data on the four pilot whales tagged at Sandvágur on 15 July 2000 (= day 197). The precision of positions of quality Q3 = 0-150 m, Q2 = 150-350 m, Q1 = 350-1,000 m and QA and QB = >1,000 m.

IDNO	Total body length (cm)	Estimated weight (kg)	Sex	Stage	No of trans-missions	Day of last position NQ > 0	Day of last signal	Transmitter longevity (days)	Quality of positions						
									Q3	Q2	Q1	Q0	QA	QB	Q1-Q3
20167	585	1.916	♂	Ad.	16222	212	212	15	8	26	41	76	86	117	75
20692	550	1.642	♂	Ad.	-	197	197	0	-	-	-	-	-	-	-
20693	420	837	♀	Ad.	19516	216	216	19	8	28	70	36	125	147	106
20696	450	994	♂	Juv.	38967	242	244	47	14	33	78	70	134	214	125

with only one single hole in the saddle to the other side where seven holes were available to receive the cork borer. As the cork borer was pulled out, a bolt was pushed in through the hole to the opposite side. The bolt was held in place with a nut and the saddle was thus secured to the dorsal fin (Fig. 2). There were a total of three such attachment points for each saddle. The whales showed no visible reaction to the penetration of the dorsal fin or the attachment of the transmitter. Four different videos were taken of the whole procedure and they confirm the lack of reaction by the whales.

The whales chosen for tagging were two, large animals believed at the time to be mature males, and two, smaller whales, judged to be either females or juvenile males. Two people measured the total length of the whale to the nearest centimetre, following standard procedures (Bloch, Lockyer & Zachariassen 1993b; Table 1). From the total length, the weight of the whales was estimated by comparing with standard curves of length-weight relationship (Lockyer 1993).

The four blubber and skin biopsies from the inside of the cork borers from each whale were conserved for later genetic examination and the cork borers were washed in 96% ethanol before tagging of the next whale. The biopsies were used for genetic determination of the sex of the whales at the Agriculture Science laboratory in Foulum, Denmark, and for determination of the genetic relationship of the whales by the National Environmental Research Institute, Kalø, Denmark (see Table 1).

The whales were followed by the Argos Data Collection and Location System (e.g. Harris, Fancy, Douglas, Garner, Amstrup, McCabe & Pank 1990). An executive order (Directive No. 126, dated 23 June, 1997) was issued that protected any pod of long-finned pilot whales that contained tagged whales and made it illegal to attempt to drive them towards the shore.

Genetic analyses

DNA was extracted from skin biopsies using the method described by Andersen, Holm, Siegismund, Clausen, Kinze & Loeschcke (1997) and the sex of the four individuals was determined according to Bérubé & Palsbøll (1996). A total of eight microsatellite loci with dimer repeat motifs were used to establish the relationship between the tagged whales (Fullard, Early, Heide-Jørgensen, Bloch, Rosing-Asvid & Amos 2000). The microsatellite primers were labelled fluorescently, and the fragments were scored on an ABI sequencer.

Data analysis and swimming speed

Only positions assigned by Service Argos to be of quality 1-3 NQ with predicted errors of <1 km were used for mapping the movements of the whales. The whale positions were projected in MapInfo Professional 5.0.

Swimming speed was found by dividing the time lag between consecutive positions with the spherical distance between these positions. Spherical distance between positions was found by:

$$\sqrt{(lat_b - lat_a)^2 + ((long_b - long_a) * \cos(radian(lat_a + lat_b)/2)^2)} * 1,852 \text{ km}$$

where lat is latitude and long is longitude for consecutive positions a and b. Swimming speed was only calculated for good quality positions (NQ 1-3). Also, swimming speed was only calculated for positions separated by 2-5 hours, as these may provide the most realistic swimming speeds for the whales, because of the relatively high significance of positioning errors when estimating swimming speed for positions separated by short time intervals.

To investigate for potential differences in swimming speed between whales, we used a Kruskal-Wallis statistical test, performed in STATISTICA 6.0 (StatSoft 2001).

Results

Tag performance

Four tags were available for mounting. A fifth failed before mounting and was not deployed. One of the four deployed tags apparently failed shortly after the

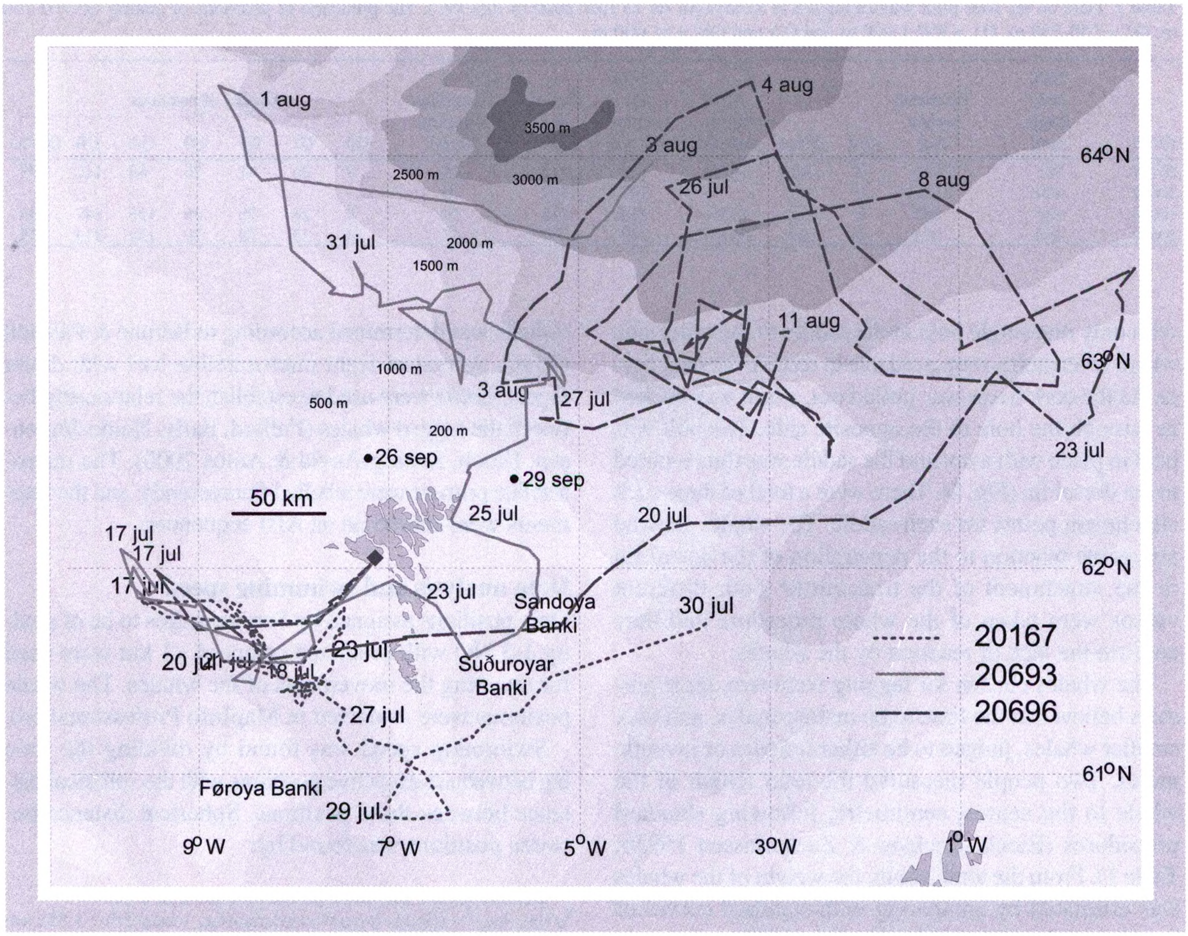

Figure 3. Routes of the three satellite-tagged long-finned pilot whales male 1 (IDNO 20167), the female (IDNO 20693) and the juvenile male (IDNO 20696) from the tagging locality at Sandavágur from 15 July 2000 until 30 July, 1 August and 11 August 2000, respectively. The observations on 26 and 29 September 2000 were made by the Faroese Fishery Inspection vessel M/S Tjaldrið.

whales were tagged as no signals were received after the release of the whale (male 1; IDNO 20692). The remaining three tags transmitted for 15-47 days and provided 16,222-38,967 transmissions (see Table 1). The last transmitter stopped sending on 1 September. One of the Faroese Fishery Inspection vessels, M/S Tjaldrið, observed a tagged whale on 26 and 29 September (Fig. 3).

The battery voltage remained unchanged and there was no sign of battery drainage that could explain the premature failure of the transmitters.

Sex determination

Based on the number of bands obtained after PCR amplification with the ZFXY, ZFX and ZFY primer set designed for odontocetes (homozygote ZFX/ZFX for female and heterozygote ZFX/ZFY for male; Berubé & Palsbøll 1996) the gender of the four individuals was determined. The biopsy-sample from IDNO 20693 was a homozygote indicating a female whereas the other three samples were heterozygotes indicating three males.

Table 2. Combined genotype of eight microsatellite loci for the four pilot whales. For each locus the genotype is given as the allele-length in base pairs, e.g. locus 199/200 has two alleles, one with the length 113bp and one with the length 131bp.

		Locus							
IDNO	Sex	199/200	EV 37	409/470	468/469	417/418	464/465	415/416	EV94
20167	♂	113113	184198	181189	151151	182182	146150	230232	248248
20692	♂	113129	182184	187189	113151	186186	150150	232234	236248
20693	♀	113131	182184	187187	151151	182186	150152	228232	236236
20696	♂	113131	182184	187197	151151	182186	150152	232236	236236

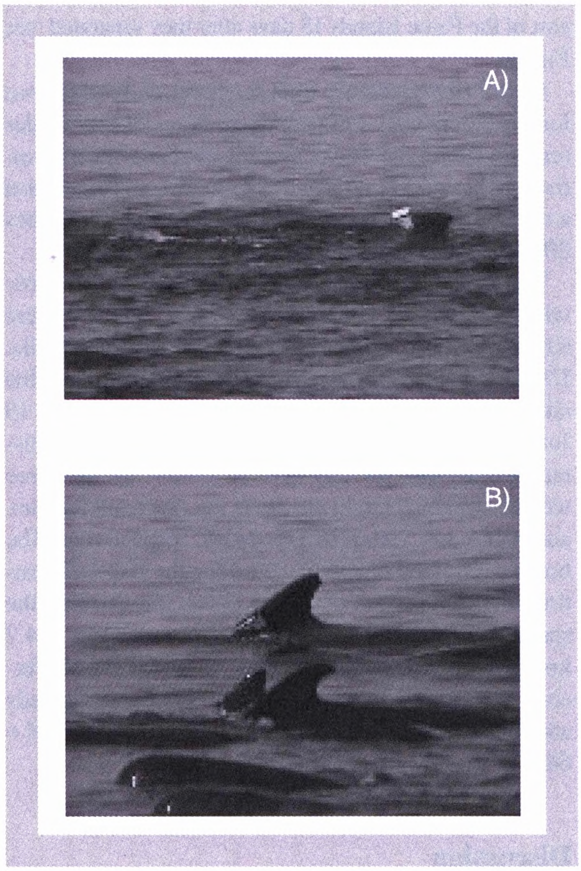

Figure 4. Photos taken by the staff of the Faroese Museum of Natural History at Skopunarfjørður on 23 July 2000 showing the female long-finned pilot whale (IDNO 20693) with the tag visible (A) and male1 (IDNO 20692) with the attachment saddle intact and sitting well, whereas the tag itself was lost. Pictures are from www.ngs.fo.

Relationship between and associations among the whales

From the combined genotypes, it is highly likely that the female (IDNO 20693) is the mother of the juvenile male (IDNO 20696), but neither of the two adult males could be the father under this assumption (Table 2). This exclusion is based on locus 409/470 for male 1 (IDNO 20692) and locus 409/470, locus 415/416 and locus EV94 for male 2 (IDNO 20167). If the female is not the mother, male 1 can be the father of the juvenile male. The female and male 1 could be closely related (siblings) while the relationship between those two and the last male cannot be established. The third possibility is that the female, the juvenile male and male 1 are all siblings.

Overall movements of the whales

After tagging, the whales swam 100-150 km west-south-west of the Faroe Islands where they stayed together the first two days (see Fig. 3). After 17 July, i.e. three days after the tagging, the three whales apparently separated and followed different routes.

After 17 July, male 2 (IDNO 20167) swam slowly southeast through the Faroe Bank Channel following the Faroe shelf border, and on 28-29 July it arrived at the southern tip of the Faroe Plateau. Between 29 and 30 July it swam rapidly 180-200 km to the east-north-east, and 30 July was the last day with an uplink from the tag. The whale was seldom in water shallower than 200 m; most of the time it stayed at depths exceeding 500 m. When the transmitter stopped, the whale was in waters more than 1,000 m deep.

The only female whale (IDNO 20693) was, according to its length, an adult (Bloch et al. 1993b). During 17-22 July, it swam slowly southeast through the Faroe Bank Channel. On 23 July, it was swimming from the west through Skopunarfjørður in a pod numbering around 100 whales. The whale was photographed by the staff of the Faroese Museum of Natural History together with male 1 (IDNO 20692; Fig. 4).

On 24 July, the female (IDNO 20693) swam out on the Suðuroyar and Sandoya Banks and on 25 July approached the northeastern tip of the Faroe Islands archipelago at Svínoyarvík, but without being observed from land or sea. The whale then swam to the north-north-east to the deep sea (> 1,500 m in depth) and remained at the deeper side of the 1,500 m depth curve as it moved northwest towards eastern Iceland. Upon reaching the border of the Outer Faroe Islands Fishery Limit on 1 August, the whale turned and swam nearly directly east. The transmitter ceased on 3 August. On the last day of contact, i.e. 3 August, the female (IDNO 20693) and the juvenile male (IDNO 20696) were at the positions 5.069°W, 63.595°N and 5.099°W, 63.579°N, respectively, an estimated 2.3 km from each other (see Fig. 3).

Male 1 (IDNO 20692) was the whale whose transmitter failed directly after attachment. On 23 July, it was approached and photographed by the staff of the Faroese Museum of Natural History together with the adult female (IDNO 20693) in Skopunarfjørður. The whale was in good shape and the saddle was visible, but the transmitter was not attached to the saddle. The transmitter must have been lost just after the release, because it was working when the whale rejoined the pod as the last of the four.

From 17 July, the juvenile male (IDNO 20696) swam eastward until 24 July, where it was at water depths of more than 1,500 m. The whale swam around in this area, approaching Norway between 25 July and 28 August. As mentioned above, this whale seems to have met the

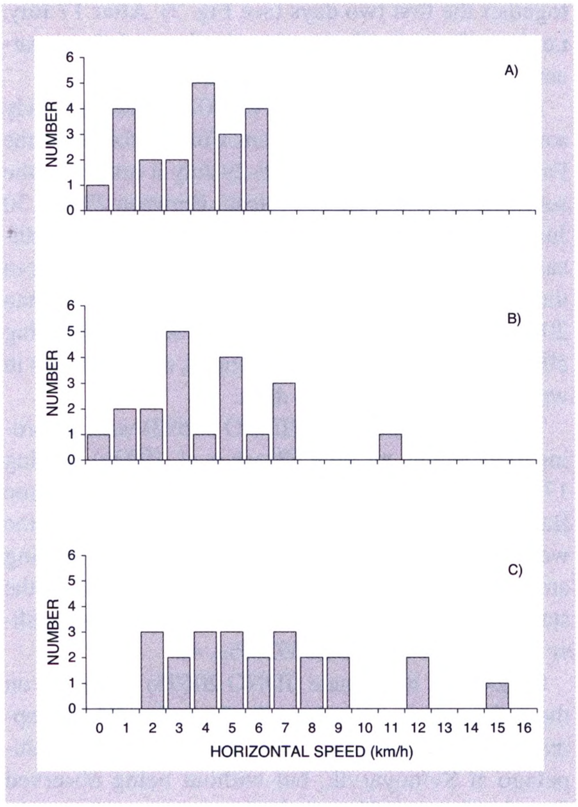

Figure 5. Distribution of horizontal speed registrations on 16 categories (km/hour) based on quality positions of the classes NQ 1-3 for the long-finned pilot whales: A) male 2 (IDNO 20167; mean = 3.5 km/hour, SD = 1.9; N = 21), B) adult female (IDNO 20693; mean = 4.2 km/hour, SD = 2.6; N = 20), and C) juvenile male (IDNO 20696; mean = 6.3/hour, SD = 3.4; N = 23)

adult female (IDNO 20693) again on 3-4 August, about the time when her transmitter stopped sending.

Fishermen fishing for cod *Gadus morhua* and haddock *Melanogrammus aeglefinus* reported that many whales, including thousands of long-finned pilot whales, were observed east of the Faroe Islands in July-September at the time when the tagged whales were in this area and, as mentioned above, a tagged whale was observed in late September 2000.

Movements relative to bathymetry, distances travelled and swimming speed

None of the whales spent much time on the Faroe Shelf (<200 m). Shortly after being released, they moved out to the slope and travelled along the 200-500 m depth contour. The juvenile male (IDNO 20696) and the adult female (IDNO 20693) later crossed over the shelf and migrated northeast to an area where water depths exceeded 2,000 m. Despite their wide separation for most of the time, they apparently met again in the area northeast of the Faroe Islands 18 days after they separated (see Fig. 3).

Male 2 (IDNO 20167) went southeast, and contact was lost in waters over 1,000 m deep. None of the whales remained over the banks around the Faroe Islands although these are known to be productive and to support a relatively high fishery of various fish stocks (Debes 2000, Gaard, Hansen, Olsen & Reinert 2002).

The total spherical distances travelled by the three whales based on positions of quality NQ 1-3 were 3,003 km from 15 July to 11 August (the juvenile male; IDNO 20696), 1,577 km from 15 July to 3 August (the adult female; IDNO 20693) and 1,048 km from 15 July to 30 July (male 2; IDNO 20167). The average distances travelled per day (i.e. 24 hours) by the three whales were 69.9 km (male 2), 83 km (the adult female), and 111.2 km (the juvenile male), respectively. The horizontal speed data calculated for the NQ 1-3 positions and time intervals of 2-5 hours showed that the speed ranged within 0.2-14.5 km/hour (mean = 4.7 km/hour, SD = 2.9, N = 64; Fig. 5). Significant difference was found in the estimated swimming speeds among the three whales ($H = 9.08$, $df = 2$, $P = 0.01$, $N = 64$).

Discussion

Capturing, handling and tagging of the whales

After the project was started in 1997, it took several years before a satisfactory opportunity for capturing the whales emerged. This circumstance stems perhaps from mere unfortunate luck as long-finned pilot whales did not frequent the area that had been specifically selected as the best site available for tagging of the whales during 1997-2000. The capturing of the whales depended on both access to a sandy beach with a relatively slow-rising slope of the coast and a place where the land contours could assist in the trapping of the whales. We were also dependent on local assistants that had agreed to assist the project, as well as about 10-15 well-trained biological assistants. Moreover, the weather conditions had to be optimal with a totally calm sea with flood tide. Finally, the chosen locality had to be easily accessible, as the whales always appear on short notice. These special conditions made it impossible for us to choose another capturing locality even though other places were frequently visited by long-finned pilot whales.

Even though the pod of 80 long-finned pilot whales was relatively large, it appeared easy to drive them into and hold them inside the bay for the 50 minutes the tagging required. Beaching the whales, tagging and releasing them again also went without problems. Evidently all four, tagged whales survived the experience and no short-term effects could be discerned from their movement and diving activity (*cf.* Heide-Jørgensen, Bloch, Stefansson, Mikkelsen, Ofstad & Dietz 2002). The capturing and handling techniques employed, made it possible to handle even big and heavy whales, such as long-finned pilot whales weighing close to two tonnes (see Table 1), on the beach.

Transmitter performance

The tags were expected to last much longer than they did. There were no signs of battery drainage, but several other factors might have contributed to the premature failure of the tags: (i) long-finned pilot whales, especially large ones as those tagged, may have reacted by attempting to rub off the tags, (ii) the attachment of the epoxy cast transmitter to the stainless steel saddle was weak and in combination with the whales' effort to get rid of the tags the transmitter might have detached from the saddle, and (iii) the mounting of the tags on the anterior aspect of the dorsal fin might be a preferred position from a hydrodynamic perspective, but it definitely leaves the tags more exposed if the whales seek to rub off the transmitter. In future, mounting at the side of the dorsal fin is worth trying.

Relationship and movement of long-finned pilot whales

Genetic studies of long-finned pilot whales indicate that pods consist of matrilinearly related individuals with offspring (Andersen 1993, Amos et al. 1993). During the annual mating seasons in May-June and again in October-November, it looks as if two to several pods meet and cross-mating takes place between pods (Desportes, Saboureau & Lacroix 1993, Martin & Rothery 1993, Andersen & Siegismund 1994, Bloch 1994b). Thus, the pods are considered to consist of family units with strong ties. This was also supported by the genetic results from our study in which three out of the four tagged whales were related. Moreover, two of the three related whales (the adult female (IDNO 20693) and male 1 (IDNO 20692)) were seen together on 23 July in a pod similar in size to the one from 15 July. The behaviour of these two whales as observed on 23 July did not seem to be affected by the tags and did not depart from observations made on other occasions. What we learned from the short-term tracking of the three individuals was that the spatio-temporal cohesiveness of a pod of long-finned pilot whales is less than and different from what was previously believed and the animals did not indicate a strong affinity for each other during the period when all three tags were transmitting. Apparently, the whales split up two days after their release and went in different directions. The finding that two of the whales were as close as 2.3 km from each other again after 19 days does not prove that they were swimming in the same pod again. Further studies with longer lasting tags will be necessary to determine if the whales depart for a while only to meet again or if the social cohesion within a pod is not as strong as previously thought.

Speeds

Our data suggest that there may be some specific differences in swimming speeds among individuals. The juvenile male (IDNO 20696) was swimming faster than the other two whales (see Fig. 5). The female (IDNO 20693) was generally travelling slowly, and there were no indications of periods with faster swimming speeds as seen for both males. However, this may not be the case all the time, but rather an artefact caused by the short period of contact with the whales, in which they travelled over quite different water depths.

It was not possible to test for diurnal effects on swimming speed, because the positions received at night were not useable.

Implications for management

The North Atlantic Sightings Surveys were conducted in 1987, 1989 and 1995 and the estimated number of long-finned pilot whales has been of similar magnitude in all years (Butterworth 1996). Nevertheless, the long-finned pilot whales were not observed at the same localities at the same time from year to year. The immediate finding in our study is that long-finned pilot whales observed in the coastal areas of the Faroe Islands, where the population was estimated at 55,112 (C.V. = 0.52) in 1987, are by no means restricted to this area (Buckland et al. 1993). Considering the mobility of these long-finned pilot whales, it seems more likely that the catches on the Faroe Islands are recruited from a much larger area in the North Atlantic. This suggests that the whales are taken from a larger population than that estimated from coastal areas around the Faroe Islands hence increasing the probability that the harvest is sustainable.

Our study offers very little in terms of understanding the movements of the long-finned pilot whales; no simple bathymetric contours seem to attract the whales and no migrational patterns have emerged. The main food items of long-finned pilot whales are the squids *Todarodes sagittatus* and *Gonatus* sp. Examination of the Faroese statistics on long-finned pilot whaling has shown a positive correlation between good squid years and years with many grinds in the Faroes (Sundet 1985, Gaard 1988, Jákupsstovu 1993). Moreover, there is a correlation between the annual position of the polar front in the Faroese area and the occurrence of long-finned pilot whales and blue whiting *Micromesistius poutassou*, another main prey species of the whales (Desportes & Mouritsen 1993, Hoydal & Lastein 1993, Zachariassen 1993, Bloch & Lastein 1995). Presumably the movements of long-finned pilot whales are in some way linked to these pelagic prey resources. Increasing the understanding of such links calls for data on spatio-temporal ditribution and behaviour of the prey species as well as data on the foraging behaviour of the whales.

Our study has provided some insight into how long-finned pilot whales use the area around the Faroe Islands, but further studies are necessary to determine the area used by long-finned pilot whales at other times of the year and over the years. Moreover, more questions have arisen concerning the cohesiveness of a pod and only further tracking and experiments of longer duration can help to explain this.

Acknowledgements - we would like to thank the pilot whaling crew in Vágoy for all their help and assistance. Without them it would not have been possible to conduct this project. The Faroese people are thanked for their enthusiasm in learning something new about the long-finned pilot whales. Even though only 588 long-finned pilot whales were caught in 2000, no one expressed any disappointment that around 80 pilot whales were released during the tagging process and another 100, including a tagged whale, were protected a week later. On the contrary, the Faroese people followed the daily movements of the four, tagged whales with great interest at the website of the Faroe Islands Museum of Natural History (www.ngs.fo). Michael Reveal is thanked for correcting the English. The project was funded by the Danish Environmental Protection Agency, as part of the programme, Dancea Co-operation for the Environment in the Arctic. The authors are solely responsible for all results and conclusions presented in the report and the authors do not necessarily reflect the position of the Danish Environmental Protection Agency.

References

Amos, W., Bloch, D., Desportes, G., Majerus, T.M.O., Bancroft, D., Barrett, J. & Dover, G.A. 1993: A review of molecular evidence relating to social organisation and breeding system in the long-finned pilot whale. - Report of the International Whaling Commission, Special Issue 14: 209-218.

Andersen, L.W. 1988: Electrophoretic differentiation among local populations of the long-finned pilot whale, Globicephala melaena, at the Faroe Islands. - Canadian Journal of Zoology 66: 1884-1892.

Andersen, L.W. 1993: Further studies on the population structure of the long-finned pilot whale, Globicephala melas, off the Faroe Islands. - Report of the International Whaling Commission, Special Issue 14: 219-231.

Andersen, L.W. & Siegismund, H.R. 1994: Genetic evidence for migration of males between schools of the long-finned pilot whale Globicephala melas. - Marine Ecology Progress Series 105: 1-7.

Andersen, L.W., Holm, L-E., Siegismund, H.R., Clausen, B., Kinze, C.C. & Loeschcke, V. 1997: A combined DNA-microsatellite and isozyme study of the population structure of the harbour porpoise in Danish waters and West Greenland. - Heredity 78: 270-276.

Bérubé, M. & Palsbøll, P. 1996: Identification of sex in Cetaceans by multiplexing with three ZFX and ZFY specific primers. - Molecular Ecology 5: 283-287.

Bloch, D. 1994a: Grindadráp í øðrum londum. - Frøði 3: 30-31. (In Faroese).

Bloch, D. 1994b: Pilot whales in the North Atlantic. Age, growth and social structure in Faroese grinds of the long-finned pilot whale, Globicephala melas. - PhD thesis, the University of Lund, Sweden, 175 pp.

Bloch, D. 2001: Færøernes grindefangst med en tilføjelse om døglingefangsten. - Føroya Náttúrugripasavn, 6th revised edition, 54 pp. (In Danish).

Bloch, D., Desportes, G., Mouritsen, R., Skaaning, S. & Stefansson, E. 1993a: An introduction to studies of the ecology and status of the long-finned pilot whale (Globicephala melas) off the Faroe Islands, 1986-1988. - Report of the International Whaling Commission, Special Issue 14: 1-32.

Bloch, D. & Lastein, L. 1995: Modelling the school structure of pilot whales in the Faroe Islands, 1832-1994. - In: Blix, A.S., Walløe, L. & Ulltang, U. (Eds.); Whales, seals, fish and man, pp. 499-508.

Bloch, D., Lockyer, C. & Zachariassen, M. 1993b: Age and growth parameters of the long-finned pilot whale off the Faroe Islands. - Report of the International Whaling Commission, Special Issue 14: 163-207.

Borrell, A. & Aguilar, A. 1993: DDT and PCB pollution in blubber and muscle of long-finned pilot whales from the Faroe Islands. - Report of the International Whaling Commission, Special Issue 14: 351-358.

Buckland, S.T., Bloch, D., Cattanach, K.L., Gunnlaugsson, T., Hoydal, K., Lens, S. & Sigurjónsson, J. 1993: Distribution and abundance of long-finned pilot whales in the North Atlantic, estimated from NASS-1987 and NASS-89 data. - Report of the International Whaling Commission, Special Issue 14: 33-49.

Butterworth, D. (Ed.) 1996: Report of the Study Group on Long-Finned Pilot Whales. - Report of Meeting, held in Cam-

bridge, UK, during 22-26 April 1996. International Council Exploration of the Sea, ICES C.M.1996/A:6, pp. 1-37.
Caurant, F. & Amiard-Triquet, C. 1995: Cadmium contamination in pilot whales Globicephala melas: source and potential hazard to the species. - Marine Pollution Bulletin 30: 207-210.
Caurant, F., Amiard-Triquet, C. & Amiard, J-C. 1993: Factors influencing the accumulation of metals in pilot whales (Globicephala melas) off the Faroe Islands. - Report of the International Whaling Commission, Special Issue 14: 369-390.
Dahl, S. 1971: The Norse settlement of the Faroe Islands. - Medieval Archaeology 14: 60-73.
Dam, M. 2001: Analyses of mercury and organochlorines in individual marine mammals from the Faroe Islands. - Fróðskaparrit 48: 145-174.
Dam, M. & Bloch, D. 2000: Screening of mercury and persistent organochlorine pollutants in long-finned pilot whale (Globicephala melas) in the Faroe Islands. - Marine Pollution Bulletin 40: 1090-1099.
Debes, H.H. 2000: Plankton in the Faroe-Shetland Channel - a review. - The Faroese Fisheries Laboratory, Unpublished Report, pp. 1-67.
Desportes, G., Andersen, L.W., Aspholm, P.E., Bloch, D. & Mouritsen, R. 1994a: A note about a male-only pilot whale school observed in Faroe Islands. - Fróðskaparrit 40 (1992): 27-33.
Desportes, G., Bloch, D., Andersen, L.W. & Mouritsen, R. 1994b: The international research programme on the ecology and status of the long-finned pilot whale off the Faroe Islands: Presentation, results and reference. - Fróðskaparrit 40: 9-29.
Desportes, G. & Mouritsen, R. 1993: Preliminary results on the diet of long-finned pilot whales off the Faroe Islands. - Report of the International Whaling Commission (special issue 14): 305-324.
Desportes, G., Saboureau, M. & Lacroix, A. 1993: Reproductive maturity and seasonality of male long-finned pilot whales, off the Faroe Islands. - Report of the International Whaling Commission, Special Issue 14: 233-262.
Dietz, R., Heide-Jørgensen, M.P., Richard, P.R. & Acquarone, M. 2001: Summer and fall movements of narwhals (Monodon monoceros) from northeastern Baffin Island towards northern Davis Strait. - Arctic 54(3): 244-261.
Donovan, G.P., Lockyer, C.H. & Martin, A.R. (Eds.) 1993: Biology of Northern Hemisphere Pilot Whales. - Report of the International Whaling Commission, Special Issue 14: 1-479.
Fullard, K.J., Early, G., Heide-Jørgensen, M.P., Bloch, D., Rosing-Asvid, A. & Amos, W. 2000: Population structure of long-finned pilot whales in the North Atlantic: a correlation with surface temperature? - Molecular Ecology 9: 949-958.
Gaard, E. 1988: Agnhøgguslokkurin. - Fiskiransóknir 5: 72-88. (In Faroese).
Gaard, E., Hansen, B., Olsen, B. & Reinert, J. 2002: Ecological features and recent trends in the physical environment, plankton, fish stocks, and seabirds in the Faroe shelf ecosystem. - In: Sherman, K. & Skjoldal, H.R. (Eds.); Large Marine Ecosystems of the North Atlantic, pp. 245-265.
Harris, R.B., Fancy, S.G., Douglas, D.C., Garner, G.W., Amstrup, S.C., McCabe, T.R. & Pank, L.F. 1990: Tracking wildlife by satellite: Current systems and performance. - Fish and Wildlife Technical Report 30, 52 pp.
Hay, K. 1982: Aerial line-transect estimates of abundance of humpback, fin, and long-finned pilot whales in the Newfoundland-Labrador area. - Report of the International Whaling Commission 32: 475-486.
Heide-Jørgensen, M.P. & Bunch, C. 1991: Occurrence and hunting of pilot whales in Greenland. - ICES Study Group on Pilot Whales, 3-5 December 1991.
Heide-Jørgensen, M.P., Hammeken, N., Dietz, R., Orr, J. & Richard, P. 2001: Surfacing times and dive rates for narwhals (Monodon monoceros) and belugas (Delphinapterus leucas). - Arctic 54(3): 184-198.
Heide-Jørgensen, M.P., Bloch, D., Stefansson, E., Mikkelsen, B., Ofstad, L.H. & Dietz, R. 2002: Diving behaviour of long-finned pilot whales Globicephala melas around the Faroe Islands. - Wildlife Biology 8: 307-313.
Hoydal, K. & Lastein, L. 1993: Analysis of Faroese catches of pilot whales (1709-1992), in relation to environmental variations. - Report of the International Whaling Commission, Special Issue 14: 89-106.
Jákupsstovu, S.H. í. 1993. Nøkur dømi um, hvussu havstreymar ávirka fisk og annað lív í havinum kring Føroyar. - Frændafundur, Fyrilestrar frá Íslendsk-føroyskari ráðstevnu í Reykjavík 20.-21. august 1992, Háskóla Íslands, Háskólaútgafan, pp. 146-161. (In Faroese).
Lockyer, C. 1993: Seasonal changes in body fat condition of northeast Atlantic pilot whales, and the biological significance. - Report of the International Whaling Commission, Special Issue 14: 325-350.
Martin, A.R. & Rothery, P. 1993: Reproductive parameters of female long-finned pilot whales (Globicephala melas) around the Faroe Islands. European Research on Cetaceans. - Proceedings from the 7th Annual Conference of the European Cetacean Society, Inverness, Scotland 18-21 February 1993, p. 95.
Mate, B. 1987: Abstract - Monitoring the movements and respiratory patterns requirements of a free-ranging pilot whale by satellite. - Proceedings of the Society for Experimental Biology and Medicine 186 (3), p. 394.
Nawojchik, R. & Aubin, D.J. St. 2003: Movements and dive behaviour of two stranded rehabilitated long-finned pilot whales (Globicephala melas) in the Northwest Atlantic. - Marine Mammal Science 19: 232-239.
Payne, P.M. & Heinemann, D.W. 1993: The distribution of pilot whales (Globicephala spp.) in shelf/shelf-edge and slope waters of the Northeastern United States, 1978-1988. - Report of the International Whaling Commission, Special Issue 14: 51-68.
Sergeant, D.E. 1962: The biology of the pilot or pothead whale (Globicephala melaena T) in Newfoundland waters.

Journal of Fishery Research Board. - Canada Bulletin 132: 1-83.
Smith, R. 1993: The whale hunters. - John Donald Publishers Ltd. Edinburgh, pp. 1-116.
StatSoft Inc. 2001: STATISTICA (data analysis software system), version 6. - www.statsoft.com.
Sundet, J. 1985: A short review on the biology and fishery of the squid Todarodes sagittatus. - ICES C.M., 1985/K:44, pp. 1-15.
Winn, H.E. (Ed.) 1982: A characterization of marine mammals and turtles in the Mid- and North Atlantic areas of the US outer continental shelf. Final report. - Final report of the cetacean and turtle assessment program by the University of Rhode Islands, Graduate School of Oceanography to the US Department of the Interior, Bureau of Land Management, National Technical Information Service (NTIS) Publication PB83-215855, Springfield, VA, 586 pp.
Zachariassen, P. 1993: Pilot whale catches in the Faroe Islands, 1709-1992. - Report of the International Whaling Commission, Special Issue 14: 69-88.