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International Council for the Exploration of the Sea — CM 1998/CC:3
Population Biology

HERRING *Clupea harengus* AS A KEY SPECIES IN NORTHEAST ATLANTIC MINKE WHALE *Balaenoptera acutorostrata* DIETS

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ABSTRACT

Using results from annual studies since 1992 in the Barents Sea, the dynamics in Northeast Atlantic minke whale *Baleaenoptera acutorostrata* predation upon Norwegian spring spawning herring *Clupea harengus*, including the effect of the collapse and subsequent increase in the herring stock, were assessed. The location of herring spawning is along the western coast of Norway, whereas the larvae are transported northwards to fjord and coastal areas, but in particular to the Barents Sea. Here the immature herring spend their first 2-4 years. The abundance of immature herring year classes in the Barents Sea has been highly variable. One or a few strong year classes are usually followed by several years of poor year classes. In the period 1992-1995, the northeast Atlantic minke whale appeared to have consumed 610 000 tonnes of adolescent Norwegian spring spawning herring annually in the Barents Sea area. The major part of this belonged to the strong 1991 and 1992 year classes. The abundance and distribution of herring appears to be well correlated with its diatary importance for the whales. An example of this was when the major part of the 1992 year class migrated out of the Barents Sea in 1995. This was followed by a subsequent reduction in the dietary importance of herring by 50% (in fact, to virtually absence) compared with the year before. During the period 1992-1995, minke whales may have consumed as much as 1.3-1.4 and 0.8-1.0 million tons of the two strong herring year classes of 1991 and 1992, respectively.

Key words: Northeast Atlantic, minke whale, predation, herring

INTRODUCTION

The Barents Sea serves as nursery area for several fish stocks spawning at the western and northwestern coast of Norway, including also the stock of Norwegian spring spawning herring *Clupea harengus*. Along with two main fish species that spend their entire life cycle in the Barents Sea, capelin *Mallotus villosus* and polar cod *Borogadus saida*, adolescent herring constitute the main plankton feeders in a generalized food web for the area (Hamre 1994, Gjøsæter 1995).

There have been substantial changes in the marine ecosystem of the Barents Sea during the past 30 years. The most conspicuous changes relate to the collapses and subsequent permanent or intermediate rises of the stocks of the pelagic shoaling Norwegian spring spawning herring and Barents Sea capelin (Røttingen 1990, 1992, Hamre 1994, Gjøsæter 1995). After a collapse in the late 1960s, the Norwegian spring spawning herring stock terminated the rebuilding period in the 1990s. Since 1988, when the major part of the strong 1983 year class spawned for the first time, the southern Barents Sea has served as the main nursery area for immature herring (Røttingen 1990, Hamre 1994, Gjøsæter 1995). Good larval survival gives strong cohorts and large abundance of young, adolescent (0-3 years old) herring in the Barents Sea. Upon maturation the herring migrate westwards out of this sea. High larval mortalities, however, yields weak cohorts and will reduce the abundance of young herring in the southern Barents Sea nursery areas. The abundance of adolescent herring in the Barents Sea is fairly well studied, and a considerable variation in young herring abundance has been observed in the 1990s (ICES 1996a, b).

Herring is known to be an important forage fish for northeast Atlantic minke whales *Balaenoptera acutorostrata* along the coast of Norway and in the southern Barents Sea (Haug *et al.* 1995a, b, 1996). In fact, the whales appear to have a particular preference for herring as food (Haug *et al.* 1996, Skaug *et al.* 1997), and the first runs with the Barents Sea multispecies model MULTSPEC indicate that herring is the fish stock most likely to be affected by changes in the abundance of minke whales (Bogstad *et al.* 1997). It is, therefore, likely that recent fluctuations in distribution and abundance of herring may have had an impact on the feeding habits of the whales.

In order to evaluate the ecological significance of minke whales in the northeast Atlantic, a scientific program, addressing particularly questions concerning feeding ecology by using stomach analyses, was conducted in Norway in 1992-1994. This scientific program was followed by collections of similar data from commercially caught minke whales in 1995-1997. This has provided a time series (1992-1997) on diets which, in combination with existing knowledge about the abundance of adolescent herring, may serve as a tool to assess the dynamics in minke whale predation upon herring, including how whales may affect different year classes of adolescent herring, and how fluctuations in herring abundance influence the feeding habits of minke whales in the Barents Sea. The purpose of this paper is to address these questions.

MATERIAL AND METHODS

Assessment of herring abundance

Since 1984, when the strong 1983 year-class of the Norwegian spring spawning herring was distributed in the southeastern part of the Barents Sea, annual resource surveys has been conducted in May/June in order to estimate the abundance of the year-class components spending the adolescense in the Barents Sea. In 1996 and 1997, Russian scientists conducted their part of the survey (in the Russian Economic Zone) in May while Norwegian scientists conducted their part further to the west in June. These abundance estimates are, together with 4 other survey series, used for predicting the total abundance of recruiting herring year classes (ICES 1998). The results from the Barents Sea surveys should not be considered as absolute estimates, but rather to give relative estimates.

The acoustic surveys were carried out using standard methods (e.g. Foote, 1991), including a Simrad EK-500 split beam echo sounding system (Bodholt *et al.*, 1989) and a BEI post-processing system (Foote *et al.*, 1991). The echo integration surveys were conducted by cruising along predetermined transects in the actual area. The allocation of acoustic values to species groups were carried out on the basis of the acoustic character of each species group and the results from trawl hauls. The integration was interrupted each time trawling was carried out, and trawl hauls were taken in response to changes in the echo sounder observations. Simultanously with the echo integration, a SIMRAD sonar was used to help verify herring recordings and especially the distribution borders. The echo recordings were processed applying the standard echo integration method, described in detail by Maclennan & Simmonds (1992). The registrations were scrutinized daily, and the s_A-values for herring were used to calculate the abundance of the species. The following TS function was applied to convert the s_A-values to herring densities:

$$TS = 20 \cdot \log L - 71.9 \quad (dB)$$

where L is the total length of the herring.

Both pelagic and demersal trawls were used to sample the observed acoustic scatterers. For pelagic trawling an "Åkra" trawl (opening 25x30m) and a Harstad trawl (opening 20x10m) was used. Demersal trawling was carried out using a "Super Campelin" 1800 mesh shrimp trawl with rubber bobbins. Total lengths were measured and age determined (from otoliths) for subsamples of herring taken in the trawl hauls.

In 1996 and 1997, the abundance estimates of 3+ herring made by the Russians in May and the Norwegians in June were averaged between the two surveys in order to recieve abundance estimates that covered the sampling period for minke whales (ICES 1998).

Sampling of whales

In 1993, the International Whaling Commission (IWC) decided that the so-called "small areas" boundaries should be retained for the management of Northeast Atlantic minke whales. According to this division, minke whales from the North Sea (EN), coastal areas of Lofoten and Vesterålen (EC), coast of Finnmark and the Barents Sea (EB), and Bear Island and Spitsbergen waters (ES) are considered to belong to different breeding stocks (see Fig 1), although there was evidence of exchange between some of the areas, in particular EB-ES-EN (Anon. 1993). During commercial catch operations, quotas are set per small area, and each operating vessel is allocated a particular boat quota in one or two of the designated small areas in each season.

The material used in these analyses were collected in area EB during scientific (1992-1994) and commercial (1995-1997) whaling operations. The scientific whaling operations occurred independently of the small-area boundaries, and were organised in five separate and assumed representative subareas (Haug *et al.* 1995a). However, since two of these subareas (coast of Finnmark and coast of Kola) were included in the EB area, 44 of the whales taken for scientific purposes could be included in the present analyses by allocation to this area. Since 1995, stomach samples have been collected from whales caught by commercial vessels in area EB.

Minke whales are known to occur in Norwegian and adjacent waters from March/April to October (Jonsgård 1951), and the scientific whaling operations were designed to span a feeding period from early May to late September (Haug *et al.* 1996). Commercial whaling occurs over a much shorter period, usually from early May to the end of June. Since some extent of seasonality is known to occur in minke whale feeding habits (Haug *et al.* 1996), the present analyses were restricted to whales caught within the period 1 May – 1 July. The material from 1992, however, also include whales caught in July and early August. Whales taken in scientific whaling operations were sampled randomly on chartered whaling vessels using procedures which included searching along predetermined transects (Haug *et al.* 1995a, 1996). The whales taken in commercial whaling operations were sampled opportunistically in areas with expected high densities of whales (see Christensen & Øien 1990).

Analyses and reconstruction of minke whale stomach contents

The complete digestive tract was taken out of each examined whale as soon as possible (1-3 hours *post mortem*). Minke whale stomachs consist of a series of four chambers (Olsen *et al.* 1994), but Lindstrøm *et al.* (1997) have shown that sampling and analyses of contents from the first chamber (the forestomach) is sufficient to describe the minke whale diet. Thus, only forestomach contents were used in these analyses. The onboard and laboratory treatment of the full forestomach contents are as described in detail by Haug *et al.* (1995a, 1996).

Intact specimens of fish were identified according to gross morphological characteristics (Pethon 1985), while sagittal otoliths and crustaceans were identified to lowest possible taxon (Enkell 1980, Breiby 1985, Härkönen 1986). The total number of each fish species was calculated by adding the number of fresh specimens, intact skulls and half the total number of otoliths. From otolith length-fish length/mass correlations and random sub-samples of 200 undigested otoliths (or as many as possible) from each fish species, the initial prey masses at the time of ingestion were estimated.

The otolith length-fish length regressions used to estimate the fish length from otolith length in 1992-1997 are given in Table 1. In 1992, 1993 and 1996 where no otolith length-fish length correlations are available, a pooled regression equation, based on the data from 1994, 1995 and 1997, was used. All regression equations were significant (Table 1). The age of the ingested herring was determined from age-length distributions kindly provided by the Institute of Marine Research, Bergen.

When estimating the biomass of crustaceans found in the stomachs at the time of ingestion, mean individual masses of digested crustaceans were recorded. These masses were based on masses of a known number of individuals (usually 250-300) in a subsample. Using known mean masses of fresh crustaceans (see Haug *et al.* 1995a), the original biomass of the crustaceans eaten by the minke whales was crudely estimated.

Several feeding indices are commonly used in stomach analyses of top predators (Hyslop 1980, Pierce & Boyle 1991). No feeding index gives a complete or fully realistic picture of dietary composition, and in the 1992-1994 diet studies of the minke whale, the prey was quantified using frequency of occurrence, and mass and numerical fractions of individual prey categories (Haug *et al.* 1995a, 1996). In the present analyses, only the relative contribution of each prey species to the total diet expressed in terms of recalculated fresh weight, was used.

RESULTS

Herring abundance

In 1992, the immature herring was distributed in three main patches: one to the west of 31°00'E; a second north of the Varangerfjord (east of 31°00'E and north of 70°00'N); and a third close to the Murman coast (east of 31°00'E). The western patch consisted mainly of 3-year olds (1989 year class) while the patch north of the Varangerfjord was dominated by the 1-year olds. In the more coastal patch, along the Murman coast, 2-year olds dominated the abundance. The older herring in the western patch was mainly found at 60-150m depth, while in the two eastern patches the herring inhabited the upper 50m. The total abundance of immature herring in 1992, in terms of numbers, was estimated to 53.4 billion individuals (corresponding to 1.7 million tonnes) (Table 2). The major part (62%) of this herring belonged to the 1991 year class, followed by the 2- and 3-year olds (27% and 11%, respectively). Additionally, a few 4-year olds were recorded in the western part of the survey area this year.

In 1993, the immature herring was distributed off the Norwegian and Russian coasts between 23°00'E and 38°30'E and extending northwards to about 72°30'N. The highest densities were recorded in a belt (30-180 nautical miles) along the coast of Norway from about 29°30'E and eastwards along the Russian coast to about 38°30'E. Additionally, some dense recordings were also made along the Murman coast. The herring in the western part of the survey area consisted mainly of 2-year olds while the recordings in eastern part were mainly 1-year olds. In most of the distributional area, herring was found close to the surface (10-30m). The total estimated number of adolescent herrring in 1993 was 130 billion individuals (corresponding to 1.5 million tonnes) (Table 2). The estimated number of 1-year olds (102 billion) was the highest number of 1-year olds ever recorded in the area. The estimated number of the 1991 year-class of 25.8 billion confirms the strength this year-class. In 1993, only few individuals of the 1990 year-class (1.5 billion) were found in the survey area, and no recording were made of 4-year olds.

In 1994, the area with the highest density of herring was resurveyed in the end of the cruise. The major part of the herring was distributed off the Norwegian and Russian coasts between 31°00'E and 35°00'E, extending 100 nautical miles northwards off the coast. The most dense recordings were made off the Russian coast at about 33°00'E. Another high-density patch of herring was localised around 70°30'N and 33°00'E. When resurveying this area at the end of the cruise, the distributions had changed and the previously observed dense recordings of herring around 70°30'N were no longer there. The western part of the survey area was dominated by 2- and 3-year olds, while the consentrations further to the east was dominated by 2-year olds. Very few 1-year old herring occurred in the samples in 1994. The herring was allocated in the upper 30m in most of the distributional area. The total number of immature herring was estimated to 85.5 billion individuals (corresponding to 2.9 million tonnes) (Table 2). The 1992 year-class accounts for approximately 70% of the stock in numbers, followed by the 1991 year-class (21%). One- and 4-year olds was also present in 1994, but in low numbers.

In 1995, the herring was distributed off the Norwegian and Russian coasts (24°00'E - 38°30'E), and extending about 100 nautical miles northwards. The major part of the herring occurred in small shoals and layers of low densities at 100-300m depth. The western part of the area consisted mainly of 3-year old specimens, while in the eastern part the shoals were a mixture of 2- and 3-year olds. The total numbers of adolescent herring in the Barents Sea was estimated to 17.3 billion individuals (corresponding to 633 thousand tonnes) (Table 2). The 1992 year class was estimated to 8 billion individual and counts for almost 50% of the total herring component, followed by the 1993 year-class. As in 1994, the 1- and 4-year olds occurred in low numbers.

In 1996, the distribution and abundance of immature herring was reduced drastically compared with previous years (1992-1995). The herring occurred only in restricted areas north of the Varangerfjord, in small shoals at 100-200m depth. The Russian resource survey, which was conducted one month prior to the Norwegian, showed a slightly different year-class abundance as compared to the Norwegian. The 1995 and 1996 year-classes of herring were estimated to 200 and 50 million individuals, respectively, in May. These year-classes were not completely absent in June. Furthermore, the Russian abundance estimates of the 1992, 1993 and 1994 year-classes were in general 1.5-3 times higher than the Norwegian. The average abundance estimates of herring, based on both the Russian and Norwegian data, are given in Table 2. The total (adjusted) abundance of adolescent herring was calculated to 2.78 billion individuals, 6 times less than in 1995. The 1993 year-class of herring was by far the most numerous (1.8 billion individuals) of the year-classes, followed by the 4-year olds (0.6 billion individuals).

In 1997 immature herring was distributed along the Norwegian and Russian coasts (24°00'E - 37°00'E), extending about 60 nautical miles offshore. A high density belt, 10 to 60 nautical miles off the coast, consisting mainly of 2- and 3-year olds, was recorded around 71°20'N and 27°00'E. The major part of 1996 year-class was distributed east of 30°00E in the upper 100m of the water column, while the 2-5 year olds were distributed west of 30°00E at 200-250m depth. Similar to 1996, the May estimates were in general higher (1-7 times) than the June estimates. The average abundance estimates of herring, based on Russian and Norwegian data, are given in Table 2. The total adjusted abundance of adolescent herring was estimated to 4.49 billion individuals, about 1.5 times more than in 1995. The 1996 year-class of herring was by far the most numerous (2.6 billion individuals) of the year-classes, followed by the 3-year olds (1.45 billion individuals).

Dietary importance of herring

In describing the diet of the minke whales, the prey was separated into three main groups: Herring, other fish species (mainly cod *Gadus morhua*, haddock *Melanogrammus aeglefinus* and capelin) and krill (Fig. 2). In 1992-1994, herring constituted 58-80 % of the biomass consumed by the whales in the investgated area, while the remaining biomass included 20-42 % of other fish species, and very small fractions (0-5%) of krill. In 1995 the dietary importance of herring were reduced to 16%, while other fish species constituted more than half (57 %) of the prey bimass. The krill fraction had now increased to 27 %. In 1996 the herring fraction had diminished to less than 1 %, whereas other fish species and krill constituted 84 % and 15 %, respectively. An increase in herring importance occurred from 1996 to 1997 when herring constituted 26 %, other fish species 26 % and krill 48 % of the minke whale diet.

Year-classes of herring (1+) exploited by the minke whales

Table 3 and Fig. 3 illustrates the frequency of occurrence (FO) and relative biomass (B), respectively, of eight year-classes of Norwegian spring spawning herring (1+) exploited by minke whales in 1992-1997. The 1991 and 1992 year-classes were by far the most exploited year-classes in the period 1992-1997, both in terms of frequency of occurrence and relative biomass. 0-group herring was excluded from the presentation.

In the period 1992-1994, the strong 1991 year-class of herring was the dominant herring component in the minke whale diets, both in terms of frequency of occurrence (80-96.3%) and biomass (51-99%) (Table 3 and Fig. 3). Additionally, the 1991 year-class was exploited by the minke whales in 1995 (FO=50%, B=15%) and 1996 (FO=14.3%, B=2%) (Table 3 and Fig. 3). The 1990 year-class occurred 30.4-80% of the minke whale stomachs in the period 1992-1994, and constituted approximately 0.1-39% of the eaten herring biomass in this period. Additionally, the 1989 year class occurred sporadically in 1992, but was hardly present in terms of relative biomass.

In 1993-1997, the strong 1992 year-class occurred in varying frequencies in the minke whale diets (20-91.7%) (Table 3). The minke whales predation upon the 1992 year-class was most conspicuous in the period 1994-1996 when this year-class constituted 44-80% of the relative herring biomass (Fig. 3). As 1- and 5-year olds (1993 and 1997, respectively) the 1992 year-class constituted approximately 6% and 12% of the herring biomass, respectively.

The 1994 and 1995 year-classes were present in the minke whale diets both in 1996 and 1997 (Table 3). Together, they constituted about 11% and 13% of the herring biomass in 1996 and 1997, respectively (Fig. 3).

In 1997, the 1996 year-class of herring predominated the herring component in the minke whale diets in 1996, both in terms of frequency of occurrence (84.6%) and biomass (56%) (Table 3, Fig. 3).

Herring year-classes exploited *vs* abundance in the sea

In 1992, the strong 1991 year-class of herring was by far the most numerous herring component in the Barents Sea (62%, Fig. 4). The minke whales had almost exclusively exploited the 1991 year-class (99.9%), while the numerical contributions of the larger sized 1989 and 1990 year-classes to the minke whale diets were negligible. This is also well illustrated by the length composition of herring found in the whale stomachs as compared with those found in the sea (Fig. 5).

In 1993, the strong 1992 year-class dominated in the sea in terms of relative numerical abundance (79%), accompanied by the 1991 (20%) and 1990 (1%) year-classes. The 1991 year-class completely dominated the minke whale diets (65%), followed by the year-classes of 1992 (20%) and 1990 (15%) (Fig. 4). As seen also from Fig. 5, the whales had exploited only the larger-sized (>120mm) herring in 1993.

Similar to 1993, the 2-year olds (1992 year-class) completely dominated the abundance of herring in the sea in 1994 (69%), followed by the 1991 (21%), 1993 (8%) and 1990 (2%) year-classes. The 3-year olds were the most conspicuous herring component in the minke whale diets (68%), accompanied by the 2-year olds (30%). The minke whale foraging behaviour with respect to herring year-classes appeared to correlate with the relative abundance of the different year-classes in the sea (Fig. 5).

The 1992 and 1993 year-classes of herring dominated the resource situation in 1995, and contributed with more than 90% to the total numbers of herring. The 4- and 1-year olds constituted about 6% and 3% of the relative numerical abundance of herring, respectively (Fig. 4). Similar to 1993-1994, the minke whales had a stronger preference for the 1992 year-class as compared with the 1993 year-class, which constituted approximately 78% and 15% of the dietary importance, respectively (Fig. 4). The size groups of herring found in the whale stomachs were similar to those found in the sea (Fig. 5).

In 1996, when herring contributed less importantly to the overall diet of minke whales (Fig. 2), the 3-year olds dominated the relative abundance of herring (65%) in the sea, followed by the 1992 and 1994 year-classes which contributed with 22% and 9% to the herring composition, respectively (Fig. 4). The remaining year-classes, 1991 and 1995, contributed with less than 5% to the year-class composition. The minke whale diets appeared to correlate relatively well both with the relative abundance (Fig. 4) and size composition (Fig. 5) of herring in the sea.

The 1996 and 1994 year-classes dominated the relative abundance of herring in 1997, and made up for approximately 58% and 32% of abundance composition, respectively (Fig. 4). The remaining year-classes, i.e., 1992, 1993 and 1995, contributed less importantly to the herring abundance. The 1-year olds was by far the most numerous year-class (94%) in the minke whale diets (Fig. 4). The other larger-sized year-classes, 1992-1995, constituted only a minor part of the herring component ingested by the minke whales. This is also evident from Fig. 5.

DISCUSSION

The observed year-to-year heterogeneity indicate that minke whale feeding habits are affected by environmental changes. In particular, the relative importance of herring as forage fish for minke whales seems to have changed considerably in the Barents Sea during the investigation period 1992-1997. Herring was the most important food constituent for the whales in this area in 1992-1994 (see also Haug *et al.* 1995a, b, 1996), but the component was greatly reduced in 1995 and was virtually absent in 1996. Summer predation of minke whales upon herring has been observed in coastal areas of North Norway in previous years (Jonsgård 1951, 1982, Lydersen *et al.* 1991, Nordøy & Blix 1992). Changes comparable with those observed in whale diets have been observed also for several seabird species breeding in the southern Barents Sea, in that the recent changes in herring (and capelin) stocks have proved to cause changes in both chick diet and breeding success (Barrett & Krasnov 1996).

The observed variation in herring importance seems to relate closely to the fate of the herring stock in the area in the same period. Improvements in recruitment of Norwegian spring spawning herring from 1988 onwards have increased the abundance of adolescent herring in the minke whale feeding areas in the southern Barents Sea (EB), and the particularly strong 1991 and 1992 cohorts (ICES 1996a, b) seems to explain the dominant role of immature herring in the minke whale diet in 1992-1994 (see also Haug *et al.* 1996). In fact, these two year classes dominated the herring component in the whale diet in the whole period 1992-1995. Although strong herring year classes may be exploited by the whales in 5 consecutive years, most of the herring of the 1991 and 1992 cohorts had migrated westwards out of the Barents Sea during 1995. Since the 1993-1995 year classes of herring were rather weak (Anon. 1996a), a reduction in the availability of adolescent herring as prey were the result. This has apparantly caused a diet switch to other fish species and krill in the area in 1996. The 1995 year class of herring is considered particularly weak, estimated to only 1% of the 1992 year class as 0-group (ICES 1998).

In their calculations of the total food consumption of northeast Atlantic minke whales during the period 1992-1995, Folkow *et al.* (1997) suggested that approximately 610 000 tons of adolescent herring might have been taken annually in the southern Barents Sea by the whales. With the observed representation of the 1991 year class of herring on the whale diet, the implication is that the whales may have consumed as much as 1.3-1.4 million tons of this year class during the period 1992-1995. The total whale consumption of the 1992 year class may have been of a magnitude of 0.8-1.0 million tons in the same period. In addition to the consumption of adolescent herring in the Barents Sea, minke whales are known to feed on adult herring during summer and autumn further to the west and south along the Norwegian coast (e.g., in the EC area, see Fig. 1) (Haug *et al.* 1996, Folkow *et al* 1997).

It is evident that adolescent herring is abundant both in the Norwegian and Russian Economic Zones in the southern Barents Sea, and that the geographical distribution of year classes may vary from year to year. Certainly, this may have effected the results from the whale stomach analyses since whaling in the period 1993-1997 was allocated exclusively to the Norwegian Economic Zone. It is well known that minke whales occur and forage also in the Russian Economic Zone (Øien 1991, Øien et al. 1987), and more samples from this area may have caused changes both in total abundance and relative age composition of herring on the whale menu.

While krill was scarce in the observed 1992-1994 diets of minke whales in the southern coastal areas of the Barents Sea and North Norway, it contributed significantly to the EB area diet in spring in 1995 and in summer in 1996. Krill has been reported as important minke whale food in the southern Barents Sea also in previous years, e.g., in 1972-1973 (Christensen 1972, 1974). These were years when the herring stock had very recently collapsed and the stock abundance of this species was extremely low (Røttingen 1990). Very little young herring were observed in the Barents Sea in the years 1970-1982 when the main nursery area for the stock was Norwegian fjords and coastal areas. Even though it is evident that minke whales are rather euryphagous and flexible in their choice of prey, it seems evident that krill may represent an important food alternative for the whales in periods when more preferred food, such as herring (see Haug *et al.* 1996, Skaug *et al.* 1997), occur more scarcely. Most probably there is a predator-prey interrelationship between capelin and krill in the Barents Sea (Dalpadado & Skjoldal 1996), which may implicate an increased krill abundance following the collapse in the capelin stock in 1992/1993 (see Hamre 1994, Gjøsæter 1995). However, whenever the stock of Norwegian spring spawning herring produces strong year classes, it seems as if it is the most consumed forage fish for minke whales in the southern Barents Sea.

ACKNOWLEDGEMENTS

The ecological studies of Northeast Atlantic minke whales are supported economically by the Research Council of Norway, project 113485/122.

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Table 1.Regression equations between fish length (FL, in mm) and otolith length (OL, in mm) in Norwegian spring spawning herring. N = number of specimens included in the analyses. ## = P<0.001.

Year	Equation	Range	N	r^2	P
1994	$FL = -17.77 + 71.71 \cdot OL$	140-285	131	0.89	##
1995	$FL = 37.19 + 51.47 \cdot OL$	170-260	26	0.68	##
1997	$FL = -6.82 + 66.84 \cdot OL$	85-175	157	0.83	##
(1994,1995,1997)*					
	$FL = -11.55 + 69.18 \cdot OL$	85-285	314	0.96	##

*Pooled regression equation.

Table 2. Acoustic estimates (billion individuals) of adolescent herring in the southern Barents Sea in the period 1992-1997.

	Year					
Year class	1992	1993	1994	1995	1996*	1997*
1988						
1989	0.1					
1990	5.8	1.5	1.7			
1991	14.0	25.8	18.0	1.1	0.025	
1992	32.6	102.7	59.2	8.0	0.6	0.05
1993			6.6	7.7	1.8	0.35
1994				0.5	0.25	1.45
1995					0.1	0.04
1996						2.6
Total	52.5	130	85.5	17.3	2.78	4.49

* = the averaged abundance estimates of the Russian and Norwegian surveys

Table 3. Frequency of occurrence of eight year-classes of herring in the minke whale diets as observed in the southern Barents Sea in the period 1992-1997. N=number of whales examined.

	Year					
Year-class	1992	1993	1994	1995	1996	1997
1989	16.7					
1990	30.4	80	25			
1991	91.3	80	96.3	50	14.3	
1992		20	88.9	91.7	42.9	30.8
1993			14.8	50	57.1	23.1
1994					71.4	38.5
1995					28.6	46.2
1996						84.6
N:	23	5	27	12	7	13

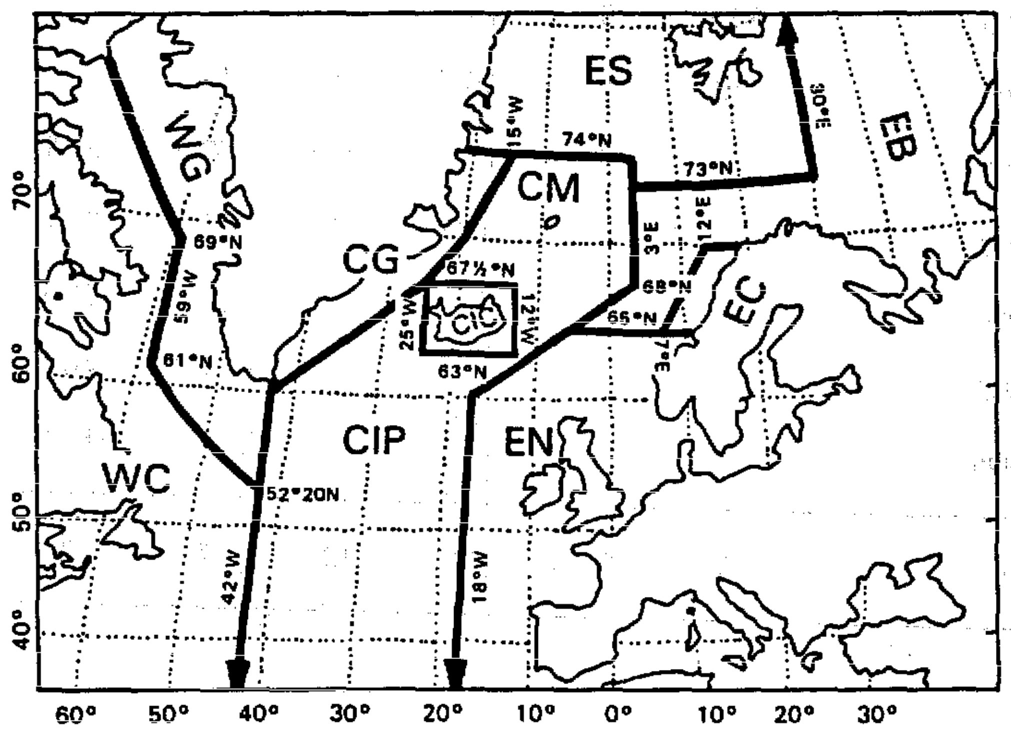

Fig. 1. Geographical subareas used in management of minke whales in the North Atlantic. The subarea included in the present study is the EB (Barents Sea and the coastal areas of Finnmark and Kola) area. From Anon. (1993).

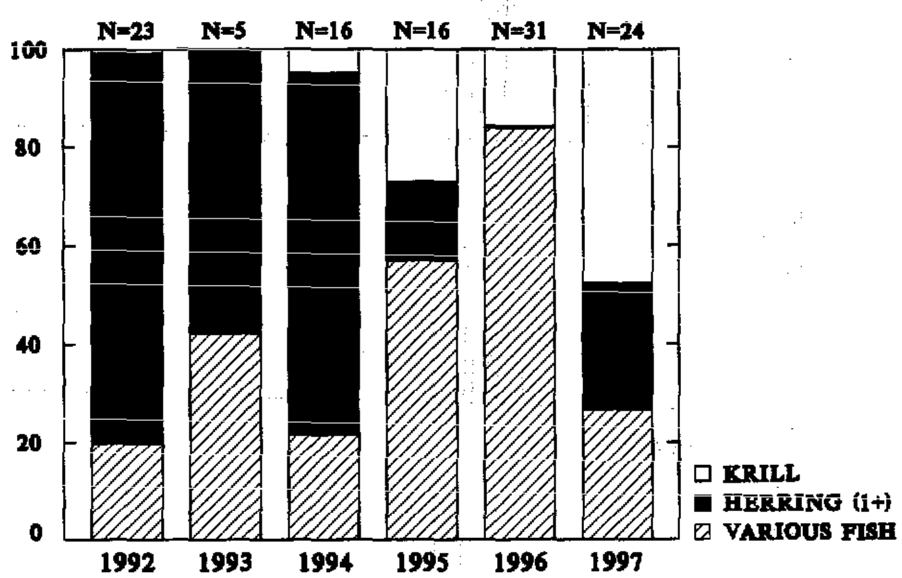

Fig. 2. Food composition, expressed as relative biomass, of prey groups in minke whales sampled in the EB (Barents Sea and coastal areas of Finnmark and Kola) area in 1992-1997. The group other fish constitute mainly cod, haddock and capelin.

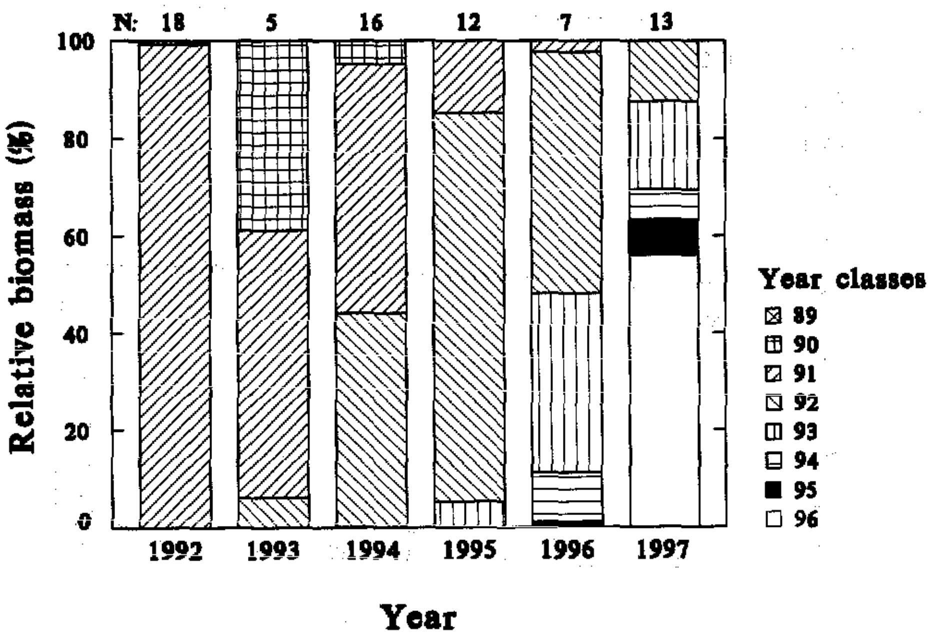

Fig. 3. Year-class composition, expressed as relative biomass, of adolescent herring in minke whale diet in the EB (Barents Sea and coastal areas of Finnmark and Kola) area in 1992-1997.

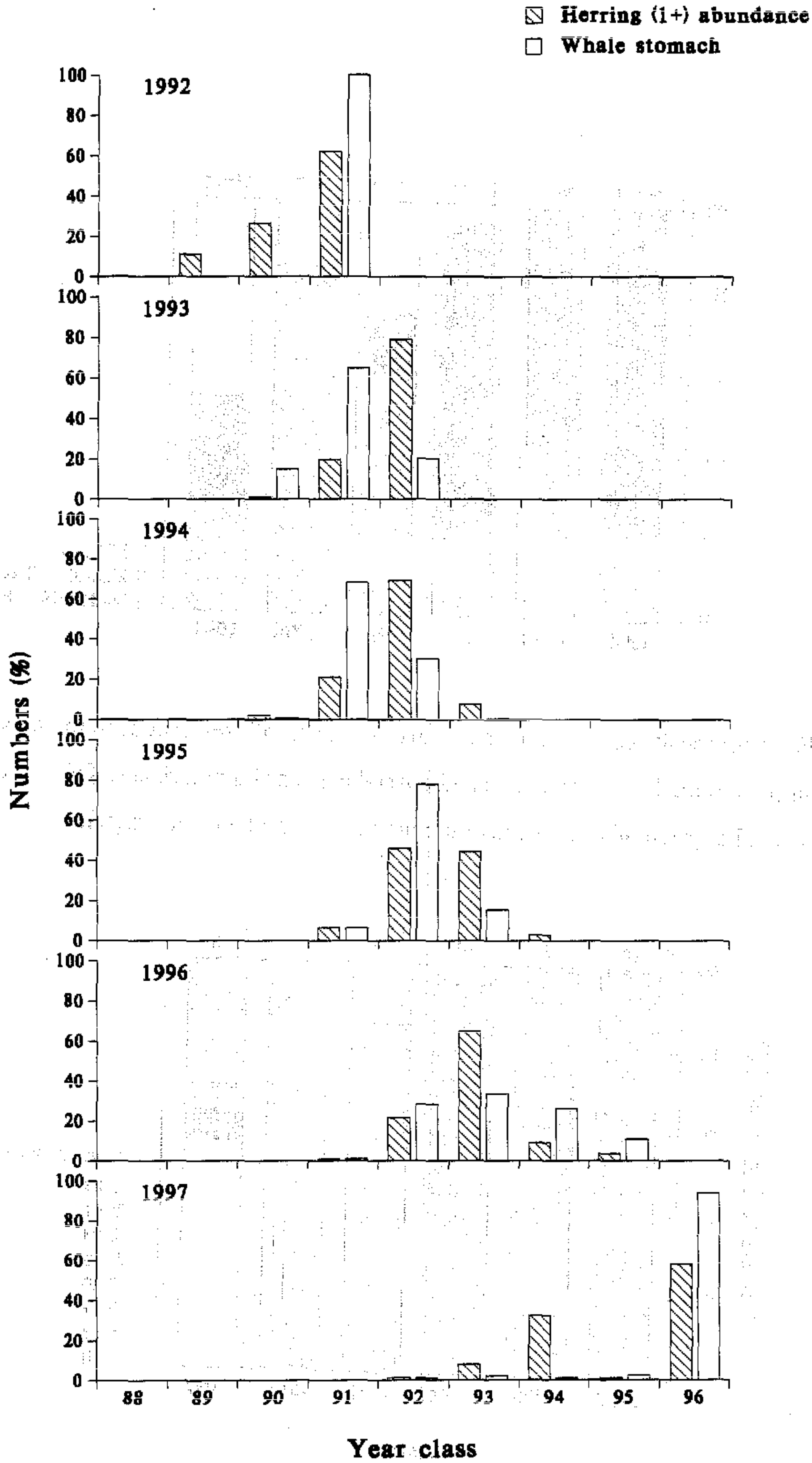

Fig. 4. Relative importance, in terms of frequency of occurrence by numbers, of year-classes of adolescent herring in minke whales and in sea in the southern Barents Sea in the period 1992-1997.

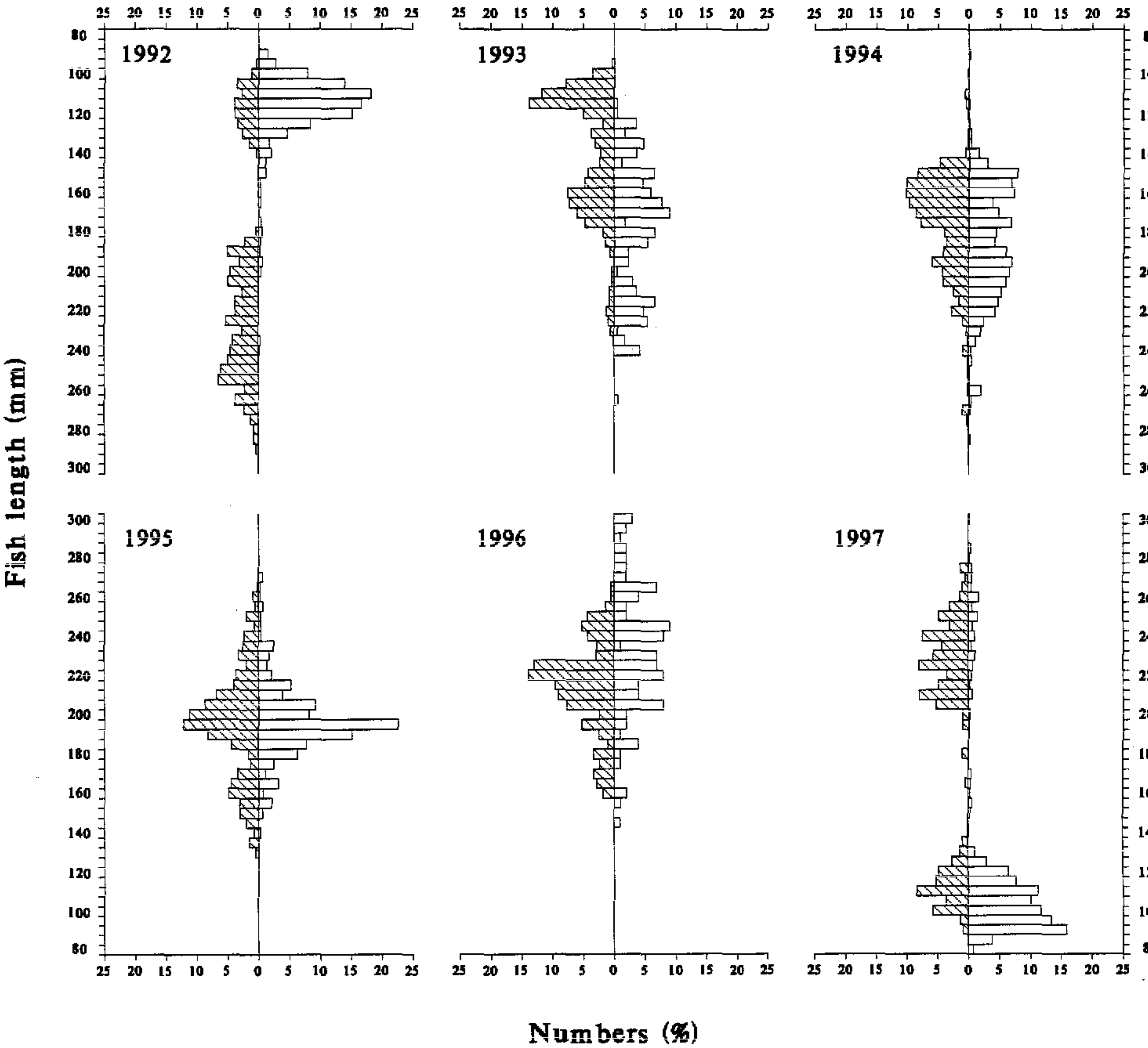

Fig. 5. Length distribution of herring sampled in minke whale stomachs (open bars) and in the sea (hatched bars) in the southern Barents Sea in 1992-1997.