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STUDIES OF MINKE WHALE (*BALAENOPTERA ACUTOROSTRATA*) ECOLOGY IN THE NORTHEAST ATLANTIC: DESCRIPTION OF THE 1993 SCIENTIFIC CATCH OPERATIONS AND PRELIMINARY RESULTS FROM STOMACH ANALYSES AND RESOURCE SURVEYS

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ABSTRACT

Ecological studies of the Northeast Atlantic minke whale (*Balaenoptera acutorostrata*), initiated in 1992, were continued in 1993. The field work was carried out in spring (15 April-15 May), summer (15 June-12 July) and autumn (25 August-20 September) using four chartered small-type whaling vessels which operated in four selected subareas. To ensure random sampling of whales, stringent sampling procedures, where the vessels searched for whales along predetermined transects within each subarea, was applied. Concurrent with the sampling of minke whales, estimates of potential prey abundance were carried out using accoustics and trawls. A total of 69 whales were shot; 5, 35 and 29 in spring, summer and autumn, respectively. Preliminary results from the stomach analyses indicate a diet where fish play a very prominent role. Diet varied between both periods and areas. Gadoid fish species dominated the spring diet. In summer and autumn the diet in the northmost areas (Spitsbergen and Bear Island) was primarily characterized by the presence of krill, to a much lesser extent by capelin. This is consistent with an increase in krill and severe decrease in capelin availability in these areas in 1993. In the coastal areas of North Norway, herring is the dominant planktivorous fish, and was also the most important food item for the whales both in summer and autumn. To some extent, however, the herring was accompanied by some gadoid species during summer. Whale consumption of 0-group fish were observed to be rather limited. Along with material necessary for the study of condition and diet, sampling was also carried out for a number of other studies included in the framework of the Norwegian scientific catch program.

INTRODUCTION

In the management of fish stocks in the Barents Sea (and other areas), increased attention has been paid to multispecies interactions. This, but also the many changes that have occurred 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. Thus, 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 & Furness 1990, Barrett et al. 1990, Erikstad 1990, Erikstad et al. 1990, Anon. 1994a) and harp seals (Haug et al. 1991, Nilssen et al. 1992, 1993). From 1992, also the minke whale *Balaenoptera acutorostrata* is included in this list of studied top predators (Haug 1993, Haug et al. 1993a).

The minke whale is probably the most frequent whale species 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 studies of its role as a top predator are considered important (Anon. 1991). In addition to biological input requested in multispecies modelling, information on minke whale ecology would help understand better which environmental processes reduce feeding opportunities for the species (and competitors 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).

During Norwegian scientific catches in 1988-1990, pilot studies of Northeast Atlantic minke whale diet were conducted (Nordøy & Blix 1992). In order to evaluate the ecological significance of the Northeast Atlantic minke whale, a scientific whaling program particularly designed to address questions concerning feeding ecology (stomach analyses and concurrent estimates of prey availability) and seasonal variations in energetic status, was initiated in Norway in 1992 (Haug 1993, Haug et al. 1992, 1993a). To fulfil the scientific objectives of this program, a three year sampling of minke whales along predetermined transects randomly laid out within five different areas in Norwegian and adjacent waters (west of Spitsbergen, Bear Island area, southeastern Barents Sea, coastal banks off Finnmark, and Lofoten-Vesterålen) at different times of the year (spring, summer and autumn) was necessary. The sampling design is based on statistical analyses, aimed at keeping the catch at an absolute minimum 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 northeastern Atlantic. The scientific catch of minke whales also permits studies of other important biological parameters such as growth, reproduction, stock identity and pollution. The whales are caught by traditional small-type whaling vessels equipped with 50 mm and 60 mm harpoon guns, using 22 g penthrite grenades (Øen 1992).

The extent of the program and the many activities which have to be coordinated made it necessary to test the methodology on a reduced scale including only the summer period during the first year of operations. Stomach contents from 92 minke whales were collected during July-August in 1992 (Haug et al. 1993a). Preliminary results from the analyses indicated 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 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.

The intended scientific catch activities for 1993 were similar to those in 1992, however now with three separate periods (spring, summer and autumn) included. This paper gives an account of the general logistics and practical accomplishments of the operations as they were conducted in spring (April 15-May 15), summer (June 15-July 12) and autumn (August 25-September 20). Furthermore, a preliminary presentation is given of results from the stomach analyses and concurrent evaluation of potential prey abundance. A presentation of the scientific catch logistics are previously reported in Norwegian by Haug et al. (1993b).

MATERIAL AND METHODS

GENERAL LOGISTICS OF THE SCIENTIFIC WHALING

Allocation of vessels to areas

Unlike the situation in 1992 (Haug et al. 1993a), the Russian authorities refused any scientific whaling in the Russian economical zone in 1993. This left the Kola subarea (Haug et al. 1992, 1993a) unsurveyed and reduced the 1993 field work to incorporate only the four subareas in Norwegian and adjacent waters: Spitsbergen, Bear Island, Finnmark and Lofoten/Vesterålen.

To catch the whales, 4 small-type whaling vessels (Table 1) were chartered at a fixed price per day. All income from whale meat sales were used by the program to help cover these expenses. There were three scientific personnel (including one cruise leader) recruited from a number of institutions in Norway (Norwegian Institute of Fisheries and Aquaculture (NIFA), Tromsø; Institute of Marine Research (IMR), Bergen; the Universities of Tromsø, Bergen and Oslo; and the Center of Veterinary Medicine, Tromsø) on each vessel.

Each vessel was allocated one main operational area in each period (Table 2). Where some surveys were completed or hampered by difficult weather conditions in one area, vessels were transferred to areas with more incomplete coverage or better weather conditions: 'Havliner' was transferred from Spitsbergen to Bear Island and 'Reinebuen' from Bear Island to Finnmark during the spring period, while 'Havliner' was transferred from Bear Island to Finnmark during autumn.

Operational patterns and whaling procedures

The chartered whaling vessels were fitted for the whaling operations with crew and equipment as outlined by Christensen & Øien (1990) and in agreement with new regulations enforced by the Directorate of Fisheries. Additional recommendations were given to the skippers and gunners to be followed throughout the whaling procedures in order to optimize the efficiency of the killing process:

1) Whales should not be shot at an estimated distance greater than 30 m from the vessel.
2) Preferably, whales should only be shot at when there is a chance for the gunner to hit one of the sides properly (i.e., not when the whale is moving straight towards or away from the gunner).
3) All shot whales should immediately be taken to the shipside in order to ascertain death. The death criteria

used were as described in Øen (1992), and in all cases of doubt, rifle shot(s) should be fired into the brain of the animal until death can be safely ascertained.

4) During all catch operations, the rifle should be kept on the ship's bow near the harpoon gun.

5) The harpoon gun should be loaded immediately after an animal has been struck to facilitate quick reshooting if necessary.

6) Only standardized harpoons with equal weights and lengths should be used during the catch operations.

The primary weapons used to kill minke whales in the Norwegian small-type whaling are 50 mm and 60 mm harpoon guns fitted with grenade harpoons, equipped with 22 g penthrite grenades.

On each of the vessels, one of the scientific personnel was specially trained and responsible for the collection of data on the efficiency of the killing process (see Øen 1994 for a more detailed description). Results concerning the killing efficiency, including an evaluation of the equipment used, are given by Øen (1994).

Transect sampling of whales

The scientific catch procedure used differs from commercial catch procedures in several important ways. During commercial catches, the vessels usually seek a few and geographically often very restricted areas (with known high abundance of whale prey) where they catch as many whales as possible (see Christensen & Øien 1990). An important goal of the scientific whaling, however, is to obtain samples representative for each sub-area; all whales present in the area should have the same probability of being caught. This calls for a procedure of random sampling that ensures geographical scattering within each sub-area and avoids preference for any particular size, sex, behaviour or other attribute (see Haug et al. 1992). To obtain this randomization, a stringent sampling procedure of searching for whales along predetermined transects, randomly laid out in each area, was used. In addition, when a whale was observed during search, an all-out attempt was made to catch that whale, regardless of catchability.

The transects were designed in saw-tooth patterns, mainly according to the principles used during the previous shipboard sightings surveys NASS-89 (Øien 1991), and based on experience gained in 1992 (Haug 1993, Haug et al. 1993a). Sets of transects were defined for all sub-areas before the scientific whaling started (Figs. 1-4). However, a certain amount of flexibility was implemented in the sampling scheme (e.g., the possibility of reducing the size of and/or moving sub-areas), depending on factors such as weather and observations of minke whale abundances. Basically, the sampling was carried out using a two-stage adaptive line transect method. Each area was divided into a certain number of sub-areas. One transect was usually completed within each area, intersecting all sub-areas, according to the original intentions (possibly with minor adjustments based on weather conditions). Results from the first run (i.e., the number of minke whales observed per sub-area) then decided how effort should be distributed on sub-areas in the second stage. These modifications were made on a case by case basis for the different areas. To avoid samples too small for meaningful interpretations, it was considered very important that searches in presumably unproductive areas with very low possibilities of finding minke whales were avoided. Even with the possibility for making such modifications in the transects, it is evident that the catch efficiency under the restrictions imposed for scientific reasons is likely to be considerably lower than during commercial whaling.

Time available for whale sampling - activity budgets

The sub-areas of scientific whaling are localized at various distances from the ports of departure and arrival, resulting in the time used for transport between ports and whaling grounds to vary (Table 3).

Catching minke whales is highly weather dependent, requiring conditions with no fog and very moderate winds (see Christensen & Øien 1990). In 1993, bad weather particularly hampered the program throughout the spring period, and the time available for searching and chasing whales was restricted to 9.9 - 19.2% of total ship time for the four vessels (Table 3). During long periods of bad weather, the search for whales was sometimes resumed when the conditions were still quite unfavourable, resulting in low efficiency in search and chase during some of the times given for these activities in Table 3. The weather during summer and autumn was generally better than during spring, resulting in more available time for searching and chasing whales (23.0-34.2% in summer, 22.2-28.8% in autumn, Table 3). During the summer period the bright nights also increased the operational time.

In order to ensure proper sampling and treatment of collected material, and also for the sake of the safety of the crew working on deck, each whale caught was processed completely before the search for a new animal was resumed. The time used for processing, often in good weather, varied from 0.3 - 7.5% of total ship time (Table 3).

ANALYSES OF MINKE WHALE STOMACHS

Killed minke whales were immediately taken on board the vessel for dissection and biological sampling. The complete digestive tract was removed as soon as possible. Minke whale stomachs consist of a series of four chambers (Olsen et.al. 1994). The content of the first chamber (the forestomach) only was used in the present analyses. Forestomach contents were separated from the rest of the stomach contents and transferred to a tub where the volume was measured. The content was then transferred to a perforated tub where the liquid free phase could be measured before it was emptied into a sieve system consisting of three sieves (20 mm, 5 mm and 1 mm) and washed out. Fresh specimens of fish were separated from the rest of the material and identified. The specimens were counted, total lengths were measured and the weights of large fish were recorded. For small fish and crustaceans, a representative subsample of fresh specimens was collected and 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 skulls 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 of 200 individuals (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 individuals 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 skulls 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. Larger otoliths (from cod, haddock and saithe) were separated into left and right otoliths and divided into geometric classes (with 0.49 mm steps) in order to achieve a more accurate number. The total number of each fish species in the forestomach contents was determined by adding the number of fresh specimens, the number of intact skulls 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. 1994).

In analyses of the numbers of the smallest prey item in question, the krill *Thysanoessa* spp., a conversion factor was applied: The number of krill is given as average "capelin biomass units", i.e., the actual number of krill specimens observed is divided by 100 since the weight of 100 average krill is similar to the weight of one average capelin.

Random subsamples of otoliths from each species (200 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 resource survey trawling. 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 mass.

ABSOLUTE ESTIMATION OF PREY ABUNDANCE

Potential minke whale prey species include fish and zooplankton. Of several methods used to estimate absolute abundance of fish stocks, acoustic surveys are probably the commonest (McLennan & Simmonds 1992). To conduct an acoustic survey aimed at absolute abundance estimation, prior knowledge of behaviour and acoustic properties of the species in question is essential. This includes:

1) Knowledge of the character of the target fish, i.e., species and length distribution.

2) Knowledge of acoustic properties (i.e., target strength) in order to express the acoustic quantities in terms of fish density.

3) Knowledge of the extent and variability in distribution in order to design an optimal sampling coverage.

Table 4 gives a list of surveys carried out in 1993 (by IMR, Bergen), aimed at obtaining absolute estimates of the fish stocks listed. These surveys form part of a time series, and are carried out at a time of the year which is thought to give the most reliable estimates of abundance of each actual species. At other times of the year the survey conditions can be less favourable, i.e., the concentrations of a fish stock may be mixed with other species or with plankton or the fish may be feeding near the surface or very close to the shore and, therefore, out of the sampling range of the echo sounder.

The surveys listed in Table 4 form the basis for the present estimation of prey abundance. As can be seen from the time periods in Table 4, the surveys were not always fully synoptic with the minke whale sampling. Further, the surveys aimed to survey the entire fish stock in question while the transects applied in the minke whale sampling program surveyed only part of the distributional area of the prey. Absolute abundances of actual species were estimated for areas according to a classification proposed for use in the Barents Sea multispecies modelling (MULTSPEC, see Bogstad & Tjelmeland 1992), so-called "MULTSPEC-areas" (Fig 5). To estimate the abundance for potential minke whale prey, the following MULTSPEC-areas were used to represent the minke whale sampling areas:

Bear Island and Spitsbergen :MULTSPEC area VI
Finnmark: MULTSPEC areas II and III
Lofoten/Vesterålen: MULTSPEC area I

Thus, interpolation in time and space was necessary, utilizing all available knowledge of migration and distribution.

In addition to the surveys listed in Table 4, an international 0-group fish survey is carried out in the Barents Sea area each year in late August and early September (Anon. 1994b). Information from these surveys contribute to the knowledge of the distribution and relative amount of targeted 0-group fish species from year to year in the area.

Several surveys, with aims other than absolute abundance estimation of fish stocks (0-group, immature and adults), were also carried out, concomitantly in area and time with the sampling of minke whales. The institutions involved were the IMR, Bergen (using R/V"GO Sars" and R/V"Johan Hjort") and the NIFA, Tromsø (using R/V"Jan Mayen"). During spring, resource data were collected in the Bear Island and Finnmark subareas during a cruise designed to assess prawn resources, and in the Bear Island and Lofoten/Vesterålen subareas during a cruise aimed to study hydrography and the occurrence and abundance of planktonic species. During the summer period, the Spitsbergen subarea was surveyed during a prawn assessment cruise, and the Finnmark subarea during plankton surveys.

Collected data during the resource mappings include hydrography (temperature and salinity, recorded from surface to bottom using a CTDO-sonde), acoustic measurements performed with scientific echo sounders connected to BEI postprocessing systems (Bodholt et al. 1989, Foote 1991, Foote et al. 1991), and supplementary trawl (benthic and pelagic) hauls to sample the observed scatters.

Plankton surveys aimed to observe annual production and year to year variability were generally conducted in late summer (see Anon. 1994c). Standard plankton nets were used to sample the whole water column from bottom to surface. Collected samples were filtered (through 2000um, 1000um and 180um meshes) in order to separate the different size fractions of plankton. The biomass determinations were based on dry weights.

SAMPLING OF OTHER MATERIAL DURING THE WHALING SURVEYS

Studies of body condition and diet were given the highest priority during field work. Material collected for condition studies, the analyses of which are still in progress, include girth and blubber measurements, meat and blubber masses and meat samples to be used in total lipid content analyses. Additional to the ecological studies, a number of other studies were carried out within the framework of the research catch (Table 5). This material is now being analyzed and results will be published by the responsible institutions.

Material for studies of demography and reproductive status, stock identity and pollution was collected as shown in Table 5. Studies of stock identity are performed using starch gel electrophoresis, DNA-analyses, and fatty acid composition, while the pollution studies include the evaluation of levels of pollutants such as PCB, DDT, and nuclear isotopes in minke whale blubber and meat. Both the demography/reproduction and the stock identity studies also received material from whales taken in the Norwegian traditional whaling operations in 1993.

During pilot studies in 1988-1990, 51 Northeast Atlantic minke whales were taken in research catches where particular emphasis was put on methodological aspects of feeding physiology, digestion and energetics (for review, see Haug et al. 1992). During the 1992 research catch, some of the sampling was designed both to support previous data and to follow up on these results (Haug 1993). Sampling for these purposes was continued in 1993.

Other studies for which samples were taken include evaluation of parasitic infestations in the digestive tract, potential diagnosis of viral infections from blood samples, studies of hormones and endocrine organs, analyses of blubber and meat to study possible health effects on humans, anatomical/histological studies of whale brains and hearts, and studies of the prevalence of disease in herring eaten by whales.

RESULTS

AVAILABILITY AND CAPTURE OF WHALES

Spring period

The first sampling period in 1993 was conducted from 15 April to 15 May. An intended catch of 39 minke whales (see Haug et al. 1992) was planned for the four available sub-areas (Spitsbergen 2, Bear Island 4, Lofoten/Vesterålen 20, Table 6) in this period.

Spitsbergen. Ice covered large parts of this subarea during the whole spring period, and searches were limited to the ice edge instead of along the intended transects (Fig. 1). No minke whales were observed (Table 6).

Bear Island. Bad weather throughout most of the spring period restricted the available searching time in this subarea (Table 3). Nevertheless, the whole sub-area was surveyed (Fig. 2). Twenty-one minke whales were seen (Table 6) of which 16 were seen after 1 May. Two whales were shot (Table 6, Fig. 6).

Finnmark. Very bad weather in the whole spring period severely hampered the activity in this sub-area where the western offshore parts could not be surveyed at all (Fig. 3). Only 6 minke whales were observed, and one was shot (Table 6, Fig. 6).

Lofoten/Vesterålen. Much of the offshore parts of this subarea was surveyed according to the original plans (Fig. 4) in the middle of the spring period. However, no minke whales were seen. Further inshore (the Vestfjord) the weather conditions permitted satisfying coverage of the inner parts of the fjord only (Fig. 4) where 9 whales were observed and two were shot (Table 6, Fig. 6).

Summer period

The second period was from 15 June to 12 July 1993. The originally intended catch for this period was 33 minke whales (Haug et al. 1992a); 8 in the Spitsbergen and Bear Island subareas, 7 in Finnmark, and 10 in Lofoten/Vesterålen (Table 6).

Spitsbergen. Ice cover also hampered the activity in this subarea during the summer period, and south of 78°N all searches of whales had to be confined to ice edges (Fig. 1). North of this latitude no ice problems occurred and weather conditions were favourable. A total of 73 minke whales were observed, with an apparent clustering of animals on the slope areas of the continental shelf (to the west of the Spitsbergen archipelago) between 78° and 79°N, in some cases to the west of this shelf over deep-water areas. Special effort during second stage searching was made in these densely populated areas, whereas the more unproductive areas were less intensively surveyed (Fig. 1). The clustered distribution of minke whales is also evident from the positions where 14 whales were shot in the Spitsbergen area during the summer period (Table 6, Fig.6).

Bear Island. Except for the northwestern part of this subarea, where the presence of an ice cover hampered activities throughout the whole summer period, the subarea was subjected to a first stage survey in accordance with the original intentions (Fig. 2). Of the 67 whales observed (Table 6), 64 were seen in areas along the continental slope areas (including a subwater trench - Kveiteholla - running eastwards into the continental shelf to the west of the Bear Island. This apparent clustering of whales resulted in an allocation of the second stage searching effort to these areas, while the unproductive areas further east were avoided. The apparent disorder in the realized transects in the northwest was caused by searches being restricted along unstable ice edges instead of transects. The clustered occurrence of whales is also reflected in the catch positions for the 8 animals shot in this subarea (Table 6, Fig. 6).

Finnmark. Except for the most offshore northwesterly parts, the first stage survey of this subarea went according to the original intentions (Fig. 3). During the summer period, 44 minke whales were observed (Table 6), but with no clear clustering in any part of the subarea. All offshore areas in Finnmark are particularly exposed to unstable weather conditions which may hamper whaling activity. This was true also during this summer, and the allocation of second stage search effort came to depend on both the weather (which in some cases only allowed activity in nearshore waters) and on the expected possibilities of finding whales. The lack of clustered distribution is also inferred from the catch positions of the 7 minke whales shot during this period (Table 6, Fig. 6).

Lofoten/Vesterålen. The first stage surveys in Lofoten/Vesterålen were carried out close to the intended plan (Fig. 4). No whales were, however, observed along the offshore first stage transects. Therefore, and based partly on reports received from vessels participating in the traditional small-type whaling, all offshore effort during the second stage surveys was allocated to continental slope areas (Fig. 4) where 15 whales were observed and 5 were shot (Fig. 6). Only two whales were observed and one was shot in the inshore (Vestfjord) areas during the summer period, thus yielding a total of 17 observed and 6 shot animals for this subarea (Table 6).

Autumn period

The autumn period lasted from 25 August to 19 September 1993. The originally intended autumn catch was 27 animals (Haug et al. 1992); 2 in Spitsbergen, 3 in Bear Island, 12 in Finnmark and 10 in Lofoten/Vesterålen subareas.

Spitsbergen. Unlike the two previous periods, there were no ice problems in this subarea during the autumn. Searches were mainly performed according to the original intentions (Fig. 1), but very few whales were observed. Even after extension of the search areas both northeastwards and westwards (to deep-sea waters off the edge of the continental slope, Fig. 1), only 10 minke whales were observed, and 3 were shot (Table 6, Fig. 6).

Bear Island. During the first stage searching throughout the area (hampered by difficult weather conditions) only 4 animals were observed, and it was decided to extend the searches in a northeastward direction (Fig. 2). In these area extensions, several clusters of minke whales (at least 36 animals, Table 5) were seen to the east of the Hopen Island where six were shot (Table 6, Fig. 6).

Finnmark. As in previous periods, unstable weather hampered whaling activities in the Finnmark subarea, in particular in the more offshore waters. There was a very low density of minke whales in the eastern parts of this subarea, and the majority of the 24 observed animals (Table 6) were recorded to the west. This encouraged allocation of second stage surveys mainly in the west where their performance was dictated by weather conditions as well as expected possibilities of finding whales. Also, some surveys were made in a southwesterly extension of the original subarea. Weather conditions did not permit coverage of the intended northwestern parts of the Finnmark subarea. The westerly distribution of whales in this period is also reflected from the catch positions for the 7 whales shot in the area (Table 6, Fig. 6).

Lofoten/Vesterålen. A first stage survey was carried out according to the original intentions in favourable weather (Fig. 4). Based on experience gained during the summer period, some additional searches were made along the offshore continental slope areas. A total of 37 minke whales was observed, with an offshore clustering of animals to the very north, and another inshore clustering in the southernmost waters. Effort during second stage searching was particularly allocated to these densely populated areas (Fig. 4), and the clustered appearance of whales is clearly indicated by the positions where 13 animals were shot in the autumn period in this subarea (Table 6, Fig. 6).

WHALE STOMACH CONTENTS

During the summer period a minimum of 10 different prey species were identified in the stomachs of the minke whales (Table 7). The corresponding numbers during spring and autumn were 9 and 7, respectively. Only fish were found in the spring. During the summer and autumn, crustaceans (mainly krill Thysanoessa sp.) were conspicuous in the northernmost areas (Spitsbergen and Bear Island/Hopen), but were accompanied by fish. Further south (the Finnmark and Lofoten/Vesterålen areas) fish (herring in particular) also dominated the summer and autumn diets.

Analyses of the relative frequencies of occurrence (by numbers) of prey items (Fig. 7) revealed a pure fish diet for the whales taken in the spring period (particularly capelin in the Bear Island area, gadoids in the Norwegian coastal areas). In the summer period, krill occurred most frequently in the Spitsbergen and Bear Island area, herring in the Finnmark area, while in Lofoten/Vesterålen a more varied diet was observed, containing particularly krill, herring, sand eels and gadoids. Krill was the most numerous prey species in the two northernmost areas also in the autumn period, however, now also accompanied by appreciable numbers of fish (0-group herring and cod in Spitsbergen, capelin in Bear Island / Hopen). 0-group gadoids (almost exclusively cod) was the most numerous prey species in the Finnmark autumn material, while the autumn samples taken in Lofoten/Vesterålen was comprised almost exclusively of herring.

Based on calculated fresh biomass (Fig. 8), gadoid fish (cod in Bear Island and Finnmark, haddock and saithe in Lofoten/Vesterålen) contributed most to the diet of the minke whales taken during the spring period. During the summer, krill was particularly conspicuous (92%) in the Spitsbergen area. In all other areas, fish contributed most to the summer diet biomass: cod and haddock with 63% in Bear Island, herring with nearly 100% in Finnmark, and haddock, herring and saithe with 90% in Lofoten/Vesterålen. In the autumn, krill contributed most to the whale diet in Spitsbergen (88%) and in Bear Island/Hopen (80%), while herring dominated the diet biomass in the two coastal areas (74% in Finnmark, 96% in Lofoten/Vesterålen).

PREY ABUNDANCE

Fish species

Spitsbergen and Bear Island. During the spring, winter conditions prevailed in the water masses both in the Spitsbergen and Bear Island subareas. A survey carried out in late April and early May 1993, i.e., concomitantly with the spring minke whale survey, revealed that the spring production of phytoplankton (Chaetoceros sp.) had only just started and that only very small biomasses of zooplankton and pelagic fish species were available (Rey 1993).

There are no absolute abundance estimates of prey organisms available for the spring and summer periods in the Spitsbergen and Bear Island region. The biomass of fish is known, however, to be rather small in both periods. The availability of fish increases in the northernmost areas from July on, mainly caused by an increasing amount of 0-group fish which drift northwards with the warm North Atlantic Current. The distributions of 0-group of Norwegian spring spawning herring and cod, as observed in August 1993, are shown in Figs 9C and 10, respectively. The 0-group specimens of these two species were distributed over a major part of the northern minke whale sampling areas in the autumn. An autumn acoustic survey (Anon. 1994b) also found some capelin in the eastern parts of the Bear Island area and east of

Hopen (Table 8, Fig. 11). The capelin stock in the Barents Sea has declined from a level of approximately 6 million tonnes in the period 1990-1992 to 0.8 million tonnes in 1993 (Anon. 1994c), and it is expected that this stock will decrease further in 1994. Results from the bottom trawl surveys are not yet available.

Finnmark. The most important planktivorous fish in this area in 1993 were young and adolescent Norwegian spring spawning herring. In spring, these immature specimens start feeding migrations into the Finnmark area from areas further to the east (Fig 9A). Apparently, there will also be considerable amounts of young cod and haddock available in the area, feeding on the herring and also on some spent capelin. The main feeding grounds of the capelin are in the central and northeastern parts of the Barents Sea, but they spawn in March-April along the coasts of the Kola Peninsula and Finnmark (Dragesund et al. 1973). The abundance of cod and haddock given for the spring period in Finnmark in Table 8 are results from a survey performed in February-March (Table 4), previously reported by Korsbrekke et al. (1993). It is assumed that by April the adult cod recorded in the Finnmark area in February-March will have migrated from the Barents Sea to the spawning grounds in the Lofoten/Vesterålen area.

In the 1993 summer period, the Finnmark area was dominated by immature herring, and from the end of July the fish biomass was further augmented by influx of 0-group fish species which were transported into the area by currents from south-west . In 1993 these 0-group fish concentrations were dominated by cod and herring (Fig 9B and 10). The autumn period in this area was similar to the summer with a predominance of young herring (Fig. 9C) and 0-group fish.

There are no reliable estimates of cod and haddock in Finnmark for the 1993 summer period, and data concerning these two species in autumn are not yet available. The estimates of immature herring in the summer and autumn periods (Table 8) are from surveys performed in June and September, respectively (Table 4).

Lofoten/Vesterålen. In spring, stocks of adult fish (cod, haddock, saithe and herring) migrate northwards through this area on their way from spawning grounds to summer feeding areas. There are also concentrations of immature herring in the area, usually distributed close to the coast. Adult herring, however, migrate at 200-400 meters depth to the west of the continental slope during spring. In summer, some fish species (saithe, cod, immature herring) feed in the Lofoten/Vesterålen area, while the amount of fish biomass increases substantially in autumn due to the arrival of adult herring which migrate towards their wintering area in the inner Vestfjord (Fig 9C).

The spring stocks of cod, haddock and saithe were mapped on a spawning ground survey (Table 4) conducted in Lofoten and Vesterålen from early March to early April (Korsbrekke 1993). Although it is expected that by late April these fish concentrations are migrating northwards, it is assumed that they are located within MULTSPEC area I (Fig 5) during the whole spring period.

The herring estimates from the spring and summer period are interpolated from stock size estimates made in the wintering area (Table 8) and data on the relative herring distribution in April and July/August. The biomass data from the autumn period are estimated from acoustic estimates on the wintering areas and from tagging estimates (Anon. 1994c).

Zooplankton

In Fig. 12, zooplankton biomass data in terms of average ash free dry weight or only dry weight from bottom to surface are presented for the MULTSPEC-areas II-VIII for the years 1985-1993. For the areas of interest to the minke whale surveys, the overall zooplankton production in 1993 was probably above average and considerably larger than in 1992 (Anon 1994c).

The yearly production of krill in the Barents Sea has been estimated to 50-70 million tonnes (Drobysheva & Panasenko 1984). The main species of krill in this area are Thysanoessa inermis, T. raschii, T. longicaudata and Meganyctiphanes norwegica. However, the exact standing stock biomass (in tonnes) of krill in the particular areas and times of minke whale sampling cannot be given.

DISCUSSION

AVAILABILITY AND CAPTURE OF WHALES

Exclusion of the Kola subarea reduced the 1993 field work to incorporate four subareas in Norwegian and adjacent waters: Spitsbergen, Bear Island, Finnmark and Lofoten/Vesterålen. The intended 1993 catch in these four areas was 99 minke whales, with 39, 33 and 27 animals in spring, summer and autumn, respectively (Haug et al. 1992, Anon. 1993). It proved difficult to obtain this number with the effort available, and the total number of whales taken during the 1993 field work was 69, with 5, 35 and 29 animals in spring, summer and autumn, respectively.

The low number sampled in spring is partly explained by bad weather that left only very restricted time available for chasing and hunting whales during the period. Also, the starting date (15 April) may have been too early since the minke whales were either completely absent (Spitsbergen) or scarce (Bear Island, Finnmark and Lofoten/Vesterålen) in the subareas surveyed. Certainly, low whale abundance, combined with the low catch efficiency due to the restrictions imposed on the sampling design (transect searching), will necessarily restrict the possibilities of obtaining a large sample.

The availability of minke whales was higher during both the summer and the autumn periods than during spring. Also, the weather conditions were more favourable during the last two periods, and the final numbers of whales obtained were in excess of the intended numbers in both periods. However, there were considerable changes in the relative distribution of whales from summer to autumn. In the southernmost subarea (Lofoten/Vesterålen), the abundance of whales appeared to be rather low also in the summer period, while in autumn this subarea turned out to be the most densely populated of all subareas surveyed. In the Finnmark subarea fewer whales were observed in autumn than in summer. Further to the north, minke whales seemed to be emigrating from both the Spitsbergen and Bear Island subareas during autumn, possibly heading eastwards into the northern parts of the Barents Sea where concentrations of whales were found and sampled to the east of the Hopen Island.

WHALE STOMACH CONTENTS

As in July-August 1992 (Haug et al. 1993a), fish were the most conspicuous constituents of the diet of minke whales examined in Norwegian and adjacent waters in spring, summer and autumn in 1993. The results confirm the impression that the northeast Atlantic minke whales are euryphagous, 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). The diet composition varied in 1993, both between periods and among the four geographical areas investigated.

The 1993 results may point towards a dominant role of gadoid fish (cod, haddock and saithe) in the spring diet of minke whales in the investigated areas. This seems consistent with previous observations made in Lofoten in the 1940s where Jonsgård (1951, 1982) reported that minke whales fed on cod, and to a smaller extent also on haddock, in spring. The present material from the spring period is, however, extremely restricted, and more firm discussions and conclusions concerning whale diets at this early period of the year must await the availability of a more extensive data base.

In contrast to the observations made in July-August 1992, where capelin dominated the whale diet in the northernmost parts of the investigated area (Spitsbergen and Bear Island, see Haug et al. 1993a), the dietary contribution of krill was much more conspicuous in the north both in summer and autumn in 1993. In fact, krill dominated the Spitsbergen whale diets in both periods. The Bear Island summer diet was a mixture of krill and adult cod and haddock, while in autumn, when the whales had moved eastwards into the northern parts of the Barents Sea east of Hopen Island, krill dominated the diet. The prominent role of krill in these northern areas in 1993 is consistent with previous summer observations made in 1950 (Jonsgård 1951, 1982) and in 1989 (Nordøy & Blix 1992).

Minke whales from the two subareas on the Norwegian coast (Finnmark and Lofoten/Vesterålen) were observed to have eaten almost exclusively fish both in summer and autumn in 1993. Herring dominated the whale diet in Finnmark in both periods as it also did in July-August in 1992 (Haug et al. 1993a). In autumn 1993, the whales were also observed to have eaten considerable quantities of 0-group gadoid fish. Similar minke whale predation upon 0-group fish was observed in this area in August in 1988 (Nordøy & Blix 1992). In July-August 1992, minke whales both from the Finnmark and the Lofoten/Vesterålen subareas were reported to have eaten large amounts of 0-group herring (Haug et al. 1993a). Similar observations were not made in any parts of the 1993 surveys. The 1993 autumn diet of minke whales from the Lofoten/Vesterålen subarea was completely dominated by adult herring, while during summer the diet was more mixed with particular large representation of haddock, to some extent also saithe. Summer and early autumn predation from minke whales upon herring in Lofoten and Vesterålen were also found in the 1940s (Jonsgård 1951, 1982) and in 1988 (Lydersen et al. 1991, Nordøy & Blix 1992).

PREY ABUNDANCE

The minke whales migrate into the eastern Norwegian Sea and the Barents sea ecosystem in early spring and emigrate in autumn. Significant changes occur in these ecosystems in this time interval.

A factor of great ecological importance is the spawning of the important fish stocks (e.g., cod and herring) and the corresponding drift of larvae and fry. These fish stocks spawn along the Norwegian coast from February to April. Later in spring the larvae and fry are carried with the prevailing currents along the coast and into the eastern part of the Norwegian Sea and the Barents Sea. In autumn, the 0-group fish are distributed over large areas in the Barents Sea. Results from annual 0-group fish surveys indicate that the amount of 0-group fish present in the Barents Sea during autumn in 1993 was above average (Anon. 1994b).

Another important factor is the general development of phytoplankton and the concentration near the surface of spawning copepods, krill and other forms of zooplankton. This process starts in the southern part of the Norwegian Sea and along the Norwegian coast in March-April. The spring increase in zooplankton gradually spreads northwest into the Norwegian Atlantic Current in May-June and later into mixed and arctic waters. The development of plankton forms the basis for the feeding migrations of the plankton eating species such as herring and capelin. As an example of the dynamics of these feeding migrations, the distribution of mature and immature Norwegian spring spawning herring in the different sampling periods of the minke whale is illustrated in Fig 9A-C. In turn, the migrations of the planktivorous fish is one of the main factors which govern the distribution of the top predators, such as cod and marine mammals (Hamre 1991).

The appearance of adult Norwegian spring spawning herring during autumn in the Lofoten/Vesterålen subarea is a relatively new phenomenon, related to the recent rebuilding of this stock (Røttingen 1992). Prior to the collapse of this stock in the late 1960s, the adults wintered in the open sea northeast of Iceland.

While large numbers of 0-group and immature Norwegian spring spawning herring are present in the Barents Sea areas, a collapse in the Barents Sea capelin seems to have prevailed from 1992 to 1993 (Anon. 1994c). Concomitantly with this change in planktivorous fish stocks, an increase seems to have occurred in the biomass of zooplankton (krill in particular) which blooms in these areas during summer (Fig. 12).

PREDATOR-PREY RELATIONSHIPS

Although the material collected during the spring period in 1993 is very limited and should be interpreted with great care, a habit of minke whale feeding upon gadoid fish can possibly be inferred. The lack of whale observations in the northernmost areas seems consistent with observations of a typical winter situation prevailing in these waters during the whole spring period (Rey 1993). Interestingly, although herring were present in considerable amounts in deep water in Lofoten/Vesterålen during spring, no herring were found in whale stomachs from this area.

The increased importance of krill in minke whale diets in the northernmost areas in summer and autumn 1993 as compared with the summer investigations in 1992 (when capelin dominated the whale diets in these areas, see Haug et al. 1993a) seems consistent with changes in the ecosystem between these two years: From 1992 to 1993 there was an increase in the zooplankton production, while a dramatic decrease occurred in the Barents Sea capelin stock (Anon. 1994c). In 1993, capelin was only observed in very restricted amounts on the minke whale diet during autumn in the Hopen area.

The capelin stock is mainly confined to the central and northeastern parts of the Barents Sea (Dragesund et al. 1973), while the dominant planktivorous fish along the Norwegian coast and in the southern Barents Sea is the Norwegian spring spawning herring. While a recent decrease has prevailed in the capelin stock, the stock of Norwegian spring spawning herring is increasing (Anon. 1994c). As observed during summer in 1992 (Haug et al. 1993a), herring was the most important minke whale prey species in the coastal subareas during summer and autumn also in 1993. The considerable amount of gadoid species on the minke whale diet in Lofoten/Vesterålen in summer is consistent with observations that considerable amounts of these fishes feed in this area in summer.

Unlike 1992, when large amounts of 0-group herring were consumed by the whales, the 1993 consumption included almost exclusively one year old and older herring. A limited amount of 0-group gadoids were consumed by the whales during the 1993 autumn (in the Finnmark and Spitsbergen subareas).

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Table 1. Small-type whaling vessels used during the Norwegian scientific catch of minke whales in spring, summer and autumn 1993.

VESSEL	LENGTH (feet)	ENGINE SIZE (hp)	NO. OF SCIENTISTS ONBOARD	MAIN AREA OF OPERATION
Reinebuen	76	565	3-4	Spitsbergen, Bear Island
Havliner	90	570	3-4	Bear Island, Spitsbergen
Nybræna	70	500	3	Finnmark
Rango	77	633	3-4	Lofoten/ Vesterålen

Table 2. Periods of allocation of vessels to the main catch areas during the Norwegian scientific catch of minke whales in spring, summer and autumn 1993.

	SPRING	SUMMER	AUTUMN
	April 15, May 1, 7, 15	June 15, July 12	August 25, September 12, 17, 20
SPITSBERGEN			
Reinebuen		<------->	<----------------->
Havliner	<----->		
BEAR ISLAND			
Havliner	<------>	<------->	<--------->
Reinebuen	<-------->		
COAST OF FINNMARK			
Nybræna	<------------>	<------->	<----------------->
Reinebuen	<--->		
Havliner			<------->
LOFOTEN/VESTERÅLEN			
Rango	<------------>	<------->	<------------->

Table 3. Activity budgets (% of total ship time) for the four small-type whaling vessels participating in the Norwegian scientific minke whale catch operations during three periods (spring: April/May, summer: June/July, autumn: August/September) in 1993.

ACTIVITY	VESSELS			
	Havliner	Nybræna	Rango	Reinebuen
	SPRING			
Total shiptime (days)	31	30	29	30
Transport	17.1	8.9	2.2	20.0
Searching/chasing	14.3	10.7	19.2	9.9
Processing/trawling	0.3	0.6	1.0	0
Passive (weather etc.)	68.3	79.7	77.6	70.1
	SUMMER			
Total shiptime (days)	28	28	27	28
Transport	19.6	6.7	2.3	19.8
Searching/chasing	34.2	23.0	30.3	30.8
Processing/trawling	2.6	2.8	1.2	7.5
Passive (weather etc.)	43.7	67.4	66.2	42.5
	AUTUMN			
Total shiptime (days)	26	26	23	26
Transport	16.6	9.5	1.4	19.9
Searching/chasing	28.8	22.2	26.6	22.5
Processing/trawling	4.2	2.8	5.4	1.7
Passive (weather etc.)	50.3	65.6	66.5	55.8

Table 4. Annual surveys carried out to estimate absolute abundance of fish stocks in 1993. Operating institution: Institute of Marine Research, Bergen, Norway.

Period	**Area**	**Type of survey**	**Target species**
Feb-Mar	Barents Sea	Combined acoustics and bottom trawl	Cod and haddock
Mar-Apr	Lofoten-Vesterålen	Acoustic survey	Cod, haddock and saithe
Jun	Barents Sea	Acoustic	Immature herring
Aug-Sep	Bear Island-Spitsbergen	Bottom trawl	Cod
Sep	Barents Sea	Acoustics	Capelin, immature herring
Dec-Jan	Vestfjord area	Acoustics Tagging	Adult herring

Table 5. Studies and institutions for which material was collected during the Norwegian scientific catch of minke whales in spring, summer and autumn 1993.

TYPE OF STUDY	MATERIAL COLLECTED	INSTITUTION
Condition	Measurements/weights, muscle	NIFA/UITØ
Feeding habits	Stomach contents	NIFA
Reproduction	Sexual organs, fetuses	NIFA/IMRN
Demography	Bullae, measurements	IMRN
Energetics/physiology	Intestines, urine, blubber, muscle, fetuses, baleen	UITØ
Population genetics	Heart, liver, kidney, skin, blubber, gonads	IMRI, UIB,
Pollution	Muscle, blubber	NCVM, IMRN
Parasite infestation	Stomach/intestines-parasites	UIO
Viral infections	Blood	CVMT
Sexual hormones	Blood, muscle, blubber, liver, kidney	NCVM
Endocrine system	Thyroid, adrenals, gonads, spleen, liver	UIAR
Whale oil/fat	Blubber	NIFA
Fatty acids	Eyes, brain	NIFA
Whale meat	Muscles	NIFA
Anatomy/histology	Brain, heart	NCVM, UIB UITR
Herring diseases	Herrings from stomachs	IMRN

CVMT = Center of Veterinary medicine, Tromsø, Norway
IMRI = Institute of Marine Research, Reykjavik, Iceland
IMRN = Institute of Marine Research, Bergen, Norway
NCVM = Norwegian College of Veterinary Medicine, Oslo, Norway
NIFA = Norw. Inst. of Fisheries and Aquaculture, Tromsø, Norway
UIAR = University of Archangelsk, Russsia
UIB = University of Bergen, Norway
UIO = University of Oslo, Norway
UITR = University of Trondheim, Norway
UITØ = University of Tromsø, Norway

Table 6. Number of minke whales caught in the Norwegian scientific catch operations during three periods (spring, summer and autumn) in 1993. "Intended catch" is the suggested number of whales required to fulfill the scientific objectives of the program. Numbers of whales per vessel are given in brackets.

SUB-AREA PERIOD VESSEL	No. of whales observed	Intended catch	No. of whales caught
SPITSBERGEN			
Spring	0	2	0
Havliner(0)			
Summer	73	8	14
Reinebuen(14)			
Autumn	10	2	3
Reinebuen(3)			
BEAR ISLAND			
Spring	21	4	2*
Reinebuen(1)			
Havliner(1)			
Summer	67	8	8*
Havliner(8)			
Autumn	40	3	6*
Havliner(6)			
COAST OF FINNMARK			
Spring	7	11	1
Nybræna(1)			
Reinebuen(0)			
Summer	44	7	7**
Nybræna(7)			
Autumn	24	12	7
Nybræna(4)			
Havliner(3)			
LOFOTEN/VESTERÅLEN			
Spring	9	20	2
Rango(2)			
Summer	17	10	6
Rango(6)			
Autumn	36	10	13*
Rango(13)			
TOTAL	348	99	69

*One or **two whales struck and lost.

Table 7. Ecological studies of minke whales 1993: Frequencies of empty stomachs and identified species of prey in stomachs of whales caught in spring, summer and autumn in four subareas in the Northeast Atlantic. N = number of stomachs examined.

PREY ITEM	PERCENTAGE OCCURRENCE			
	WEST OF SPITSBERGEN	BEAR ISLAND	COAST OF FINNMARK	LOFOTEN/ VESTERÅLEN
SPRING				
		N=1	N=1	N=2
Empty stomachs		0	0	0
Pisces				
Clupeidae				
Clupea harengus		100	100	100
Osmeridae				
Mallotus villosus		100		50
Myctophidae				
Benthosema glaciale		100	100	
Gadidae				
Gadus morhua		100	100	50
Melanogrammus aeglefinus		100	100	100
Pollachius virens				100
Unid. gadoid remains		100	100	
Ammodytidae				
Ammodytes sp.				100
Scorpenidae				
Sebastes sp.		100		
Cottidae				
Unid. cottid remains		100		
Unidentified remains		100	100	50
SUMMER				
	N=14	N=7	N=5	N=6
Empty stomachs	0	0	20	0
Crustacea				
Amphipoda				
Parathemisto sp.	7.1			
Euphausiacea				
Thysanoessa sp.	85.7	71.4		50
Pisces				
Clupeidae				
Clupea harengus		42.9	80	50
Osmeridae				
Mallotus villosus	14.3	42.9		50
Myctophidae				
Benthosema glaciale				33.3
Gadidae				
Gadus morhua	7.1	28.6		
Melanogrammus aeglefinus		28.6		33.3
Pollachius virens				16.1
Unid. gadoid remains		28.6	20	50
Ammodytidae				
Ammodytes sp.	7.1	14.3		66.7
Scorpenidae				
Sebastes sp.		14.3	20	
Unidentified remains		28.6	40	66.7
AUTUMN				
	N=3	N=5	N=7	N=12
Empty stomachs	0	0	0	0
Crustacea				
Euphausiacea				
Thysanoessa sp.	66.7	100		
Pisces				
Clupeidae				
Clupea harengus	33.3		100	100
Osmeridae				
Mallotus villosus		100	14.3	
Gadidae				
Gadus morhua	100		42.9	25
Melanogrammus aeglefinus	33.3		28.6	16.7
Pollachius virens				8.3
Unid. gadoid remains			14.3	8.3
Argentinidae				
Argentina silus				8.3
Unidentified remains	33.3			16.7

Table 8. Estimated abundance (in tonnes) of different fish stocks in the minke whale sampling areas in 1993. x) = estimates not yet available.

PREY ABUNDANCE (TONNES) 1993							
		Cod	**Haddock**	**Seithe**	**Capelin**	**Herring, adult**	**Herring, immature**
SVALBARD	Spring						
	Summer						
	Autumn	x)	x)		0	0	
BJØRNØYA	Spring						
	Summer						
	Autumn	x)	x)		57000	0	7000
FINNMARK	Spring	64000	34500				
	Summer					0	1.5 mill
	Autumn	x)	x)			0	1.93 mill
LOF/VESTER	Spring	767800	25700	89100		500000	400000
	Summer					600000	700000
	Autumn					2.5 mill	700000

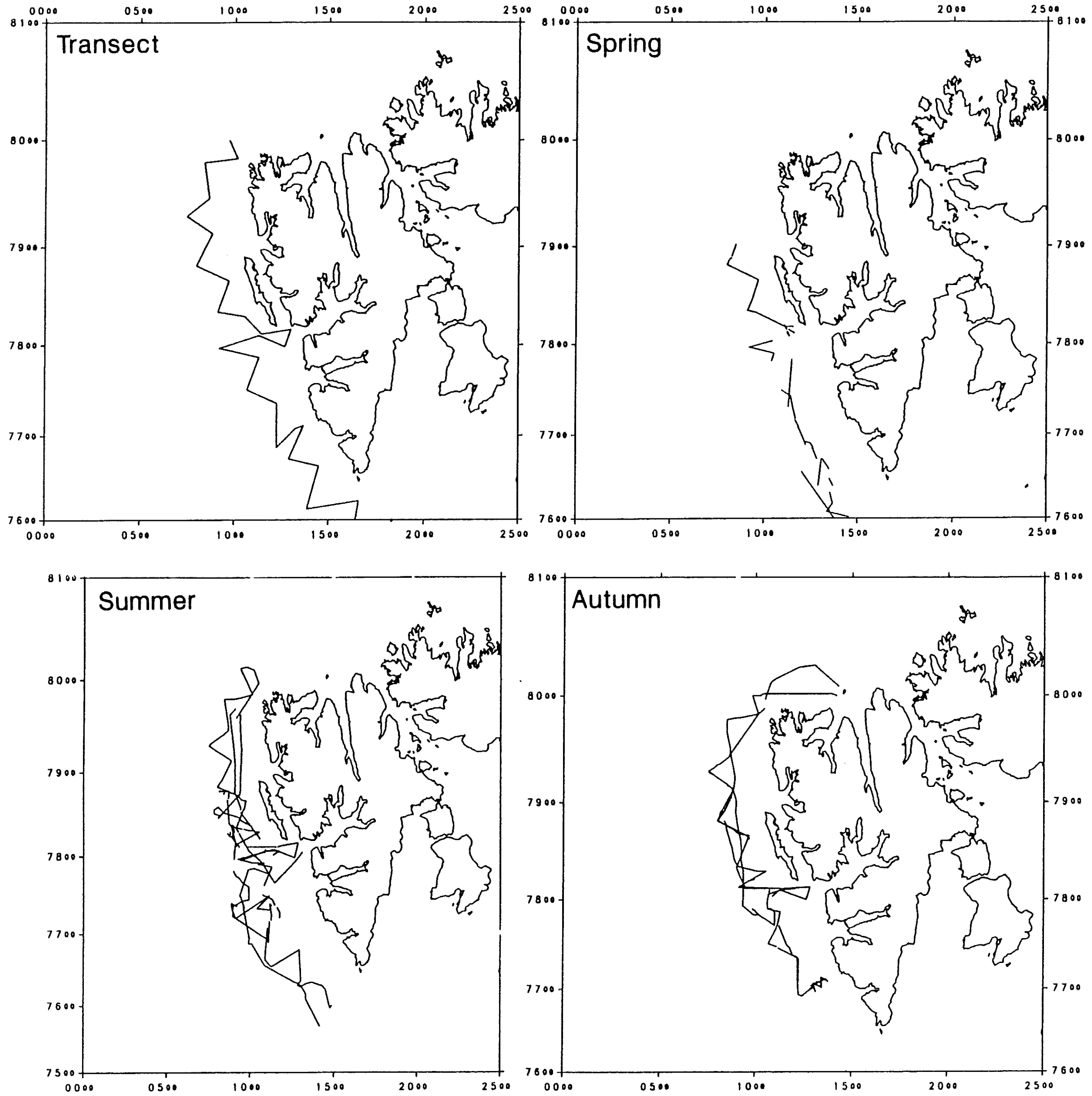

Fig. 1. Intended (upper left) and realized search transects in the Spitsbergen sub-area during the Norwegian scientific catch of minke whales in spring, summer and autumn 1993.

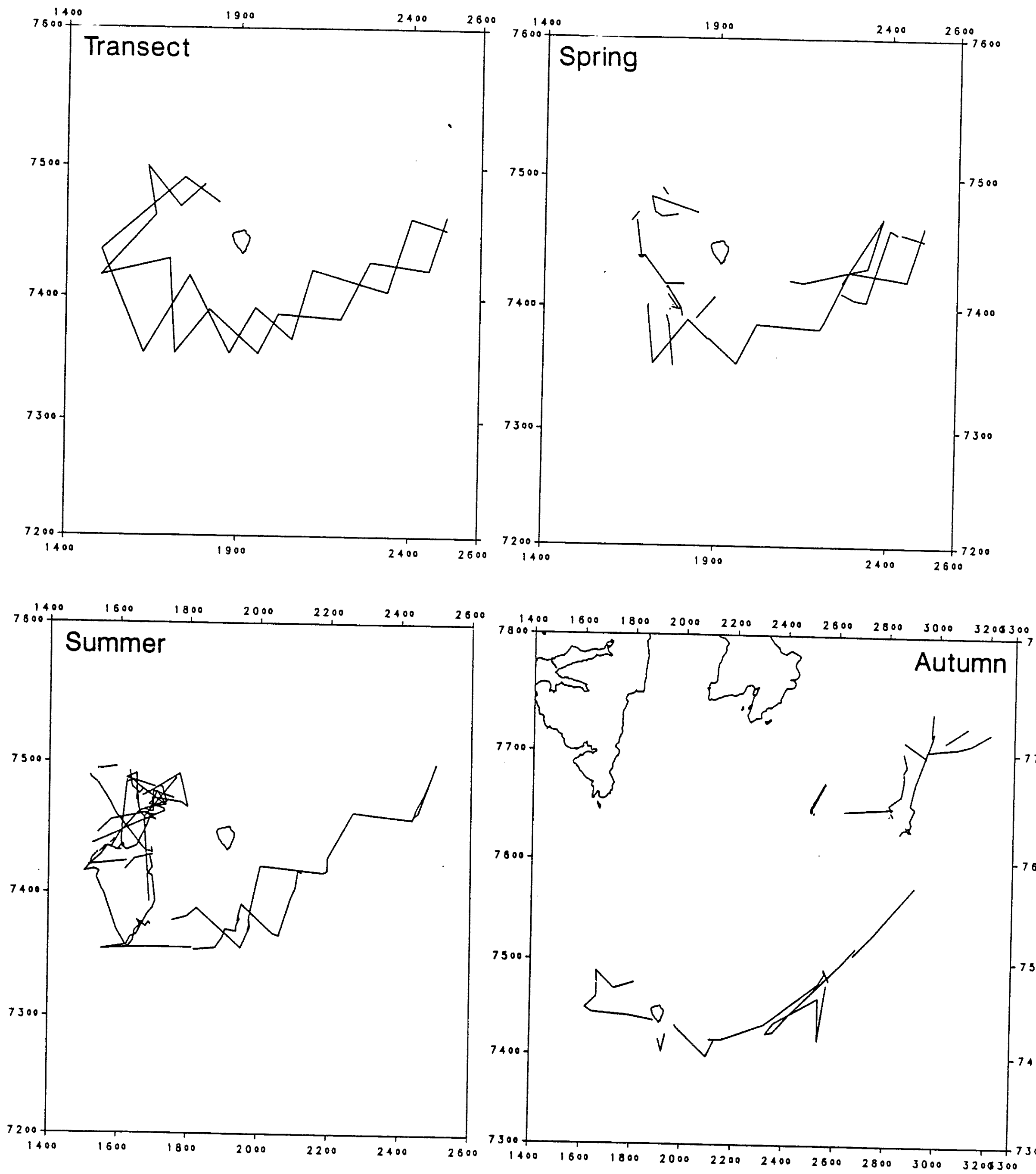

Fig. 2. Intended (upper left) and realized search transects in the Bear Island and Hopen sub-area during the Norwegian scientific catch of minke whales in spring, summer and autumn in 1993.

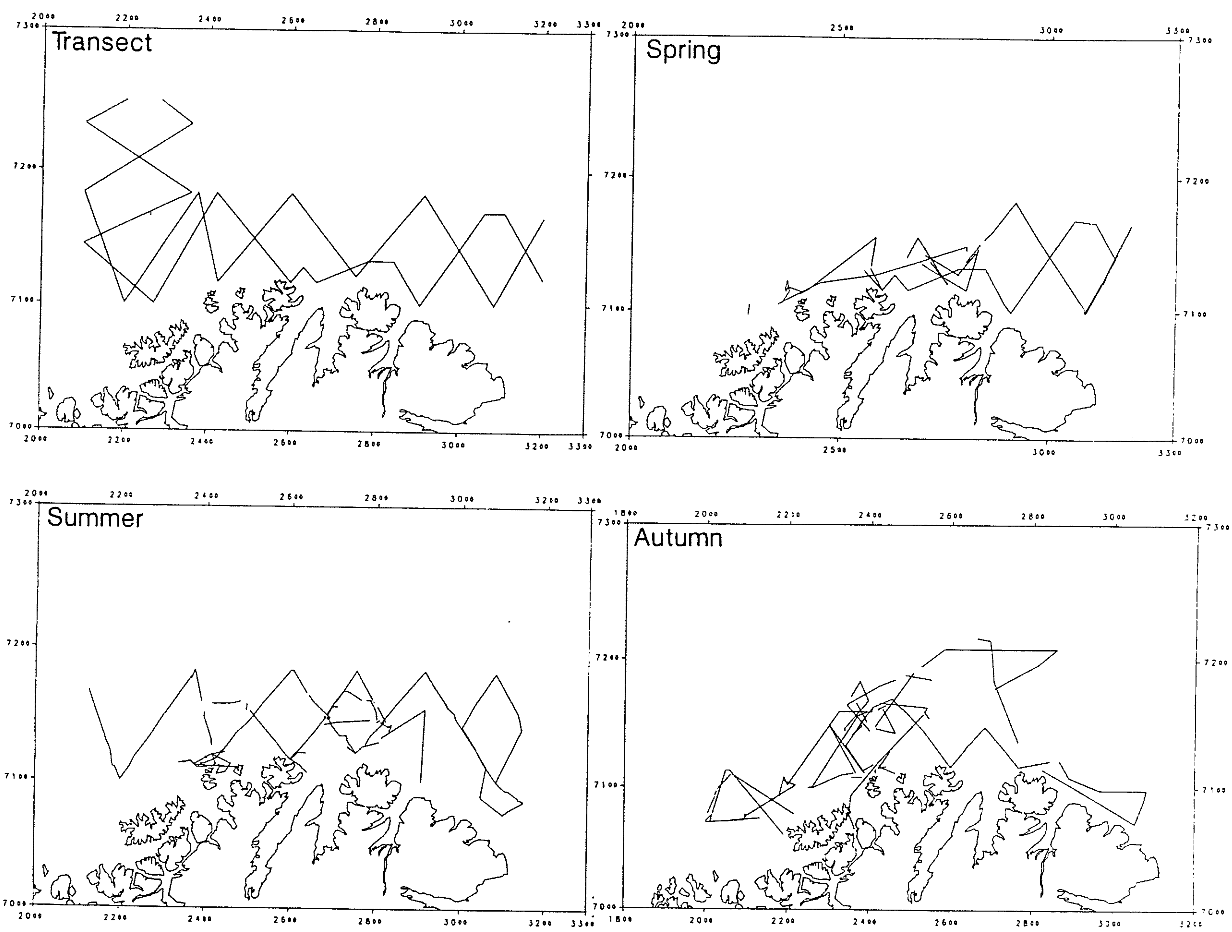

Fig. 3. Intended (upper left) and realized search transects in the Finnmark sub-area during the Norwegian scientific catch of minke whales in spring, summer and autumn 1993.

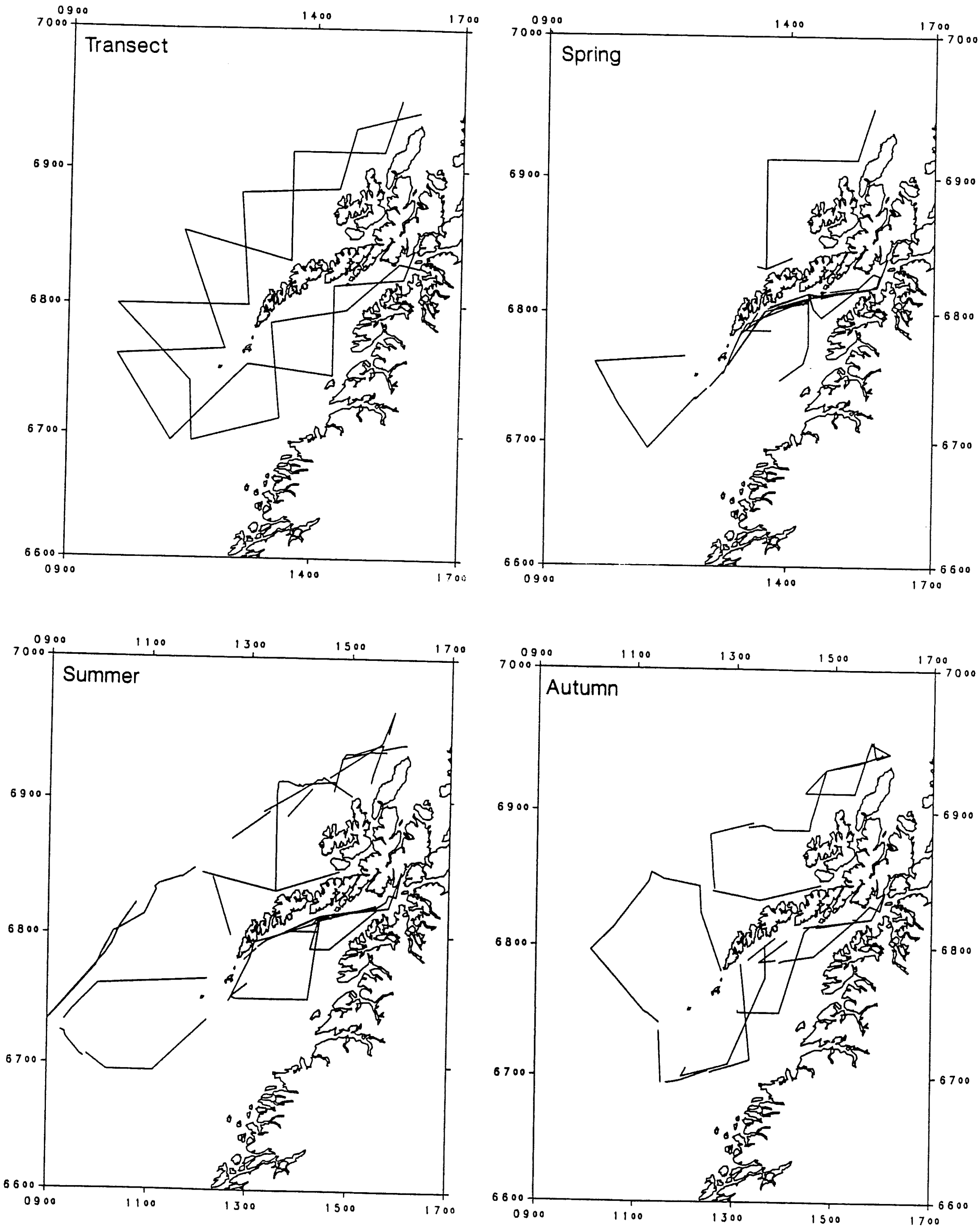

Fig. 4. Intended (upper left) and realized search transects in the Lofoten/Vesterålen sub-area during the Norwegian scientific catch of minke whales in spring, summer and autumn in 1993.

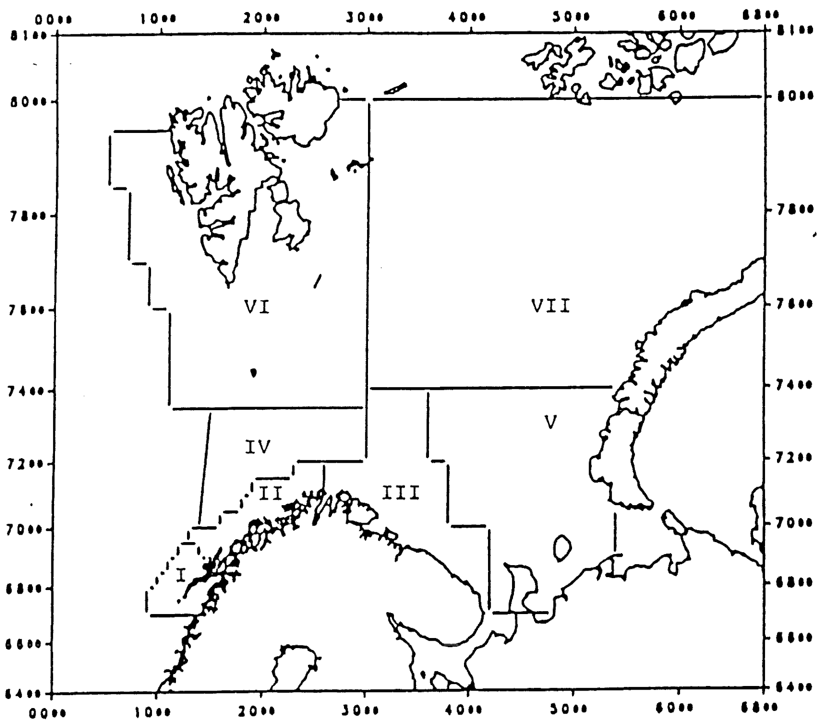

Fig 5. Geographical localisation of MULTSPEC-areas I-VII in the Norwegian and Barents Seas (see Bogstad & Tjelmeland 1992).

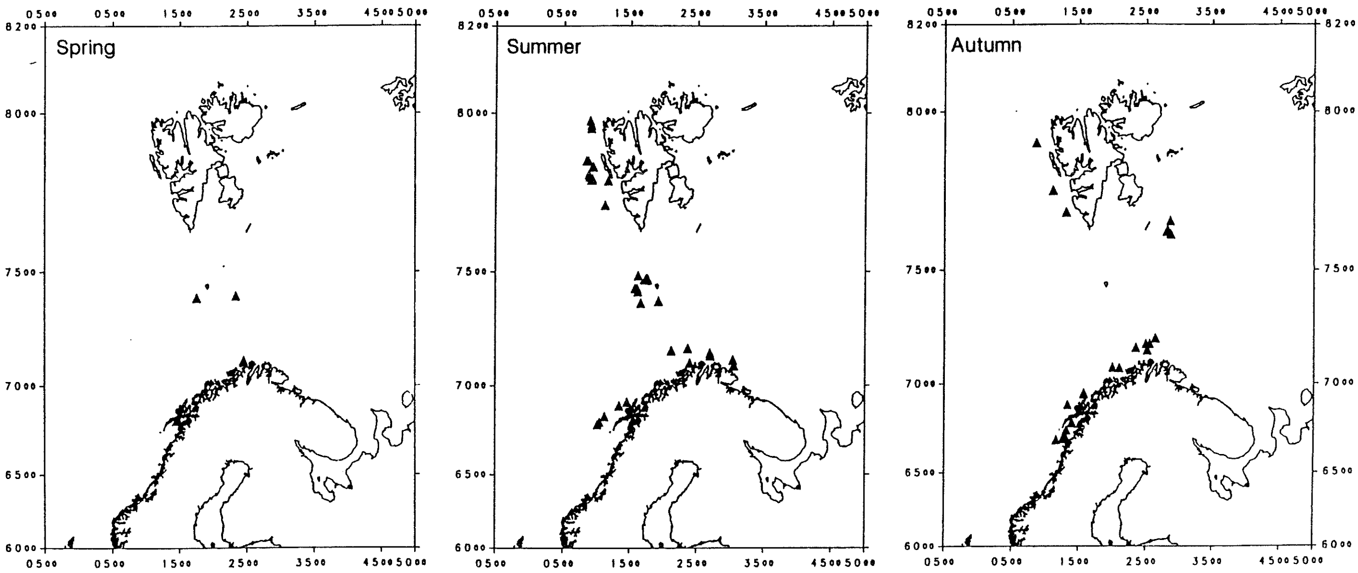

Fig.6. Catch positions for 69 minke whales shot during the Norwegian scientific catch operations in spring, summer and autumn 1993.

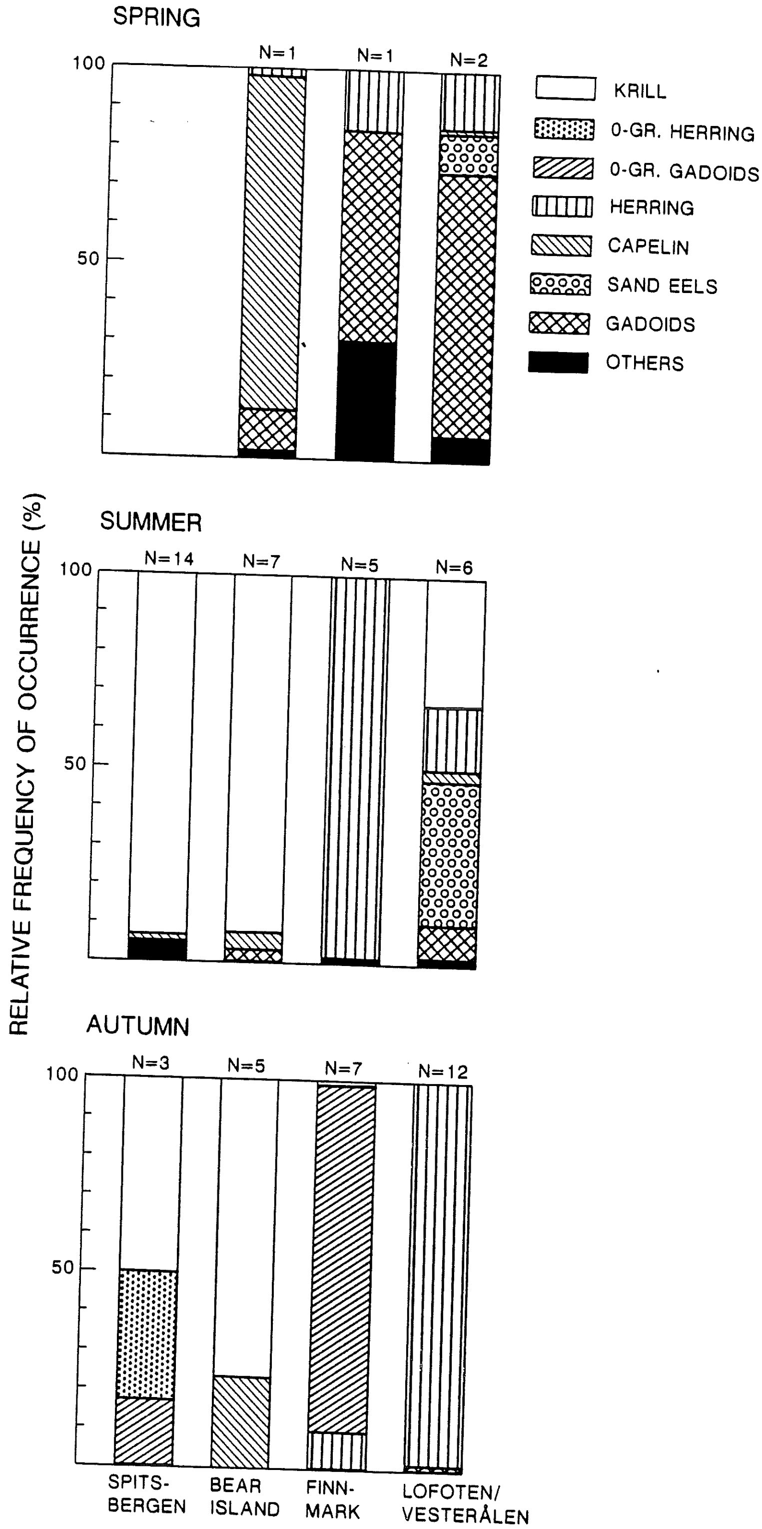

Fig. 7. Food composition, expressed as relative frequency of occurrence (by numbers) of prey organisms, in minke whales sampled in four subareas in the Northeast Atlantic in spring, summer and autumn in 1993. Herring and gadoids are presented as 0-group and one year and older fish. The actual numbers of krill were divided by 100 before presented in the figure. N = numbers of stomachs examined.

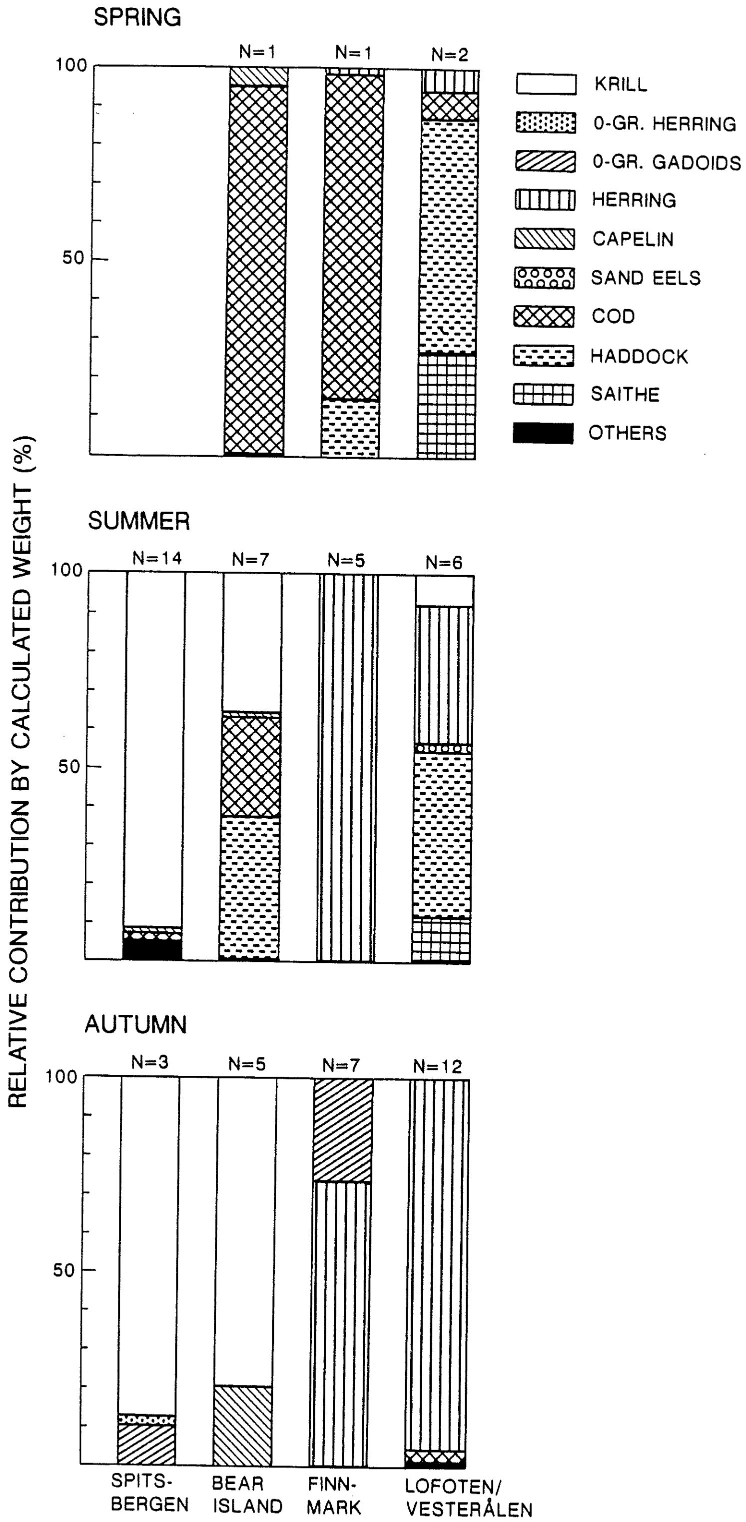

Fig. 8. Food composition, expressed as relative biomass (by calculated fresh mass) of prey organisms, in minke whales sampled in four subareas in the Northeast Atlantic in spring, summer and autumn in 1993. N = numbers of stomachs examined.

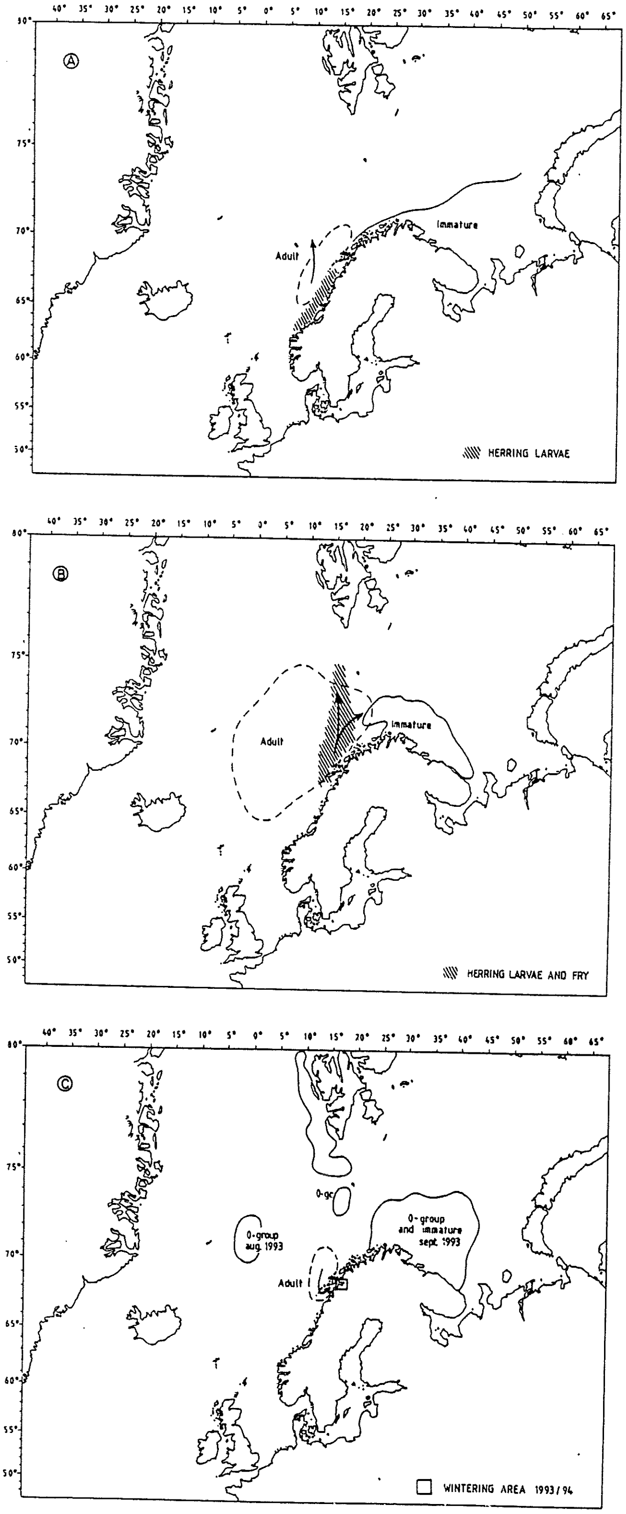

Fig. 9. Recorded approximate distribution of young and adult Norwegian spring spawning herring during the 1993 sampling periods of minke whale. A) Spring. B) Summer. C) Autumn.

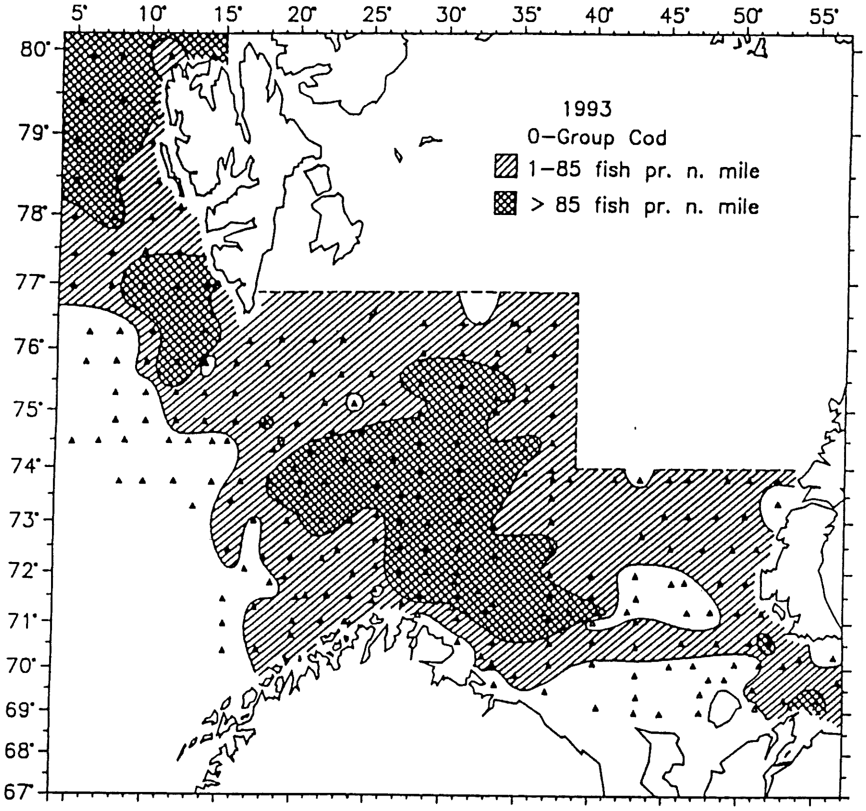

Fig. 10. Observed distribution of 0-group cod in the Norwegian and Barents Seas in August/September 1993 (from Anon. 1994a).

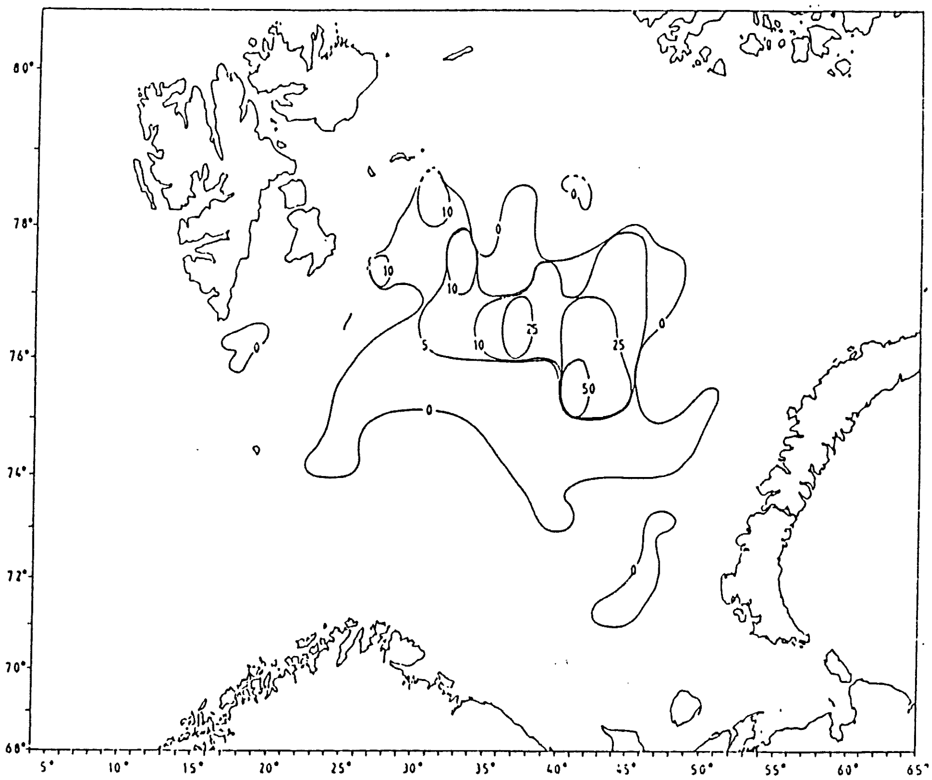

Fig. 11. Observed distribution of capelin in the Barents Sea in September 1993. Numbers indicate tonnes/square nautical mile (from Anon. 1994b).

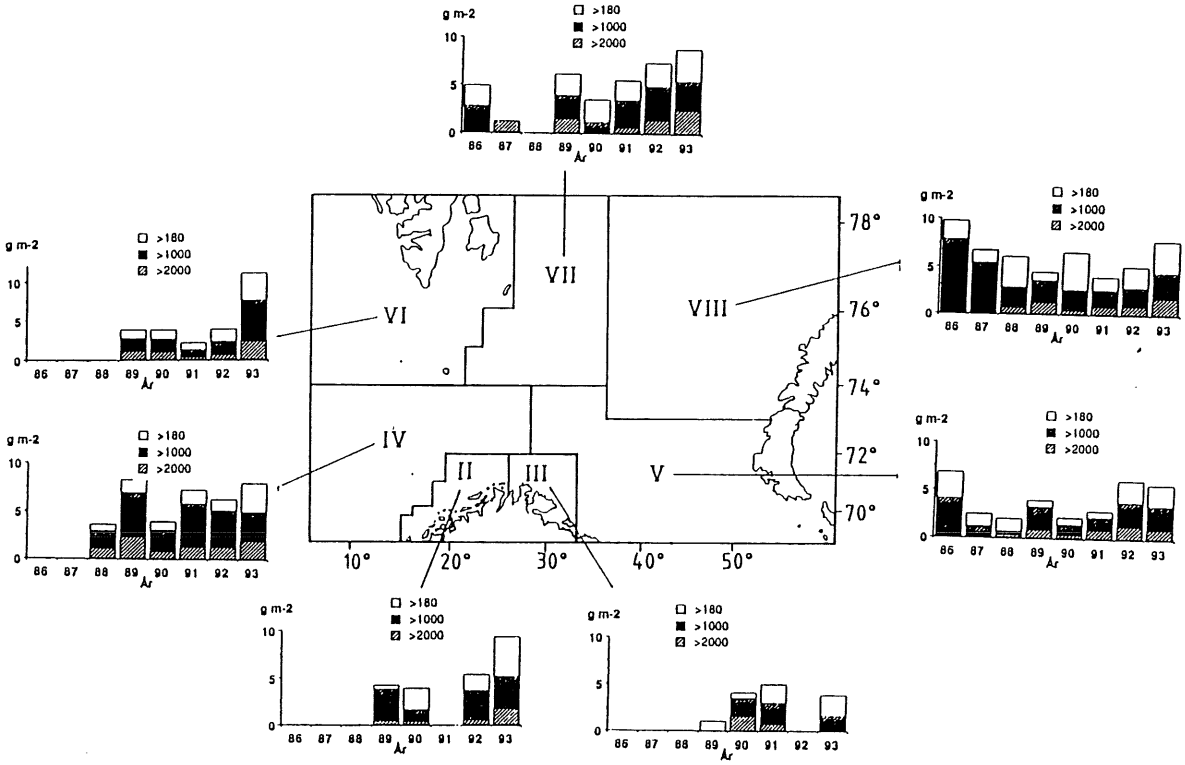

Fig. 12. Zooplankton production in MULTSPEC-areas II-VIII in the Barents Sea in the years 1985-1993. Average ash free dry weight (1985-1990) and dry weight (1991-1993) in gm^{-2} are given for the three filtered size fractions >180 (small individuals, 180-1000µm), >1000 (medium sized individuals, 1000-2000µm) and >2000 (individuals larger than 2000µm). År = years. (From Anon. 1994c).