International Council for
the Exploration of the Sea

C.M. 1993 / N:7
Marine Mammals Committee

STUDIES OF MINKE WHALE *BALAENOPTERA ACUTOROSTRATA* ECOLOGY IN THE NORTHEAST ATLANTIC: PRELIMINARY RESULTS FROM STUDIES OF DIET AND FOOD AVAILABILITY DURING SUMMER 1992

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ABSTRACT

Stomach content samples from 92 minke whales *Balaenoptera acutorostrata*, caught during scientific whaling operations in July-August 1992, were collected in five selected areas in Norwegian and adjacent waters. Preliminary results from the stomach analyses indicate a diet almost completely dominated by fish, although there was considerable heterogeneity in species composition between the areas. Capelin dominated the minke whale diets in the two northernmost study areas (Spitsbergen and Bear Island). Further south, in coastal areas of North Norway and Russia, herring was the most important food item, but was accompanied by significant amounts of sand eel, cod, haddock and saithe. A survey aimed to locate and classify fish and plankton resources was conducted simultaneously with the scientific whaling program. The northern areas were particularly dominated by 0-group cod (which was not found in whale stomachs), while capelin abundance was recorded only sporadically. Along the coast of North Norway and Russia, there appeared to be a larger degree of similarity between prey abundance and minke whale diet. Herring was documented to be very abundant both in the resource surveys and in the whale stomach analyses. The similarity in distribution was particularly conspicuous for 0-group herring.

INTRODUCTION

In the management of fish stocks in the Barents Sea (and other areas), increased attention has been paid to account for multispecies interactions. Although the state of art for multispecies assessment is not very advanced, the Multispecies Working Group of the International Council for the Exploration of the Sea (ICES) is actively working in the field. The modelling effort in the Barents Sea multispecies model (MULTSPEC, see Bogstad et al. 1992) has mainly focussed on the predation on capelin *Mallotus villosus* by cod *Gadus morhua*. Recently, however, the model has been expanded to include other top predators such as harp seals *Phoca groenlandica* and minke whales *Balaenoptera acutorostrata*.

Many changes in the marine ecosystem in Norwegian waters in the period between the late 1960s and today have given analyses of the feeding ecology of the most numerous top predators in the area particular actuality. Recent attempts to analyse multispecies interactions and ecosystem functions have, however, highlighted obvious gaps and deficiencies in both data and knowledge, and this applies in particular to marine mammals (Bax et al. 1991). With this in mind, studies of the feeding ecology of important predators are currently being carried out on cod (Mehl 1989, Aijad 1990, Mehl & Sunnanå 1991), sea birds (Barrett et al. 1990, Erikstad 1990, Erikstad et al. 1990) and harp seals (Haug et al. 1991, Nilssen et al. 1992). The minke whale is a frequent marine mammal in the Northeast Atlantic (abundance estimate as given by the International Whaling Commission (IWC): 86.736, CV = 0.1655, 95% CI 61.000-117.000; Anon. 1993), and supplementary studies of the role of this species as a top predator are considered important (Anon. 1991). Additional to the biological input requested for multispecies modelling, information on minke whale ecology would help understand better which environmental processes reduce feeding opportunities for the species (and other food competing whale species such as fin *Balaenoptera physalus* and humpback *Megaptera novaeangliae* whales; see

Christensen et al. 1992) and which may, in future, cause changes in density dependent parameters such as mortality, growth and fecundity (see Masaki 1979, Lockyer 1981, 1990).

The minke whale is a boreo-arctic species which, in the North Atlantic, migrates regularly to feeding areas in the high north in spring and early summer, and southwards to breeding areas in the autumn (Jonsgård 1966). The species is known to feed on various species of zooplankton and fish (in the Northeast Atlantic particularly herring *Clupea harengus*, capelin and cod) (Sergeant 1963, Larsen & Kapel 1981, Jonsgård 1951, 1982, Ichii & Kato 1991, Kasamatsu & Tanaka 1992). The collapse of two important stocks of potential prey species (Atlanto Scandian herring in the early 1970s and Barents Sea capelin in the mid 1980s; Anon. 1992a) is likely to have had an impact on the feeding habits and possibly also the migratory behaviour of Northeast Atlantic minke whales. Reports from stomach inspections made during previous commercial catches (e.g., Jonsgård 1951, 1982, Christensen 1972, 1974, Øritsland & Christensen 1982) are, therefore, difficult to put in present-day perspective because they relate to periods and areas with changing prey availability or with prey abundance much different from today. In fact, current studies of the ecological significance of minke whales in Norwegian and adjacent waters have shown that the availability of relevant field data, in particular from more recent years, is very limited. This applies especially to the feeding habits of the whales in the different areas of distribution throughout the year, data which is of crucial importance for calculations in multispecies models.

In order to evaluate the ecological significance of the Northeast Atlantic minke whale, a scientific whaling program, adressing particularly questions concerning feeding ecology (stomach analyses and concurrent estimates of prey availability) was initiated in Norway in 1992 (Haug et al. 1992). To fulfill the scientific objectives of this program, a minimum total catch of 382 whales taken over a period of three years, is required.

According to the Scientific Committee of IWC, such an outtake will have negligible effect on the status of the stock (Anon. 1993). Minke whales will be sampled along predetermined transects randomly laid out within five different areas in Norwegian and adjacent waters (west of Spitsbergen, Bear Island area, southeastern Barents Sea (off Kola), coastal banks off Finnmark, and Lofoten-Vesterålen) at different times of the year (spring, summer and autumn).

This paper present preliminary results from minke whale stomach analyses and concurrent estimates of potential prey abundance (carried out using accoustics and trawl equipment) from the first year of field work (1992), when the scientific whaling was limited to the summer period (July 4 - August 17), but in all areas (Haug 1993). The sampling design is based on statistical analyses, aimed at keeping the catch at the lowest possible level while making it possible to obtain statistical estimates with acceptable precision. The rationale of the sampling design is to optimize performance with respect to future calculations of the relative consumption of the various prey items over the Northeast Atlantic. These analyses implied, for the 1992 summer operation, a catch of 110 animals distributed as follows: 15 at Spitsbergen, 19 at Bear Island, 41 at the Kola coast in Russia, 18 off the coast of Finnmark, and 17 in the Lofoten-Vesterålen area (Haug et al. 1992). During Norwegian scientific catch of 1988-1990, some pilot studies of Northeast Atlantic minke whale diet were conducted (Nordøy & Blix 1992).

MATERIAL AND METHODS

Sampling of whales

Difficult weather conditions and some formal problems which delayed operations, combined with restrictions imposed on both

the searching and chasing of whales (to secure random sampling) and the whaling procedures (to optimize the killing efficiency), resulted in a very low catch efficiency in the scientific whaling operations (Haug 1993). Thus, stomach contents data were obtained from only 92 minke whales and not 110 as originally intended. The geographical distribution of the sampled minke whales were as follows (Fig. 1): West of Spitsbergen (16 whales), Bear Island area (19 whales), southeastern Barents Sea off the Kola Peninsula (19 whales), coastal banks off Finnmark (20 whales), and off Lofoten-Vesterålen (18 whales). Of the sampled whales, 51 and 41 were males and females respectively, and they ranged in size between 485 and 883 cm (Table 1). A more thorough description of the randomized transect sampling of whales and the general logistics of the scientific whaling activities which were carried out using six chartered small-type whaling vessels, is given in Haug (1993).

Analyses of minke whale stomachs

The minke whales were hunted and killed according to the whaling procedures described by Haug (1993). Killed whales were immediately taken onboard the vessel for dissection and biological sampling.

The complete digestive tract was taken out of the whale as soon as possible. Minke whale stomachs consist of a series of four chambers (Olsen et.al. 1993). The content from the first chamber (the forestomach) only was used in the present analyses. Forestomach contents was separated from the rest of the stomach contents and transfered to a tub where the volume was measured. The content was then transfered to a sieve system consisting of three sieves (20 mm, 5 mm and 1 mm) in order to filter off liqiud from the rest of the material. Fresh specimens of fish were separated from the rest of the material and identified according to gross morphological characteristics. The specimens were counted, total lengths were measured and the weights of large fish were recorded. For small fishes and crustaceans, a

representative subsample of fresh specimens was collected and kept frozen for later laboratory treatment. The remaining material was washed repeatedly with seawater in order to separate fish otoliths from the rest of the material. Subsamples including all intact sculls and free otoliths were also collected from the 5 mm and 1 mm sieves and kept frozen for later analyses in the laboratory.

In the laboratory, the total weight of the subsamples were recorded after thawing. The numbers of individuals of each fish species (small fishes) were recorded and total lengths and weights were recorded of fresh fishes (in the subsamples collected from the 20 mm sieve).

For crustaceans, a random subsample (collected from the 5 mm and/or the 1 mm sieves) was weighed and analyzed with respect to species composition. Total weight and the number of individuels was recorded for each species in the subsample, and this was used to obtain crude estimates of the numerical contribution of each prey species. Mean weights of fresh crustaceans, as obtained from random samples collected from pelagic trawl catches carried out by one of the whaling vessels in the Bear Island area during the scientific whaling period, were used to obtain crude estimates of the original biomass of the crustaceans eaten by the minke whales.

Subsamples consisting of digested fish material were placed in a tray, washed and strained through three sieves (2 mm, 1 mm and 0.25 mm) in order to separate otoliths and intact sculls from the rest of the material (Treacy & Crawford 1981, Murie & Lavigne 1985). The otoliths were identified to species or to the lowest possible taxon (Breiby 1985, Härkönen 1986). In samples consisting of a very large number of small otoliths, the total number was estimated by weighing all the otoliths (dry) and a subsample (about 10%) in which the number of otoliths were counted. The total number of each fish species in the forestomach contents was determined by adding the number of fresh specimens,

the number of intact sculls and half the number of free otoliths. Fish otoliths, particularly small and tiny ones from species such as herring and capelin, are known to be unresistant to exposure to gastric acids (Murie & Lavigne 1985, Jobling & Breiby 1986, Jobling 1987, Pierce & Boyle 1991). The problems with erosion of otoliths, which is particularly conspicuous in studies of seal stomachs (Pierce & Boyle 1991), is probably not a problem in these minke whale diet studies as the analyses were restricted to the forestomach contents where no gastric acids are produced: Digestive glands are completely absent in minke whale forestomachs where the degradation of food items occurs mainly as bacterial fermentation, and the pH appears to remain at a relative constant level of approximately 6.5 (Olsen et al. 1993).

In analyses of numbers of the two smallest prey items in question, krill *Thysanoessa* spp. and 0-group herring, conversion factors were applied. Number of krill is given as average "capelin biomass units", i.e., the actual number of krill specimens observed is divided by 100. Number of 0-group herring is given as average "1-group herring biomass units" which implies that the number of 0-group herring observed is divided by 10.

Random subsamples of otoliths from each species (200 - 400 otoliths) were measured and otolith length - fish weight correlations were used to estimate the original fish weight. For capelin and herring correlation equations were obtained from unpublished data kindly provided by the Institute of Marine Research, Bergen, Norway. For sand eels *Ammodytes* spp. and 0-group gadoids the correlation equations were calculated on the basis of material obtained in the present resource survey trawlings. All other correlation equations were taken from Härkönen (1986).

Feeding indices, commonly used in stomach analyses of top predators (Hyslop 1980, Pierce & Boyle 1991), were used to estimate the dietary contribution of different prey items. Since no feeding index gives a complete or fully realistic picture of dietary composition, the data were recorded as: (1) Percentages

of empty stomachs and stomachs containing one or more specimens of each food item; (2) relative frequencies of occurrence of each prey item as a numerical fraction of all prey specimens found in the forestomachs; (3) relative contribution of each prey species to the total diet, expressed in terms of calculated fresh weight.

Estimation of prey abundance

For estimation of prey abundance, one of the whaling vessels fitted with trawl equipment (M/S"Asbjørn Selsbane"), was used to cover the two northmost areas (Spitsbergen and Bear Island, Fig. 1). The remaining three areas (Kola, Finnmark and Lofoten/Vesterålen) were covered by R/V "Johan Ruud". Bad weather hampered the resource surveys and resulted in a less dense coverage than originally planned in some of the areas. This implicated a too open survey grid and too few trawl stations to give a satisfactory overview of the abundance of fish and plankton in the areas. The results should, however, give reliable information on the typical distribution and density of species, and their vertical distributions.

R/V "Johan Ruud" carried out an acoustic survey according to standard methods (e.g. Foote, 1991), where a Simrad EK 500 scientific echo sounder (Bodholt et al., 1989) and a BEI postprocessing system (Foote et al., 1991) were used. Various types of trawls, both pelagic and demersal, were used to sample the observed scatters. The whaling vessel "Asbjørn Selsbane" was not equipped with acoustic instrumentation that allowed for any measurements of fish density. The effort of this vessel was therefore restricted to pelagic trawling in sound scattering layers in areas where whales were observed and caught.

The "Johan Ruud" echo registrations were interpreted based on the appearance of the recordings, target strength distributions, and the results from adjacent trawl hauls. An acoustic threshold of -88 dB were used such that zooplankton could also be recorded. The recorded s_A (area backscattering cross section, an integrator

value measuring the echo density) per nautical mile and 50 m depth channel was averaged over 5 nautical miles, and distributed on the following groups of targets: 0-group fish, plankton, cod+haddock *Malanogrammus aeglefinus*, herring, capelin, other pelagic fish, and other demersal fish.

At regular intervals, temperature and salinity were recorded from surface to bottom using a CTDO-sonde. From every trawl catch samples were frozen for later use in biomass backcalculations from remains in stomachs and analysis of nutrient contents.

RESULTS

Whale stomach contents

A minimum of 14 different prey species were identified in the stomachs of the minke whales (Table 2). Fish, particularly herring, capelin and sand eels, were the prey occurring in most stomachs. The occurrence of capelin was particular conspicuous in the two northmost areas Spitsbergen and Bear Island, while herring was the food item found in most stomachs at all the other areas along the coasts of North Norway and Kola where also sand eels appeared to have been eaten by many whales. Whale stomachs from Kola and Finnmark included the broadest spectrum of prey species (fish, including several gadoid species), while krill appeared to have been taken by relatively few animals except at Bear Island and, to some extent, at Spitsbergen.

Analyses of the relative frequencies of occurrence (by numbers) of prey items (Fig. 2) revealed an apparent dominance of fish in diets of whales from all investigated areas. Capelin occurred most frequently in the two northmost areas. Sand eels were the most frequent species in the Kola material where also one year old and older herring were quite abundant. Herring, both 0-group

and one year old and older fish, dominated in numbers in the whale stomachs obtained in the Finnmark area. 0-group herring was also the most numerous prey species in the Lofoten/Vesterålen material where also considerable numbers of sand eels were found. Large amounts of krill were observed in the material from Bear Island only.

In terms of calculated fresh weight, the relative contribution of krill was small or negligible compared to fish in all areas (Fig. 3). In the two northmost areas (Spitsbergen and Bear Island), the fish component was completely dominated by capelin (70-90%). In the coastal areas of North Norway (Finnmark and Lofoten/Vesterålen), herring (0-group, I-group, and older individuals) comprised the main bulk (77-83%) of prey biomass. One year old and older herring contributed importantly (27%) to the prey biomass also in the Kola area, where the prey also included considerable amounts of sand eels (30%) and large cod (30%) and haddock (9%). A component of large cod (9%) was observed also in the Finnmark material, while large saithe *Pollachius virens* were found to contribute significantly (15%) to the prey biomass in Lofoten/Vesterålen.

Prey abundance

West of Spitsbergen. Three main localities, particularly densely populated with minke whales, were covered by pelagic trawling to the west of Spitsbergen (9 hauls, Table 3).

The two northernmost trawl localities were characterized by relatively weak echo recordings from the upper layers (10-50 m), while further south there were some dense registrations at 8-20 m depth. In all three areas, limited registrations were recorded near and at the sea floor, and were probably fish. As no continuous echo registration or echo integrations were carried out, nothing can be said about the horizontal distribution.

The pelagic amphipod *Parathemisto libellula* dominated the pelagic trawl

hauls from the two northmost localities within the Spitsbergen area (Table 3). Some few individuals of polar cod *Boreogadus saida* and capelin were also found. In general, catches were small in all the hauls taken in the northern localities (in depth from 5 to 65 m). Further south, the catches taken at 15-20 m were considerable larger, and were totally dominated by 0-group cod. Some specimens of capelin were also observed.

Bear Island. This area was surveyed on 6 August in good weather. Two pelagic trawl hauls were taken northwest of the island (Table 3).

The area was characterized by distinct echo registrations in the upper water layer (10-30 m). The two trawl hauls were dominated by 0-group cod. Additionally, some krill and herring were found, together with some few individuals of capelin. Simultaneously with the present survey, about 20 Spanish trawlers were fishing cod along the bottom in the area.

Coast of Kola. This area was covered from west towards east between the 18 and 20 July (Table 3, Fig. 4). The weather conditions were generally good, and the conditions for accoustic surveying fair. Due to limited ship time, areas east of 38°E were not covered.

The majority of echo recordings were found in the upper 50 m. Below this depth the recordings were less dense, and there were low fish concentrations near the sea floor. At some instances of calm sea, schools of small herring could be seen at the surface. It is therefore likely that much of the herring occurred above the level where integration of the echo signals start (about 13 m below surface), and therefore escaped the echo surveying. The densest registrations were recorded between the eastern parts of Finnmark and 34°E (Fig. 5). East of this position and southwards towards the Kola peninsula the echo registrations were less dense, although some dense patches of fish were recorded.

Trawling revealed a total dominance of young herring in the Kola area, mainly of the 1991 year class (Fig 6, Table 3). Some 0-group fish (Fig 7) were found, although in lower concentrations than observed in Norwegian coastal areas further to the west. The plankton registrations were mostly recorded at depths from 30 to 100-150 m. In one area, plankton was found near the bottom. The only plankton organism found in the pelagic trawl was krill, and only in small amounts. In addition to herring, the pelagic fish registrations were found to consist of small haddock, lantern fishes and sand eels (Table 3).

The temperature near the surface varied between 7° and 8°C. A pronounced thermocline at 20-30 m depth separated this warm water from a deeper water mass with temperature 2-3°C.

Coast of Finnmark. This area was surveyed from west to east during the period 14 to 18 July (Table 3, Fig. 4). Rough sea hampered both acoustic surveying and trawling.

There were generally only minor acoustic registrations in the area, especially west of 28°E, except for a periodically strong near-surface scattering layer consisting of 0-group fish. On the North Cape Bank (approximate position 71-72°N, 26°E) a few schools of capelin were found at 100-200 m depth. East of 28°E more fish were found, both within the 0-group fish layer in the upper 100 m, and at greater depths. Thus, the densest fish concentrations in Finnmark were located east of 28°E, and the concentrations decreased at with distance from the coast. North of 71°30'N, the 0-group layer was totally dominating.

The 0-group fish layer in the eastern parts of this area consisted almost exclusively of cod. To the west of North Cape (26°E), however, the 0-group fish layer was partly dominated by herring. In addition to the few schools of capelin located at the North Cape Bank, some capelin were observed in scattering layers along the eastern coast of Finnmark. In this area, herring of the 1991 year class was also found in small near-surface schools.

Deeper recordings were found to consist of other fishes such as young haddock and lumpsucker *Cyclopterus lumpus*.

The Finnmark area surface temperature varied between 8°C in the eastern part and nearly 9°C in the western part. There was no conspicuous thermocline, and the bottom temperatures were more than one degree higher in this area than in the Kola area.

Lofoten/Vesterålen. This area was surveyed from south to north in the period 11 to 14 July (Table 3, Fig. 4). The weather conditions were fair, except in Vestfjorden, where rough sea made trawling impossible in some parts of the area.

The area was totally dominated by echo registrations in the upper 50 m, where about 85% of the echo abundance was detected. The registrations decreased with depth, but again increased at near-bottom depths. The largest concentrations of echo recordings were found in the northmost offshore parts of the area (Fig. 5). In the more inshore Vestfjorden, relatively small registrations were detected, except in the outer parts, where considerable registrations of demersal fish were recorded, as well as high densities of 0-group fish near the surface. In the more southern offshore areas there were low concentrations of fish, apart from an 0-group layer which varied in density. Near the continental slope some pelagic registrations were found at greater depths, but the concentrations of fish near the sea floor was generally low.

A dense **layer** of 0-group fish dominated in the area, but the species **composition** varied. In Vestfjorden, this layer consisted of cod, haddock, saithe, herring and sand eel (Table 3). In areas with high echo densities the layer was dominated by herring. Outside Vestfjorden this dominance of herring was nearly total. In some areas along the coast, echo densities (back-scattering cross section) as high as 20 000 m^2 /nautical $mile^2$ was recorded. The deeper pelagic registrations consisted of a mixture of lanternfish, redfish *Sebastes* spp., blue whiting *Micromesistius poutassou*

and greater silver smelt *Argentina silus*. Only small amounts of plankton were measured acoustically. Jellyfishes dominated in the trawl catches in much of this area.

In Vestfjorden, the surface temperature was about 11°C, decreasing to about 7°C at depths larger than 50 m. Outside Lofoten and Vesterålen the temperature gradually decreased towards the northern part of this area.

DISCUSSION

Predator stomachs

The diet of minke whales in Norwegian and adjacent waters, as observed in July-August 1992, was almost completely dominated by fish while the contribution of planktonic crustaceans was very small. The present investigation thus confirms an euryphagous nature of North Atlantic minke whales, similar to minke whales in Japanese waters (Kasamatsu & Tanaka 1992), but quite unlike the rather stenophagous krill eating minke whales in the Antarctic (Ichii & Kato 1991). Considerable heterogeneity in diet occurred among the five geographical areas investigated.

Capelin dominated the minke whale diet in the two northmost areas (Spitsbergen and Bear Island). For Spitsbergen this is in contrast with previous (1950 and 1989) summer data where - even though capelin was known to be present - krill was suggested by far to be the most important minke whale food item (Jonsgård 1951, 1982, Nordøy & Blix 1992). Earlier (1950) minke whale stomach inspections in the Bear Island area also revealed pelagic crustaceans to be the food items most often consumed in this area, although often mixed with capelin (Jonsgård 1982). The present Bear Island data confirm a mixture of capelin and krill, although capelin was now the more conspicuous constituent.

In contrast to the two northernmost areas, capelin was almost completely absent from the diets of minke whales sampled in coastal areas of Russia and North Norway. The very low quantity of krill recorded in the minke whale stomachs collected in the Kola and Finnmark areas seems to contradict previous summer observations: In 1972-1973, krill was found to be the main minke whale prey on the Kola coast (Christensen 1972, 1974). Very little minke whale stomach data are available from the Finnmark coast, but there is some recent (1988 and 1990) evidence that they may prey upon krill, possibly also on 0-group herring, cod and haddock (Nordøy & Blix 1992). The present data suggest that minke whales, feeding in the Kola and Finnmark areas during summer in 1992, almost exlusively consumed various fish species, in Kola particularly herring, sand eel, cod and haddock, while in the Finnmark area there is a conspicuous dominance of herring (0-group as well as one year old and older fish) and an additional amount of cod.

As in Finnmark, a present dominance of herring in the minke whale summer diet is evident also in the Lofoten/Vesterålen area. In this area the proportion of 0-group herring is even larger than in Finnmark. Investigations performed in this area in the early 1940s confirm herring as the main summer prey (Jonsgård 1951, 1982), and similar observations were made in 1988 (Lydersen et al. 1991, Nordøy & Blix 1992).

Prey abundance

Referring to available prey species at Spitsbergen, there was an apparent difference between the northern parts, where the amphipod *P. libellula* dominated, and the southern part, where 0-group cod was totally dominating. 0-group cod also dominated at Bear Island area, while capelin was only detected sporadically in the two northmost areas.

In the coastal areas of North Norway and Kola (Russia), the prey abundance situation was rather different from the two northern

areas. Both the average total echo abundance pr 5 nautical mile and the species composition showed considerable variation from area to area (Table 4, Figs 5, 6 and 7). The Lofoten/Vesterålen area had the highest abundance of acoustic targets, with average s_A-values of 2000 (Table 4). The coast of Finnmark had only one third of this echo density, and the Kola area only one fifth. This large difference is primarily due to variable amounts of 0-group fish, which varied in s_A-values from 30 via 300 to 1700 in an east-west direction. Much of this difference can be explained by the large amounts of 0-group herring in the western areas. For the other groups, there were less dramatic differences. Herring older than the 1992 year class was absent from Lofoten/Vesterålen area, and increased in s_A-value from 150 in Finnmark to 280 in the Kola area. The capelin was also absent in Lofoten/Vesterålen, and was not found in large concentrations in any of the other areas covered. Plankton is only found in small quantities in the three southern areas.

Most demersal fish, mainly cod and haddock, were found in the Lofoten/Vesterålen area. This also applies for pelagic scatterers.

Predator-prey relationships

The large amounts of 0-group cod observed during the present resource surveys in the Spitsbergen and Bear Island areas were further confirmed during the international 0-group fish survey in the Barents Sea and adjacent waters in August-September when the densest and widest distributions of 0-group cod ever recorded in the time series were observed (Anon. 1992b). Interestingly, this vast amount of small cod in the upper water layers does not seem to have attracted the attention of the minke whales. The same was true for the pelagic amphipod *P. libellula*, which dominated in the northmost trawl hauls in the Spitsbergen area but were only found in very small amounts minke whale stomachs. The dominating minke whale food item in both Spitsbergen and Bear Island, capelin, was only found sporadically in the trawl hauls

in these areas. The same is true for krill.

The completely different prey abundance situation observed in the three southern coastal areas (Kola, Finnmark and Lofoten/Vesterålen) as compared with the two northern areas is also reflected in different whale diets which in the south are much more varied and include a broader spectrum of fish species. Contrary to the northern areas, some correlation seems to exist between prey availability and minke whale diets in the coastal areas of North Norway and Kola. Apparantly, herring was observed to be an important fish species both in the resource surveys and in the stomach analyses. The 1992 year class of herring (0-group), which is characterized as relatively strong (Anon. 1992b), was very abundant in the resource surveys in Lofoten/Vesterålen, less abundant in Finnmark and nearly absent off Kola. A similar west-to-east distribution of 0-group herring was found in the minke whale stomachs from these three areas.

Although present in limited numbers, big cod fish (cod, haddock, saithe) contributed significantly to the biomass of the minke whale diet in the southern coastal areas. These species were usually found in whale stomachs together with more numerous species such as herring and sand eels. It is not known whether these big fish are actively sought by the whales or if they are consumed simply because they were feeding in the same areas and on the same prey as the minke whales.

ACKNOWLEDGEMENTS

Sincere thanks are due to field assistants and crews on board the chartered whaling vessels 'Ann Brita', 'Asbjørn Selsbane', 'Brandsholmbøen', 'Leif Junior', 'Nybræna', and 'Reinebuen', and on board R/V 'Johan Ruud'. Assistance was received also from N. Øien in transect constructions, V. Frivoll and L. Svensson in

laboratory treatment of whale stomach contents, P. Grotnes in biomass calculations, and S. Hartvedt, F. Strand and G. Granaas in figure productions. R.T. Barrett is acknowledged for comments on the manuscript and improvements to the English. The ecological studies of Northeast Atlantic minke whales are supported economically by the Norwegian Council of Fisheries Research (NFFR), projects 4001-2800.084 and 4001-701.421.

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Table 1. Ecological studies of minke whales 1992: Distribution of whales according to sex and length within the five Northeast Atlantic sub-areas sampled.

	WEST OF SPITSBERGEN	BEAR ISLAND	COAST OF KOLA	COAST OF FINNMARK	LOFOTEN/ VESTERÅLEN	ALL AREAS
NO. OF MALES	1	14	11	14	11	51
FEMALES	15	5	8	6	7	41
LENGTH GROUPS (cm)						
476-500						
501-525				2	2	4
526-550		1		1		2
551-575				2		2
576-600		1	1			2
601-625	2			1	2	5
626-650			1	1		2
651-675	1		2			3
676-700		1	2			3
701-725		3				3
726-750	3	2	4		3	12
751-775	4		3		2	9
776-800	5	1	2	3		11
801-825	1	5	3	5		14
826-850		1	1	1	3	6
851-875		2		2	3	7
876-900		2		2		4
					3	3
TOTAL	16	19	19	20	18	92

Table 2. Ecological studies of minke whales 1992: Frequencies of empty stomachs and identified species of prey in stomachs of whales caught in five sub-areas in the Northeast Atlantic. N = number of stomachs examined.

	PERCENTAGE OCCURRENCE				
PREY ITEM	WEST OF SPITSBERGEN (N=16)	BEAR ISLAND (N=19)	COAST OF KOLA (N=19)	COAST OF FINNMARK (N=20)	LOFOTEN/ VESTERÅLEN (N=18)
Empty stomachs	0	0	0	5.0	0
Crustacea					
Amphipoda					
Parathemisto sp.	12.5				
Euphausiacea					
Thysanoessa sp.	37.5	57.9	10.5	15.0	
Pisces					
Clupeidae					
Clupea harengus		15.8	89.5	95.0	88.9
Osmeridae					
Mallotus villosus	100.0	63.2	26.3	40.0	21.1
Gasterosteidae					
Unid. gasterosteid remains			5.3		
Gadidae					
Gadus morhua	6.3	5.3	47.4	15.0	15.8
Melanogrammus aeglefinus	6.3	5.3	57.9	10.0	10.5
Micromesistitius poutassou			5.3		
Pollachius virens		15.8		20.0	42.1
Unid. gadoid remains	6.3	10.5	31.6	40.0	36.8
Ammodytidae					
Ammodytes sp.			89.5	55.0	47.4
Scorpenidae					
Sebastes sp.			15.8	5.0	
Triglidae					
Unid. triglid remains			36.8		
Cottidae					
Unid. cottid remains				5.0	
Pleuronectidae					
Glyptocephalus cynglossus			5.3		
Unidentified remains	6.3	5.3	57.9	15.0	26.3

Table 3. Ecological studies of minke whales 1992: Resource surveys, results from the trawl hauls. *: bottom haul, all others are pelagic hauls. 0: 0-group.

POSITION N	POSITION E	DATE	STATION NO.	TRAWL DEPTH (m)	MAIN SPECIES IN THE CATCH
West of Spitsbergen (M/S"Asbjørn Selsbane")					
79°13'	09°08'	22 Jul	AS01	15	P. libellula, polar cod, capelin(0)
79°13'	08°57'	23 Jul	AS02	20	P. libellula, polar cod, capelin(0)
79°33'	09°01'	23 Jul	AS03	5	Capelin, lumpsucker, P. libellula
79°28'	08°40'	23 Jul	AS04	20	P. libellula, capelin, polar cod
79°33'	08°46'	23 Jul	AS05	30	P. libellula, capelin
78°14'	09°36'	24 Jul	AS06	65	Polar cod, P. libellula
78°12'	09°36'	24 Jul	AS07	35	Polar cod, P. libellula, jellyfish
77°02'	12°36'	4 Aug	AS08	20	Cod(0), capelin, saithe
77°03'	13°33'	5 Aug	AS09	15	Cod(0), capelin, herring
Bear Island (M/S"Asbjørn Selsbane")					
74°43'	16°30'	6 Aug	AS10	15	Cod(0), krill, herring, capelin
74°44'	16°30'	6 Aug	AS11	15	Cod(0), krill, herring
Coast of Kola (R/V"Johan Ruud")					
70°29'	32°29'	18 Jul	1104	25	Herring
70°11'	32°38'	18 Jul	1107	12	Lumpsucker, cod(0), herring, capelin, haddock, jellyfishes
69°55'	34°26'	19 Jul	1110	170	Krill, lanternfishes, cod, Lumpenus sp.(0), jellyfishes
70°15'	36°22'	19 Jul	1113	30	Lumpsucker, haddock, sandeel, herring
70°15'	38°18'	20 Jul	1118	130	Haddock, krill
Coast of Finnmark (R/V"Johan Ruud")					
72°05'	23°49'	15 Jul	1089	30	Cod(0), saithe(0), herring(0), capelin(0)
71°37'	25°36'	15 Jul	1092	250	Krill, blue whiting, herring
71°09'	29°12'	17 Jul	1098	30	Herring, capelin, cod(0), haddock(0)
71°23'	31°38'	17 Jul	1101	75	Lumpsucker, haddock, herring, lanternfish, jellyfish
Lofoten/Vesterålen (R/V"Johan Ruud")					
67°29'	13°16'	11 Jul	1055	25	Herring(0), cod(0), haddock(0), sandeel, jellyfish
67°19'	11°35'	12 Jul	1057	150	Blue whiting, herring, saithe, great silver smelt, cod, haddock, jellyfish
68°00'	10°18'	12 Jul	1059	210	Great silver smelt, lanternfish
68°04'	11°08'	12 Jul	1060	100	Lanternfish, haddock, cod, jellyfish
68°18'	13°04'	12 Jul	1063	10	Herring(0), sandeel(0), haddock(0), jellyfish
69°05'	14°28'	13 Jul	1068	15	Herring(0), jellyfish
69°28'	15°41'	13 Jul	1074	245	Redfish, jellyfish, krill
69°47'	17°16'	14 Jul	1080*	344	Blue whiting, Norwegian pout, Greenland halibut, great silver smelt, saithe, cod, redfish, ratfish, herring(0), jellyfish
69°48'	17°22'	14 Jul	1081	20	Herring(0), jellyfish

Table 4. Ecological studies of minke whales 1992: resource surveys, mean echo abundance (s_A) of prey groups in the three areas Coast of Kola, Coast of Finnmark, and Lofoten/Vesterålen.

AREA	SPECIES OR GROUP							
	BOTTOM FISH	PELAGIC FISH	PLANKTON	HERRING	CAPELIN	0-GROUP	COD + HADDOCK	TOTAL
Coast of Kola	3.6	45.8	27.3	280.3	6.9	28.9	1.9	395.7
Coast of Finnmark	10.1	61.1	31.2	150.5	38.2	314.4	2.2	607.8
Lofoten/ Vesterålen	60.1	172.8	28.2	0.0	0.0	1700.0	42.8	2003.8

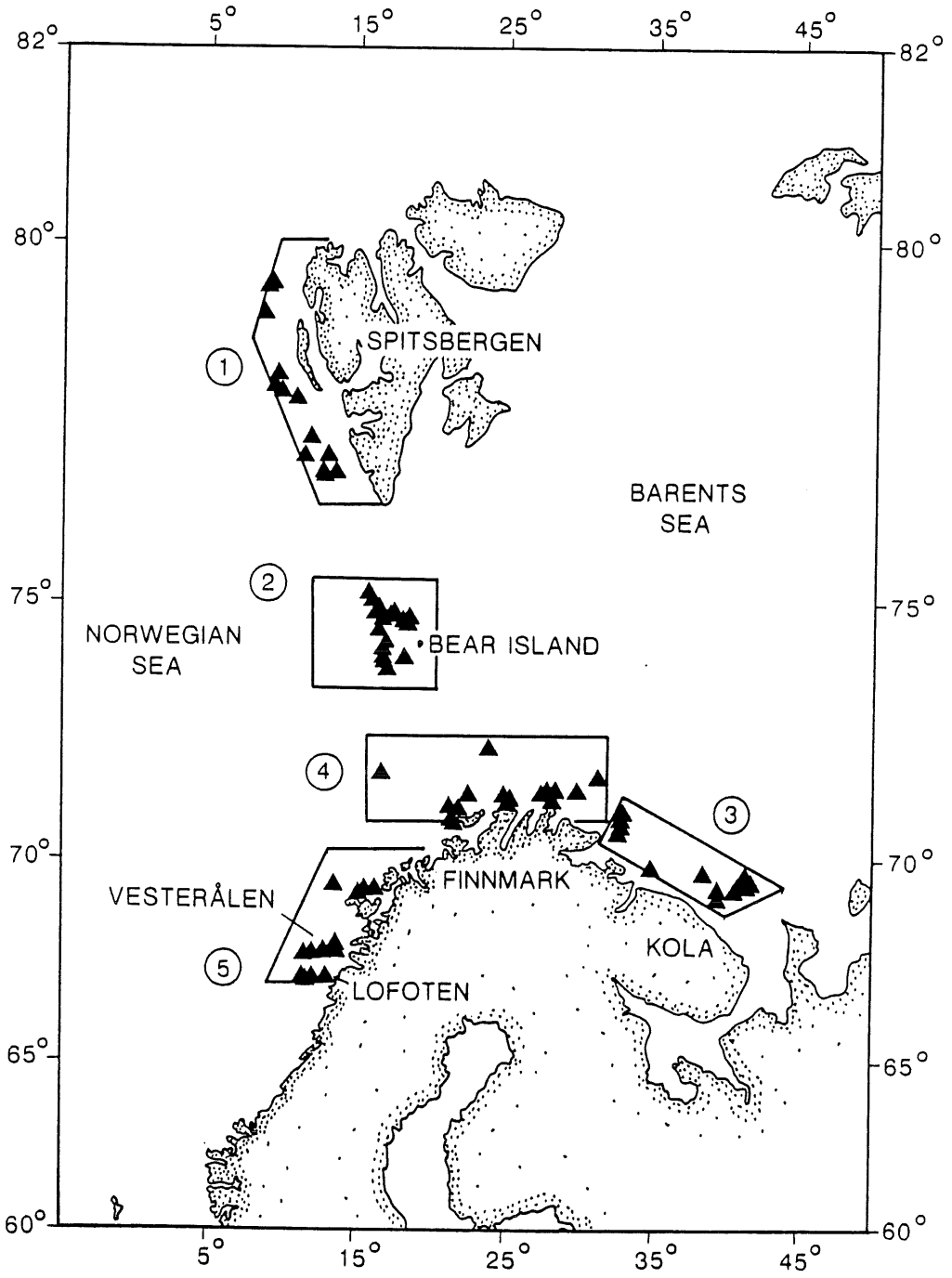

Figure 1: Selected operational sub-areas and catch positions for the minke whales sampled during the Norwegian scientific catch in July-August 1992. 1 = West of Spitsbergen; 2 = Bear Island; 3 = Coast of Kola; 4 = Coast of Finnmark; 5 = Lofoten/Vesterålen.

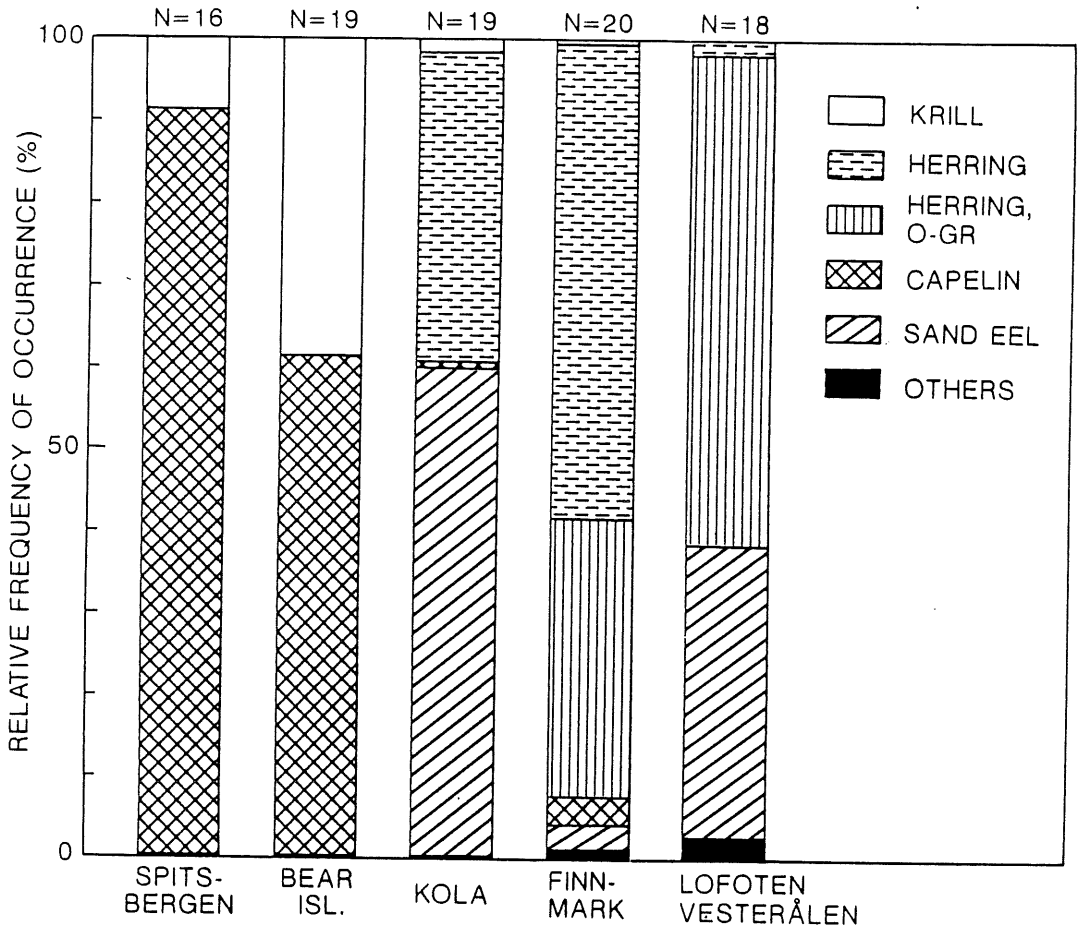

Figure 2. Food composition, expressed as relative frequency of occurrence (by numbers) of prey organisms, in minke whales sampled in five sub-areas in the Northeast Atlantic in July-August 1992. Herring is presented as 0-group and one year and older fish. 'Others' include mainly fish of the cod family. The actual numbers of krill and 0-group herring were divided by 100 and 10, respectively, before presented in this figure. N = numbers of stomachs examined.

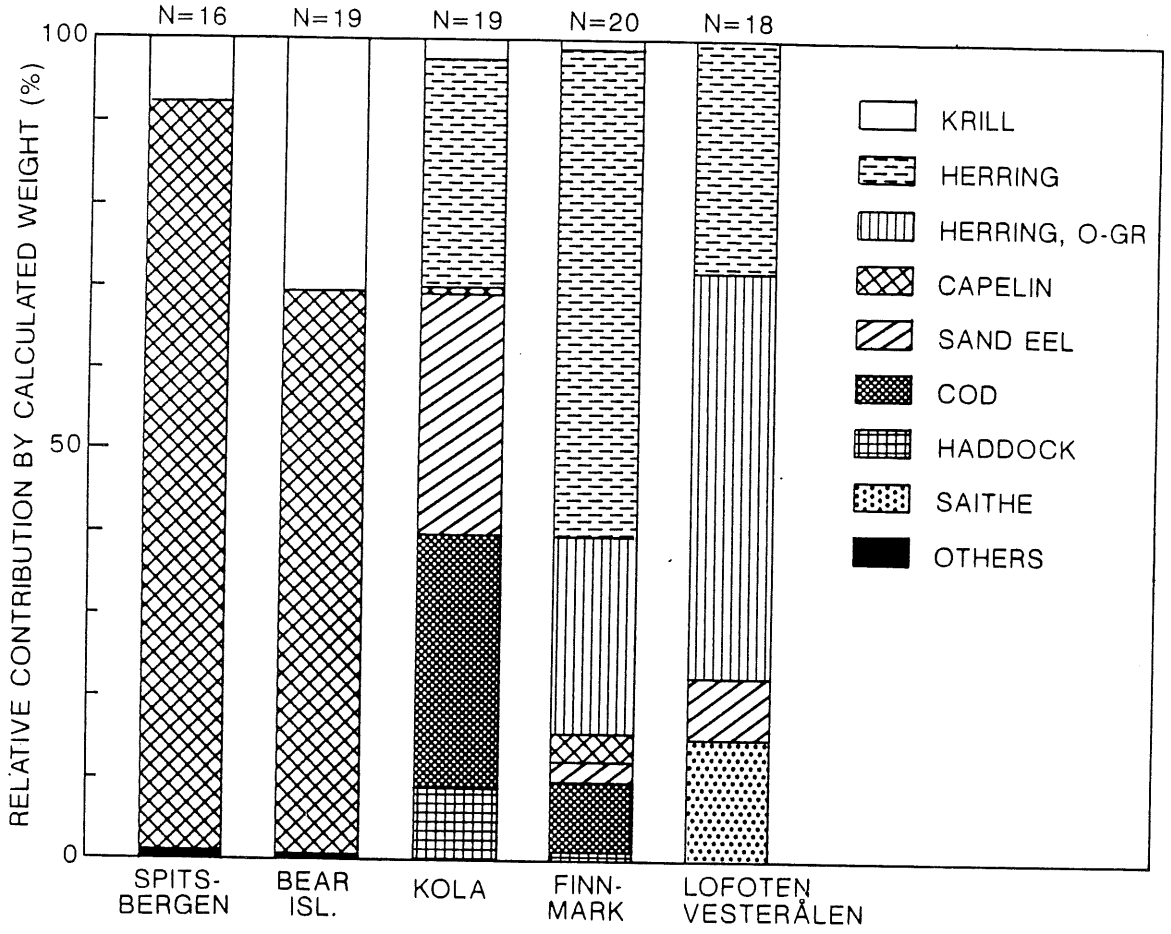

Figure 3. Food composition, expressed as relative biomass (by calculated fresh weight) of prey organisms, in minke whales sampled in five sub-areas in the Northeast Atlantic in July-August 1992. N = numbers of stomachs examined.

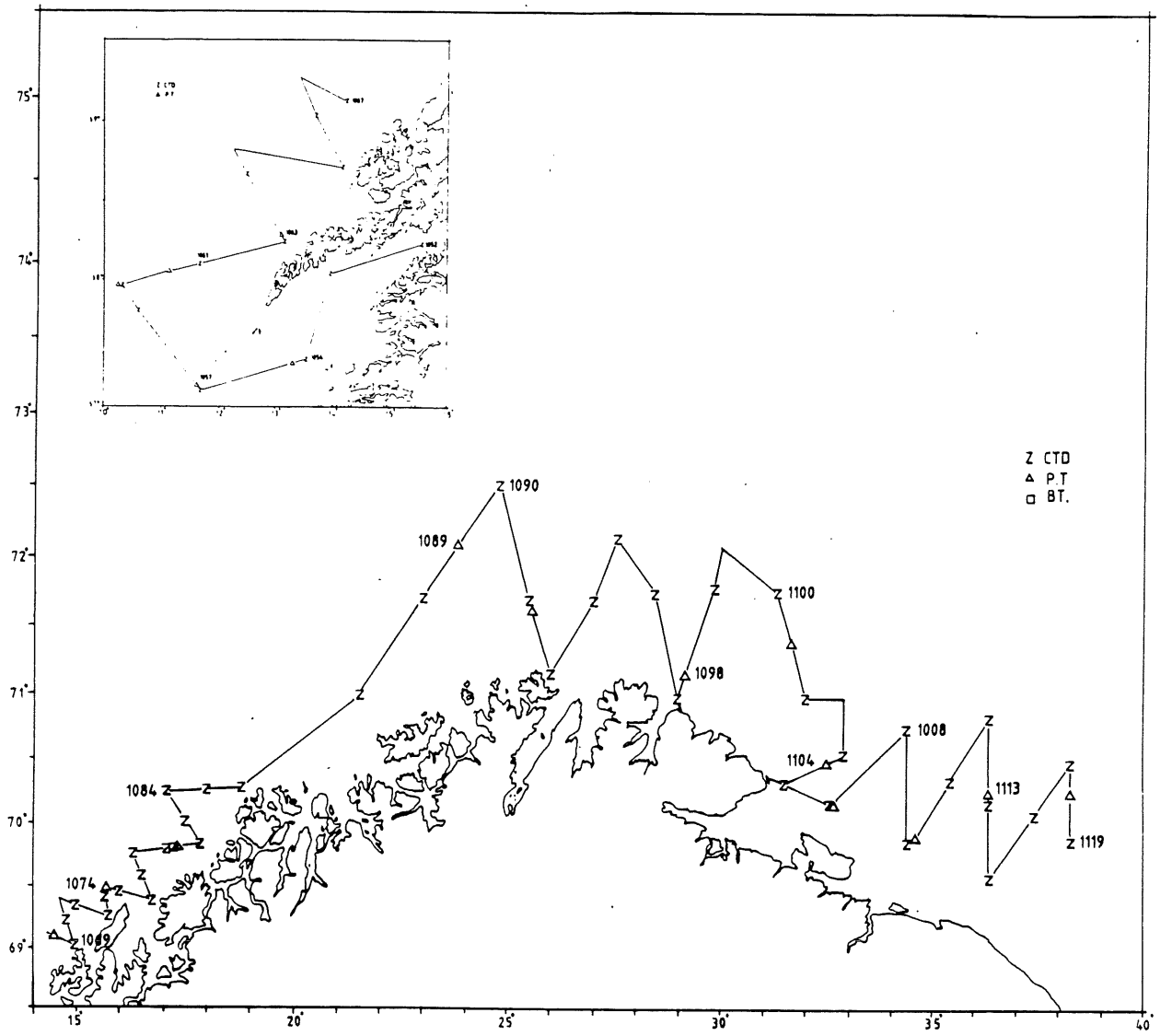

Figure 4. Cruise transects, and CTD and trawl stations used during the resource surveys conducted in conjunction with the Norwegian scientific whaling in 1992.

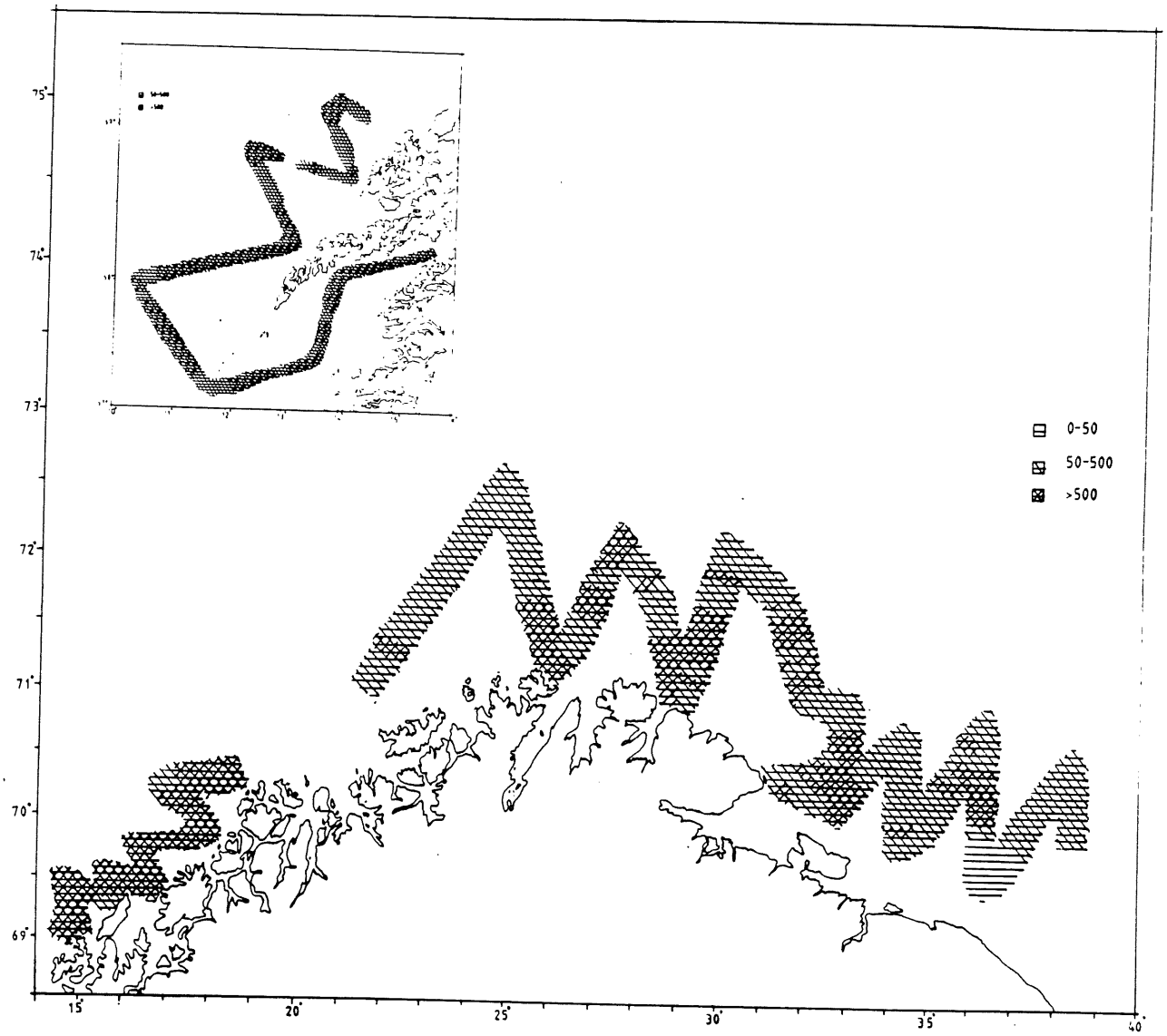

Figure 5. Mean total echo abundance (s_A, m^2/nautical $mile^2$) as observed during the resource surveys conducted in conjunction with the Norwegian scientific whaling in 1992.

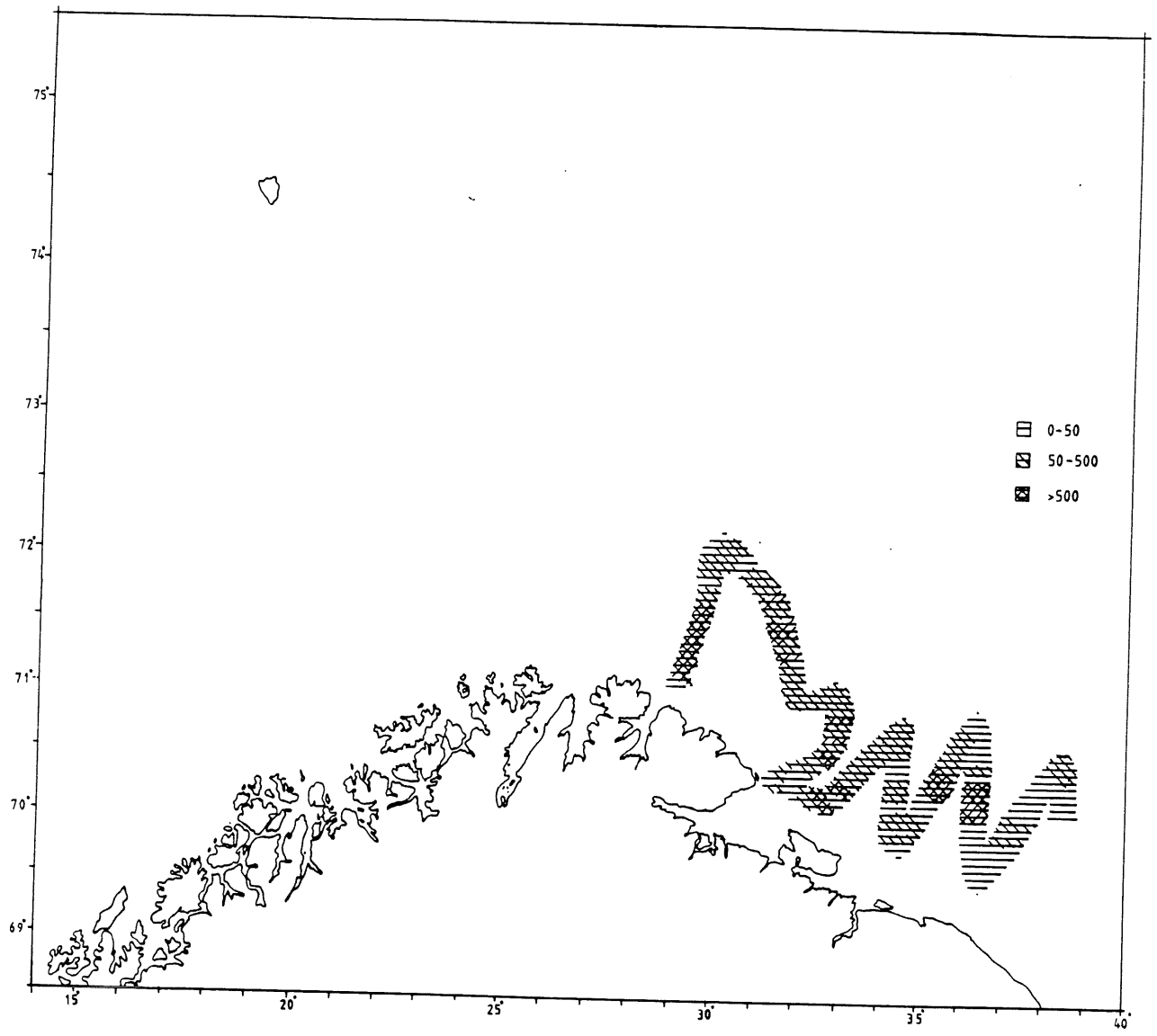

Figure 6. Mean echo abundance (s_A, m^2/nautical $mile^2$) for one year old and older herring as observed during the resource surveys conducted in conjunction with the Norwegian scientific whaling in 1992.

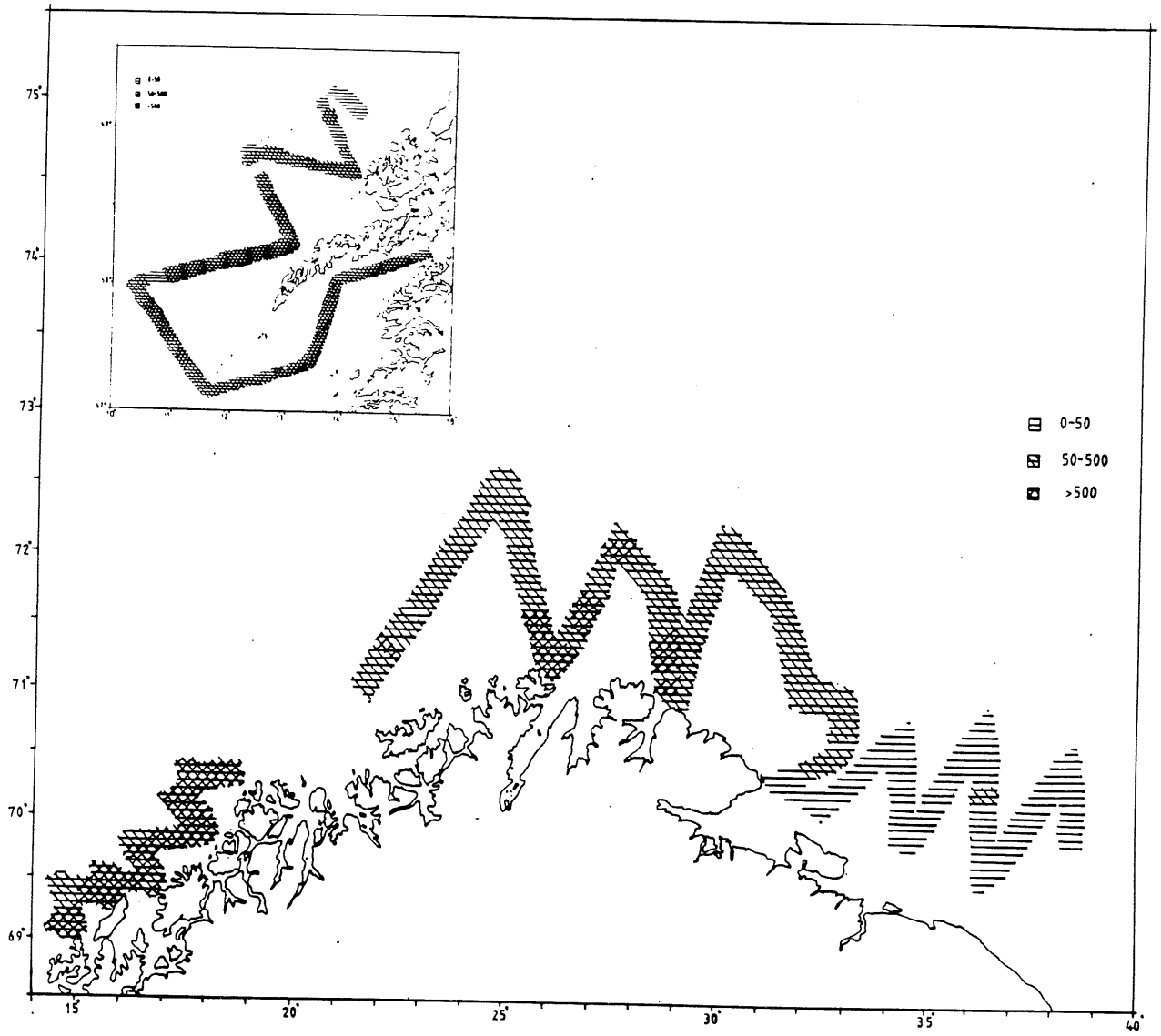

Figure 7. Mean echo abundance (s_A, m^2/nautical $mile^2$) for 0-group fish as observed during the resource surveys conducted in conjunction with the Norwegian scientific whaling in 1992.