

Stomach Contents of Three Sperm Whales (*Physeter macrocephalus*) Stranded on Andøya, Northern Norway

Tiu Similä,¹ Tore Haug,² Lotta Lindblom,²
Christina Lockyer,³ and Seán A. O’Callaghan^{1,4,5}

¹Whale2Sea, Hammegata 9, 8480 Andenes, Norway
E-mail: iolaire@online.no

²Institute of Marine Research, Fram Centre, PO Box 6606, Stakkevollan, 9296 Tromsø, Norway

³Age Dynamics, Huldbergs Allé 42, 2800 Kongens Lyngby, Denmark

⁴Atlantic Technological University, Dublin Road, Galway City, Ireland

⁵Sperm Whale Scale, Killarney, Kerry, Ireland

Abstract

Three male sperm whales (*Physeter macrocephalus*) stranded on the island of Andøya in northern Norway in 2020. This created an opportunity to do gross necropsies with a focus on stomach contents as the diet of sperm whales in Norwegian waters is poorly understood and also to study potential presence of marine debris. Four new prey types for sperm whales in Norwegian waters were identified: (1) angler fish, (2) Atlantic cod, (3) cartilaginous fish, and (4) cock-eyed squid. In general, the results support earlier studies of male sperm whale diet in high latitude foraging grounds in the North Atlantic consisting of a mixture of cephalopods and meso- and bathypelagic fish. The only type of marine debris found was part of a fishing line. Based on estimates from teeth, the whales were 25, 45, and 49 years old. The size of all individuals was smaller than the median length based on whaling data for these age classes caught in Iceland in the 1970s.

Key Words: diet, marine debris, age, sperm whale, *Physeter macrocephalus*

Introduction

Sperm whales (*Physeter macrocephalus*) are the largest of the toothed whales, inhabiting all oceans from the ice edges to the equator. Females and young individuals stay in temperate and tropical seas year-round, while subadult and adult males move to higher latitude foraging grounds (Cantor et al., 2019). Male sperm whales occur in Norwegian waters year-round, mainly along the continental shelf edge (Christensen et al., 1992b; Øien, 2009; Røddland & Bjørge, 2015). The sperm whale population in the Northeast Atlantic was estimated to be 5,704 (95% CI: 3,374 to 9,643; CV = 0.26) between 2014 and

2018 (Leonard & Øien, 2020). A well-known foraging ground for male sperm whales in Norway is present in a deep-water canyon (Bleik Canyon) off Andøya, Vesterålen Islands, which was previously a whaling ground for the species (Christensen et al., 1992a; Røddland & Bjørge, 2015).

The diet of male sperm whales in Norwegian waters is poorly understood. When sperm whales were hunted in Norway (1925 to 1971), no systematic collection of stomach contents were performed (Christensen et al., 1992a). Nevertheless, Øynes (1957) described the diet as being dominated by cephalopods (particularly armhook squid [*Gonatus* sp.]) as well as several fish species, including lumpfish (*Cyclopterus lumpus*). In 1971, stomach contents of 12 sperm whales caught off of Andøya during the summer were examined, revealing six with squid beaks and fish bones, four with squid beaks, and two with empty stomachs (Bjørke, 2001). The Boreoatlantic armhook squid (*Gonatus fabricii*) was suggested to be an important component of the sperm whale diet in Norwegian waters (Bjørke, 2001). During a tagging experiment using Discovery tags, Christensen (1980) observed that redfish (*Sebastes marinus*) had been consumed by one of the tagged sperm whales in August 1978 in northern Norway when it regurgitated prey remains.

Sperm whales have been known to depredate on Greenland halibut (*Reinhardtius hippoglossoides*) from longline and gillnet fishing boats off the Vesterålen Islands since 2014 (Similä et al., 2017; Westell, 2018), and this behaviour has occurred further north over a longer period of time. A recent study (Pedersen et al., 2021) documented sperm whales foraging in the relatively shallow (120 to 130 m) mesopelagic layer off Vesterålen, possibly on European flying squid (*Todadores sagittatus*) and Boreoatlantic armhook squid.

Using digital archival tags, four sperm whales were recorded to reach depths down to 1,860 m at Bleik Canyon off Andøya, presumably targeting epipelagic and benthopelagic prey given that echolocation buzzes were recorded on descent from 17 m down to the maximum depth documented, thus indicating a widespread prey layer (Teloni et al., 2008). However, 72% of dives in this study were within 400 m of the surface.

In spring of 2020, several species of toothed and baleen whales stranded along the coast of northern Norway near Lofoten, Vesterålen, and Troms (Bjørge et al., 2020; Aniceto et al., 2021). During this event, three male sperm whales stranded on the west coast of Andøya, which provided an opportunity to obtain samples and to investigate the species' foraging ecology in the region.

Methods

Necropsies

Gross necropsies were performed on the three stranded sperm whales to gather biological samples and data following the procedures described by Pugliares et al. (2007). The whales were sequentially numbered based on the date of stranding (hereafter called whale #1, whale #2, and whale #3). All three whales were in a moderate decomposition condition, but whale #3 was bloated with decomposition gas when necropsied (Pugliares et al., 2007). Total length measurements were made in a straight line from the anterior end of the head to the tail fluke notch (Best, 1989; Pugliares et al., 2007).

Blubber thickness measurements were made on the ventral and dorsal side of each whale anterior to the dorsal fin (Pugliares et al., 2007). Full teeth were removed from the lower mandible for aging purposes (Read et al., 2018).

Incisions were made posterior to the last rib to access the gastrointestinal tract and stomach chambers. When located, the stomach chambers from each whale were opened fully to examine their contents. Every effort was made to access all stomach chambers and remove all fish bones, otoliths, and cephalopod beaks present. Stomach samples were kept frozen at -24°C before inspection and identification. Marine debris from whale #3 was removed from the expelled remains of a stomach chamber to recover cephalopod beaks and also to preserve the debris.

Photographs were taken of the tail flukes for identification purposes using DSLR cameras and a DJI Phantom 4 Pro drone. The images of the flukes of the stranded whales were compared to the whale-watching company Whale2Seas photo-identification catalogue (initiated in 2007) of sperm whales off Andøya.

Analysis of Stomach Contents

In the laboratory, the stomach contents were thawed and weighed. The contents were sorted and filtered through a sieve system consisting of three sieves (2, 1, and 0.5 mm). The stomach contents were very digested. Prey organisms were identified to the lowest possible taxonomic level, preferably species, following the visual identification criteria of hard structures such as fishbones, denticles, beaks, and otoliths by Pethon (1985), Clarke (1986), Härkönen (1986), and Watt et al. (1997).

The number of upper and lower squid beaks was recorded where the most numerous category was used to estimate the number of squid consumed. When otoliths were available, the number of right and left otoliths were recorded, and the most numerous category was used to estimate the number of fish consumed. No corrections were made for otolith erosions.

Age Estimation

The estimation of the age of the whales was undertaken by counting the growth layer groups (GLGs) in the dentine of the sampled mandibular teeth. The teeth were longitudinally mid-sectioned (crown to root) using a low-speed circular diamond saw and then subsequently formic acid-etched to expose the GLGs (Gambell & Grzegorzewska, 1967; Evans & Robertson, 2001; Evans et al., 2002).

Results

The three sperm whales all stranded between 28 March and 21 April 2020 off the west coast of Andøya in northern Norway (Figure 1). Whale #1 stranded on 28 March 2020 (Figure 1). The animal measured 13.1 m in length and was in very poor nutritional condition as indicated by the clearly visible cranial disc and flattened body. The blubber thickness was 10.3 cm on the dorsal side and 10.1 cm on the ventral side. A high parasite burden of *Diphyllbothrium* sp. was present in the whale's blubber layer (Hermosilla et al., 2016). The low amount of prey remains within the stomach chambers and lack of a large volume of faeces indicated that the whale had not fed successfully for some time prior to death. Only one vertebra from an unidentified fish species was found in the stomach chambers when at least two were accessed; no marine debris was present. The whale's age was estimated to be 49 years old. The tail fluke had distinctive markings, but only the right side of the fluke was visible above the sand. Based on only this partial image, the individual was not recognized in the photo-identification catalogue.

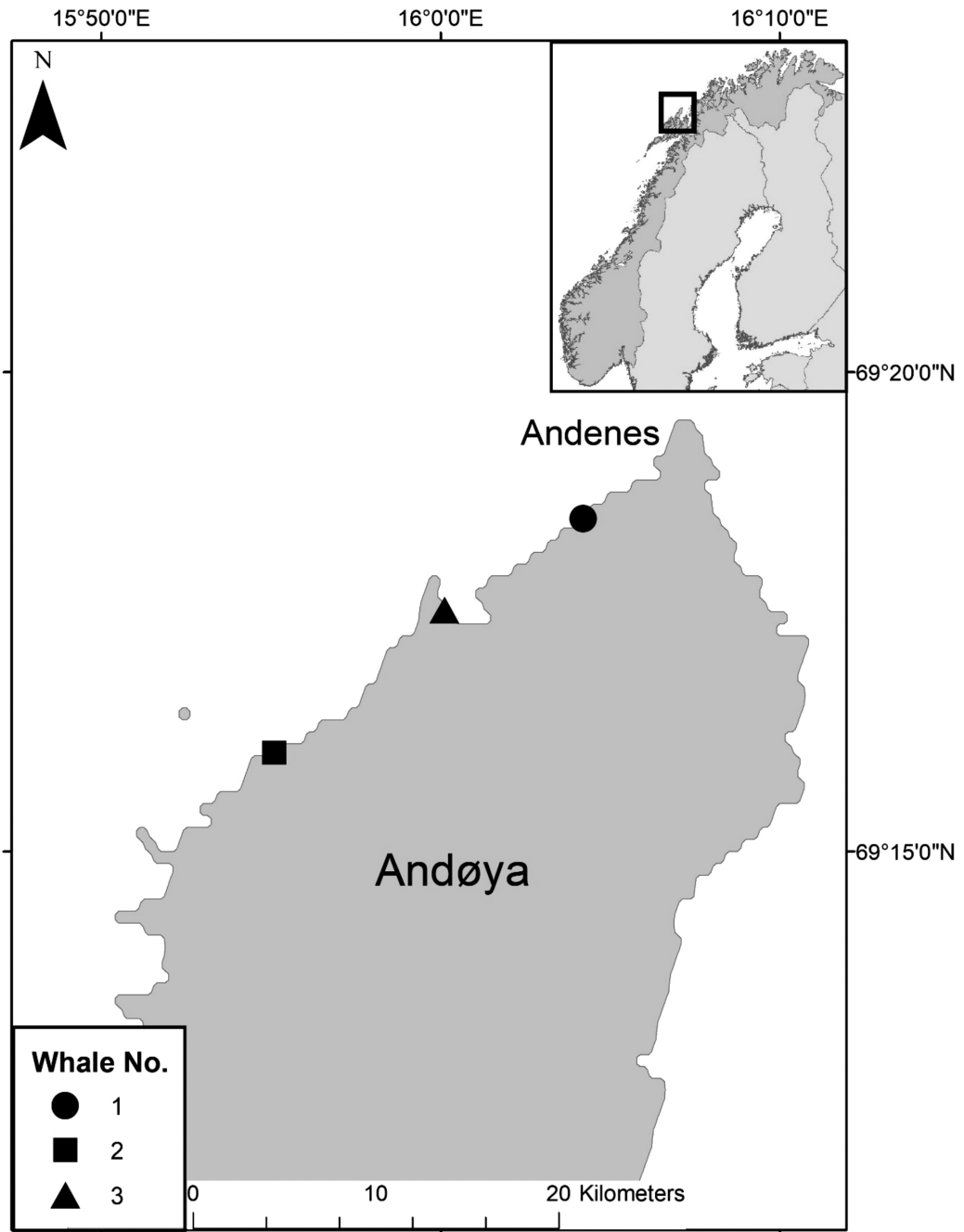


Figure 1. The locations where the sperm whales (*Physeter macrocephalus*) stranded on Andøya, northern Norway

Whale #2 stranded on 17 April 2020 (Figure 1). The animal measured 14.6 m and appeared to be in good nutritional condition with a robust body shape. The blubber thickness was 20.7 cm on the dorsal side and 17.3 cm on the ventral side. Dark brown-coloured faeces were present within cross sections of the inspected intestines which still had gas trapped within them. The forestomach was free of the ribs and was easily accessed but was almost completely empty except for some digested fish remains and digestive juices. The two other smaller stomachs did not have any contents that were present to the anterior of the animal, but the stomach most posterior held crimson-coloured fish remains (vertebrae, ribs, and skull fragments) with some squid beaks and eye lenses. No marine debris was present within the stomach. More detailed analysis of the stomach contents revealed one beak of an armhook squid, denticules of lumpfish, remains of jawbones of angler fish (*Lophius piscatorius*), bone remains of unidentified fish, and large bones probably from Atlantic cod (*Gadus morhua*) (Table 1). The whale was estimated to be 45 years old. Only a partial image was obtained of the fluke which was not recognized in the photo-identification catalogue.

Whale #3 stranded on 21 April 2020 (Figure 1). The animal was 12.2 m in length and appeared to be in good nutritional condition (body rotund and skull outline not visible); blubber thickness was 13 cm on the dorsal side and 12.5 cm on the ventral side of the body. Teeth remained to the anterior end of the jaw (others had been removed by locals) and were just above the gum line (~2.5 cm), but their crown was worn flat. The teeth at the posterior end of the jaw had not erupted. Five unerupted teeth were located on the right side of the jaw. These teeth were not fixed within tooth sockets, and a further two still had tooth buds surrounding them on the left side of the jaw; these were in the process of erupting (tooth crown visible in the centre). One tooth that was pointed and erupted was ~6 cm long and displayed a hollow pulp cavity.

A 1.79 m opening from the 1st third of the dorsal fin to the last part of the first knuckle on the tailstock was visible, and a stomach chamber was expelled out of the laceration. A bundle of fishing rope was observed next to the opening. It was covered in creamy/waxy oil, and four squid beaks were present on it. The forestomach was initially behind the posterior ribs, but when fully accessed (by removing the ribs), fish bones (vertebrae, ribs, and skull fragments), squid beaks, and eye lenses were collected. All of the fish bones were stained a crimson colour, the beaks remained a dark brown colour, and the lenses were either white or orange. There was no liquid within the stomach or noticeable parasites, ulcers, or marine debris. The rest of the stomach chamber was deeper within the animal's thoracic cavity, but attempts were made to remove as much of the prey remains as possible from deeper within the whale.

More detailed analysis of the stomach contents revealed 219 upper and 271 lower beaks of armhook squid (with lower rostral lengths of 5.1 to 6.8 mm and mantel lengths of 175 to 250 mm), a few cock-eyed squid (*Histioteuthis* sp.) beaks, otoliths of Atlantic cod with body lengths of 337 to 745 cm (Härkönen, 1986), otoliths of herring (*Clupea harengus*) with body lengths of 15 to 20 cm (Härkönen, 1986), denticules of lumpfish, jawbone remains of angler fish, a barb belonging to a cartilaginous fish (*Chondrichthyes* sp.), and bone remains of unidentified fish (Table 1). As the herring was likely to be part of the stomach contents of one of the prey species eaten by the sperm whale, they are not listed in the prey items. No plastic debris was found, but 2.8 m of fishing line was present in the stomach contents, and the line had become partially embedded in the inner lining of the stomach. The whale was estimated to be 25 years of age. The trailing edge of the fluke was well marked, but the individual was not found in the photo-identification catalogue.

Table 1. Prey species identified from sperm whale (*Physeter macrocephalus*) stomachs on Andøya Island, northern Norway

Species	Common name	Whale #1	Whale #2	Whale #3
<i>Gonatus</i> sp.	Armhook squid		X	X
<i>Histioteuthis</i> sp.	Cock-eyed squid			X
<i>Cyclopterus lumpus</i>	Lumpfish		X	X
<i>Lophius piscatorius</i>	Angler fish		X	X
<i>Gadus morhua</i>	Atlantic cod		X	X
<i>Chondrichthyes</i> sp.	Cartilaginous fish			X
Unidentified fish		X	X	X

Discussion

The findings of the study added four new types of prey to the diet of sperm whales in Norwegian waters: (1) angler fish, (2) Atlantic cod, (3) cartilaginous fish, and (4) cock-eyed squid. These four types of prey have been identified as part of the diet of male sperm whales elsewhere in the North Atlantic feeding grounds (Martin & Clarke, 1986; Santos et al., 1999). In general, it can be said that the results support the previous observations of the diet of male sperm whales in their Norwegian high latitude feeding grounds being a combination of cephalopods and mesopelagic and bathypelagic fish (Øynes, 1957; Christensen, 1980; Bjørke, 2001).

A study on male sperm whale diet based on animals caught in waters between Iceland and Greenland between 1977 and 1981 (Martin & Clarke, 1986) documented a mixture of cephalopods (22 different species, in particular armhook squids) and fish (eight species), with lumpfish dominating among the fish remains. Other important fish prey were redfish (*Sebastes* sp.), angler fish, Atlantic cod, and blue whiting (*Micromesistius poutassou*). Various sharks were on rare occasions documented as part of the stomach contents. Although the results were not conclusive, fish were indicated as more important than cephalopods in the diet of sperm whales in this area.

As the stomach contents of the sperm whales which stranded on Andøya were not fresh, it was not possible to analyze the relative importance of fish and cephalopods in the diet of the two whales where a substantial amount of prey remains were found. Santos et al. (1999) analyzed the stomach contents of 17 sperm whales stranded in the North Sea during 1990 to 1996. The contents consisted almost entirely of cephalopods, mainly armhook squid but also umbrella squid (*Histioteuthis bonnellii*), Atlantic cranch squid (*Teuthowenia megalops*), European flying squid, and gelatinous giant octopod (*Haliphron atlanticus*). The species' composition indicated that the foraging grounds of these whales had not been in the North Sea but further north in the North Atlantic. In a more recent mass stranding event involving 30 sperm whales in the North Sea in 2016, IJsseldijk et al. (2018) documented similar results, with only squid beaks present and Boreoatlantic armhook squid dominating the prey remains. However, as Santos et al. (1999) pointed out, cephalopod beaks may accumulate in the sperm whale stomachs while fish remains are retained for shorter time periods and/or are digested more quickly.

Sperm whales are known to ingest marine debris, which has proved fatal for individuals elsewhere in the world (Jacobsen et al., 2010).

The low amount of marine debris ingestion in these three necropsied whales is in contrast to the recent 2016 mass stranding event in the North Sea in which large amounts of marine debris were present in the stomachs of sperm whales (Unger et al., 2016).

Male sperm whales caught off Iceland between 1976 and 1978 ranged in age between 13 and 52 years old, with most animals being 20 to 40 years old and showing considerable variation in length of individuals of the same age class (Martin, 1980). For example, 25-year-old whales (14 individuals) measured between 13.4 and 15.9 m (Martin, 1980). In the Icelandic data, there were only two individuals in each of the following age classes: 45 years old and 49 years old (i.e., the ages of the two oldest stranded whales). The length of the 45-year-old ranged from 15.6 to 15.9 m, and the 49-year-old's length ranged from 15.2 to 16.2 m. All three male sperm whales that stranded on Andøya were smaller than the median length for their age, based on the Icelandic data (Martin, 1980).

It should be noted that hunted whales were measured stretched out at the flensing platform which may explain the smaller lengths observed on the stranded sperm whales measured unstretched on a beach or rocky shores. Male sperm whales are estimated to reach physical maturity around 50 years of age and at approximately 16 m in length (Best, 1989).

Sperm whales occasionally strand along the Norwegian coast (Haug & Gulliksen, 1981; Christensen, 1990), but a necropsy protocol is not in place to regularly gather samples and data from carcasses, and this results in missed opportunities to gather important biological data (Jørgensen, 2000; Stenløkk, 2013; Syvertsen, 2017). Nevertheless, this study shows the value of doing gross necropsies, including analysis of the stomach contents, for improved knowledge of the diet of sperm whales and also for recording the presence of marine debris.

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