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A note on common minke whale (*Balaenoptera acutorostrata*) diets in the Norwegian Sea and the North Sea

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ABSTRACT

Visual observations and quantitative samples of forestomach contents were made of minke whales caught in the Norwegian Sea (15 visual observations in 1999, 8 in 2000 and 1 stomach sample) and North Sea (15 visual observations and 7 stomach samples, all from 1999). Prey species were identified, and from the forestomach samples, each prey's relative contribution by weight to the diet was calculated. In the Norwegian Sea, the diet was dominated by Norwegian spring-spawning herring (100%). This was consistent with the large and dominant abundance of herring in the area. Observations and forestomach samples from the North Sea indicated a more varied diet, with sandeel (*Ammodytes spp.*) contributing 86.7% to the diet by weight, followed by mackerel (9.3%), whiting (2.4%), herring (1.1%) and Norway pout (0.5%). Haddock was observed in one stomach, but was not found in any of the samples. Sandeel occurred in all observed and four of the sampled stomachs. The domination of pelagic species in the diet strongly indicates pelagic feeding behaviour in both areas.

KEYWORDS: COMMON MINKE WHALE; ECOSYSTEM; FEEDING GROUNDS; FISH; FOOD/PREY

INTRODUCTION

The common minke whale (*Balaenoptera acutorostrata*) is both in numbers (Schweder *et al.*, 1997) and biomass one of the largest marine mammal populations in the ecosystems of the eastern North Atlantic. In the 19th century, minke whales in Norwegian waters were described as herring predators (Sars, 1897) and ichthyophagous (Greig, 1894). Later studies by Jonsgård (1951) and Haug *et al.* (1995) revealed that North Atlantic minke whales were rather euryphagous.

There have been few formal studies of the diet of this species in the North Atlantic. Larsen and Kapel (1981) made *ad hoc* observations of the regurgitated stomach contents of seven whales caught west of Greenland in 1979. Only two prey items were observed: krill in two stomachs and sandeel (*Ammodytes* spp.) in five stomachs. When observing at whaling stations on the Canadian east coast in 1948 and 1951-61, Sergeant (1963) recorded seven prey items in the stomach contents. The dominant prey was capelin (*Mallotus villosus*) occurring in 85% of stomachs sampled. Cod (*Gadus morhua*), herring (*Clupea harengus*), salmon (*Salmo salar*), and several species including squids, euphausiids and copepods constituted the rest.

The only quantitative analyses of diet in the North Atlantic are available from the Barents Sea and along the coast of Northern Norway (Haug *et al.*, 1995; 1996; Lindstrøm *et al.*, 1999). These studies showed large variations in relation to area, season and year. Along the coast of Norway, fish predominated, with herring being the major component. Gadoid fish predominated in the central Barents Sea. In the areas further to the north (around Bear Island and Spitzbergen), krill (*Thysanoessa* spp.) and capelin characterised the diet (Haug *et al.*, 1996). This study also indicated a preference for the pelagic fish species capelin and herring over other prey items.

In recent years, emphasis has been given to an ecosystem approach to fisheries management. However, *inter alia* this requires considerable knowledge of the ecological significance of large predator populations. Both total consumption and the consumption of the individual prey populations are therefore of interest. Based on recent information on minke whale abundance (Schweder *et al.*, 1997) and diet, Folkow *et al.* (2000) presented an estimate of the total annual prey consumption of minke whales in the northeast Atlantic waters. The consumption by prey species was presented for the Barents Sea and off the coast of North Norway. However, they had no information on prey species for the North Sea.

This paper presents information on the diet of minke whales in the North Sea and the Norwegian Sea, two important feeding areas for North Atlantic minke whales for which information is lacking. The observed diets are discussed in light of the differences between the North Sea and Norwegian Sea ecosystems.

MATERIALS AND METHODS

The stomach contents of minke whales were recorded or sampled by personnel from the Institute of Marine Research (Bergen) onboard commercial whale catchers in the central North Sea and Norwegian Sea in June and July of 1999 and 2000. Catch positions are shown in Fig 1. As the study was based on a commercial operation, the sampled animals may not be representative of animals in the broad areas of the North and Norwegian Seas.

Stomach contents from 46 whales were examined, 22 from the North Sea and 24 from the Norwegian Sea. Stomach contents of 38 whales (15 North Sea, 23 Norwegian Sea) were determined by visual observation of ruptured forestomachs or from regurgitated stomach content, whilst for eight whales (7 North Sea, 1 Norwegian Sea), the contents of the forestomach were sampled and total volume measured. In the sampled stomachs, forestomach contents were separated from stomach fluids using a 1mm sieve. A 5 litre sample of the remaining content was frozen at –23 °C and later analysed at the Institute of Marine Research. From this sub-sample, prey was identified to genera or species based on morphology of whole prey, or from otoliths and bones of digested prey. Each prey group was weighed, and when possible, individuals were counted and their length

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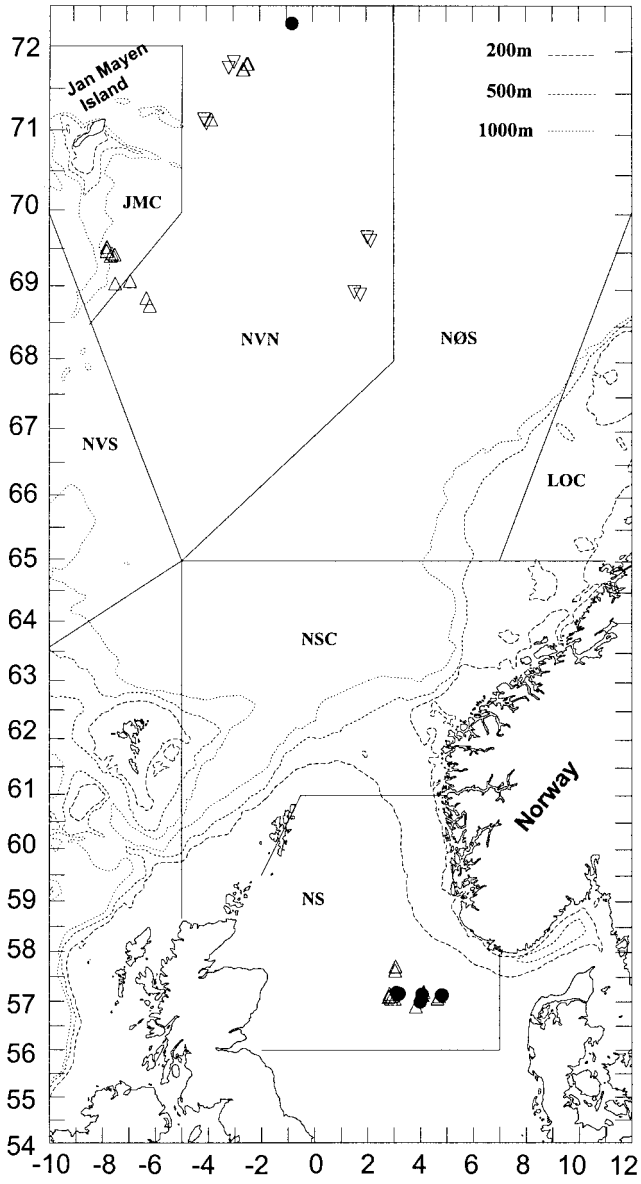

Fig. 1. Survey blocks for which individual abundance estimates of minke whales had been estimated in 1995 with catch positions of investigated minke whales from the Norwegian Sea and North Sea. Positions where visual observations of stomach content were made are marked by △ for the whales sampled in 1999 ($n = 30$) and ▽ for whales sampled in 2000 ($n = 8$). Positions where samples of the stomach content was taken is marked by ● ($n = 8$).

measured. Prey were allocated to age groups either by estimating the age from the otoliths, e.g. Norway pout (*Trisopterus esmarkii*), or by using ICES length-at-age tables (ICES, 1999) to calculate the age, e.g. for herring, sandeel, whiting (*Merlangius merlangus*) and mackerel (*Scomber scombrus*). For each prey species the relative and absolute contribution to diet by weight was estimated. In addition the weight of the total stomach content was calculated by multiplying the weight of the 5 litre sample with the measured volume of the stomach content.

RESULTS

Norwegian Sea

The only prey observed in the stomach contents of the 24 minke whales caught in the Norwegian Sea in 1999 and 2000 was adult (> 29cm) herring (Table 1); herring length in 2000 ranged between 34 and 40cm. These observations were supported by the findings in the single sampled whale where herring was the only species recorded in the analysed stomach sample (Table 2). The total weight of stomach contents of the sampled whale was 39.9kg.

Table 1

Area, date, catch position and visually observed stomach content of minke whales (*Balaenoptera acutorostrata*) caught in the Norwegian Sea (1999 and 2000) and North Sea (1999).

Area	Date	Catch position	Stomach content
Norwegian Sea 1999	30 May	68º46'N, 6º12'W	Herring (adult)
	31 May	68º52'N, 6º20'W	Herring (adult)
	01 June	69º06'N, 6º57'W	Herring (adult)
	01 June	69º04'N, 7º31'W	Herring (adult)
	04 June	69º27'N, 7º32'W	Herring (adult)
	04 June	69º28'N, 7º38'W	Herring (adult)
	04 June	69º26'N, 7º41'W	Herring (adult)
	05 June	69º33'N, 7º50'W	Herring (adult)
	05 June	69º30'N, 7º58'W	Herring (adult)
	05 June	69º33'N, 7º49'W	Herring (adult)
	15 June	71º10'N, 3º53'W	Herring (adult)
	19 June	71º46'N, 2º40'W	Herring (adult)
	20 June	71º46'N, 2º42'W	Herring (adult)
	20 June	71º50'N, 2º33'W	Herring (adult)
	20 June	71º50'N, 2º30'W	Herring (adult)
Norwegian Sea 2000	09 June	68º55'N, 1º44'E	Herring (34-40cm)
	09 June	68º57'N, 1º31'E	Herring (34-40cm)
	12 June	69º41'N, 2º00'E	Herring (34-40cm)
	12 June	69º38'N, 2º07'E	Herring (34-40cm)
	17 June	71º10'N, 4º10'W	Herring (34-40cm)
	17 June	71º07'N, 4º04'E	Herring (34-40cm)
	18 June	71º47'N, 3º14'E	Herring (34-40cm)
	18 June	71º51'N, 3º02'W	Herring (34-40cm)
North Sea 1999	17 June	57º38'N, 3º03'E	Sand eel
	12 June	57º43'N, 3º04'E	Sand eel
	13 June	56º54'N, 3º50'E	Sand eel, haddock, mackerel
	14 June	57º10'N, 2º50'E	Sand eel
	15 June	57º07'N, 2º56'E	Sand eel
	15 June	57º06'N, 2º48'E	Sand eel
	16 June	57º07'N, 2º51'E	Sand eel, herring
	18 June	57º04'N, 3º02'E	Sand eel
	18 June	57º04'N, 2º54'E	Sand eel
	08 July	57º07'N, 4º43'E	Sand eel
	08 July	57º04'N, 4º39'E	Sand eel
	08 July	57º12'N, 4º08'E	Sand eel
	09 July	57º08'N, 4º06'E	Sand eel
	10 July	57º08'N, 4º06'E	Sand eel
	10 July	57º09'N, 4º03'E	Sand eel

North Sea

The visual observations made in the North Sea in 1999 indicated a more mixed diet in this area, dominated by sandeel. Sandeel was recorded from all 15 stomachs observed. Additional prey was observed in two of these: herring in one stomach, and haddock (*Melanogrammus aeglefinus)* and mackerel in the other (Table 1). In the sampled stomachs, sandeel was by far the most common prey species, constituting 86.7% by weight (Table 2, Fig. 2). Sandeel, mackerel and herring comprised 97.1% of the total weight of stomach content by weight. Gadoid fish (whiting and Norway pout) constituted the rest (2.9%). None of the seven sampled stomachs were empty, but the total weight of the stomach contents (excluding liquid) varied from 1.7kg to 110.9kg. In all but one sampled stomach, only one prey species was found. This stomach contained a mix of sandeel (93.2% by weight) and herring (6.8%). The degree of

Table 2

Date, catch position and fore-stomach content of minke whales from the Norwegian Sea and North Sea in 1999. All weights are in kg.

					Composition of samples							
					Herring		Sand eel		Whiting		Norway pout	Mackerel
No.	Date	Position	Sample weight	Calc. total weight	Weight	No.	Weight	No.	Weight	No.	Weight	Weight
Norwegian Sea												
17	23 June	72º18'N, 0º51'W	4.156	39.9	4.156							
North Sea												
19	11 July	57º0'N, 4º0'E	4.856	64.1			4.856					
23	11 July	57º9'N, 4º4'E	3.715	54.2	0.25	10	3.456	1,728				
29	18 July	57º8'N, 5º50'E	0.071	110.9			0.071	50				
30	18 July	57º9'N, 4º48'E	3.363	71.3			3.363					
33	29 July	57º11'N, 3º6'E	4.046	8.1					4.046	14		
34	30 July	57º10'N, 3º12'E	2.124	1.7							1.77	
35	30 July	57º9'N, 3º10'E	3.886	31.9								3.886

Parasitic nematoda (*Anasakis spp.)* were found in stomach no. 23 and 34. These were separated from the rest of the content and their weight subtracted from the calculated weight of the stomach content.

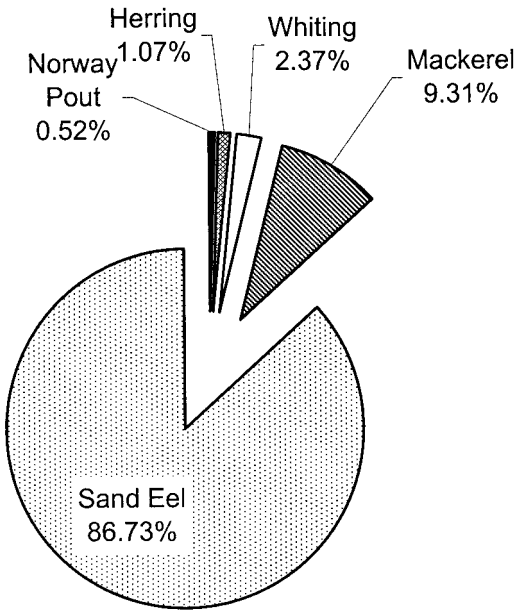

Fig. 2. Forestomach content compositions of North Sea minke whales (n = 7) presented as relative contribution by calculated weight.

digestion in the stomachs (and hence time since feeding) varied; only two stomachs (nos 23 and 29) had undigested prey (sandeel). Based on otoliths found and length measurements of whole prey, all sandeels were 0-1 years, the whiting were 3-4 years, the Norway pout 0-1 years and the mackerel over 3 years. The observed prey age distribution suggested that a large component of the minke whale diet in the central North Sea consisted of young fish. No herring otoliths or whole herring were found, and the age of this prey could therefore not be estimated.

DISCUSSION

The dietary data in this study are based on both quantitative stomach samples and *ad hoc* observations of stomach contents. As might be expected, more prey species were recorded from properly sampled stomachs. As such, the records from the sampled stomach contents are probably more reliable although the sample size is small.

The results indicate that herring was the only prey species for minke whales feeding in the western Norwegian Sea in June-July. This is the main feeding area of the Norwegian spring spawning herring stock, which was estimated at 6,400,000 tonnes in the actual area in 1999 (Holst *et al.*, 1999a) and somewhat less in 2000 (Holst *et al.*, 2000). The size of the herring observed and sampled from the whale stomachs was in agreement with the known size of herring in the area during June-July (Nøttestad *et al.*, 1999). This is further substantiated by age and length distributions from research trawl catches made by the Institute of Marine Research in the sampling area in May and August 1999 which found herring of the 1990, 1991 and 1992 year classes, measuring approximately 31-35cm (Holst *et al.*, 1999a).

By late July, the herring migrate to the east towards the Norwegian coast for the wintering areas in the Lofoten archipelago (Nøttestad *et al.*, 1999). At this time they probably become available as prey for the near-shore portion of the Northeastern Atlantic minke whale population prior to their southward migration in the autumn (Jonsgård, 1951).

During the 1970s and early 1980s, Norwegian spring spawning herring was effectively removed as an important minke whale prey in the western Norwegian Sea, following an almost total collapse of the herring stock in the late 1960s. This may have forced minke whales to feed on less preferred prey species, or caused profound changes in distribution of foraging minke whales. Apart from herring, blue whiting (*Micromesitius poutassou*) (Holst *et al.*, 1999a), lumpsucker (*Cyclopterus lumpus*) (Holst, 1993) and post-smolt salmon (Holst *et al.*, 1999b; Holm *et al.*, 2000) feed in these areas during summer. However, their biomass was probably many orders of magnitude less than the current herring biomass. In addition, blue whiting, being meso-pelagic (200-500m) are probably less available to minke whales than the schooling, pelagic herring, which is found from 0-450m depth in the Norwegian Sea during summer (Vilhjálmsson *et al.*, 1997). Therefore, it seems reasonable that the western Norwegian Sea feeding areas were sub-optimal during the 1970s and 1980s when compared with today.

In the North Sea, minke whales had a more a mixed diet, although sandeel dominated in both observed and sampled stomachs. Field observations made by on-board observers of daytime minke whale feeding behaviour in the area indicated feeding in sandeel schools close to the surface. Sandeels hide in the sediments during night and migrate to the surface

during daytime to feed (Helfman, 1993). Mackerel, the second most frequently occurring prey species, has pelagic distribution close to the sea surface during summer (Iversen and Skagen, 1989). Whiting, the third most frequently occurring prey species, is known to feed on sandeels (Pedersen, 1999), and may have been caught by minke whales targeting sandeels. These findings support a hypothesis that pelagic foraging is important for minke whales in relatively shallow continental shelf waters. However, the finding of haddock in one stomach shows that demersal foraging does occur in North Sea minke whales. Both cod and haddock are described as demersal predators on sandeel (Adlerstein *et al.*, 1998).

Similar indications of a pelagic feeding behaviour in continental shelf waters have been found in other areas, e.g. the Barents Sea (Haug *et al.*, 1996). Fewer prey species were found in the diet in the present study than in the studies of the Barents Sea minke whales (Haug *et al.*, 1995; 1996), but the latter study covered a much larger geographic area and spanned four months, while the present study was more limited in geographic range and time. Neither euphausiids nor any other crustaceans were recorded in any of the stomach samples. This is in contrast to the Barents Sea where euphausiids have been shown to constitute up to 45% of the diet (Lindstrøm *et al.*, 1999). Euphausiids have also been shown to be the main constituent of the Antarctic minke whale (*Balaenoptera bonaerensis*) diet in the Antarctic (Ichii and Kato, 1991).

Given the commercial nature of the operations, the sampling locations were aggregated, particularly in the North Sea. Since the samples were taken from a limited area, they probably do not represent the diet for the entire North Sea minke whale feeding grounds. Haug *et al.* (1996) showed that the minke whale diet varies dramatically between areas and seasons in the Barents Sea. In the western Norwegian Sea, prey occurrence is less spatially variable suggesting less variability in minke whale diet between areas. It is possible that the diet observed from the Norwegian Sea samples is more likely to represent the diet of a wider part of the Norwegian Sea ecosystem. However, further samples from the waters north of Jan Mayen Island and north of the polar front may alter this impression.

Although the results presented here are only based on small sample sizes and thus may not be wholly representative of the summer diet of minke whales in the Norwegian and North Seas, they suggest interesting differences in the diet in the two areas. These differences probably reflect differences in the fish fauna of the two ecosystems rather than different minke whale prey preferences. The Norwegian Sea pelagic ecosystem is characterised by few but abundant species where herring is the dominant plankton feeding fish. The North Sea ecosystem comprises a fish community with less dominance by one or a few fish species and a more complex trophic structure.

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