ABSOLUTE AND RELATIVE ABUNDANCE OF MINKE WHALES (*Balaenoptera acutorostrata* Lacépède) IN THE NORTHEAST ATLANTIC

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SYNTHESIS

INTRODUCTION

Effective management of whales with the objectives of optimum utilization and conservation requires knowledge of biology, distribution, abundance, and dynamics of the stock under consideration. The general lack of adequate information for most whale species may be ascribed to the difficult accessability of whales as compared to terrestrial animals. Neither have scientific investigations in connection with the catch operations given final answers in the fields mentioned above. Also for the species to be dealt with in this thesis, the minke whale (Balaenoptera acutorostrata Lacèpède), there are major gaps in knowledge of importance to a rational management.

Whaling has been regulated through the International Whaling Commission (IWC) which was established in 1949 by the International Convention for the Regulation of Whaling, 1946. IWC set up a Scientific Committee to give it advice on scientific matters. In recent years this Committee has expressed increased concern about the status of the minke whales in the North Atlantic. In 1976, the Scientific Committee classified the North Atlantic minke whales into four management stocks which they believed to be fairly independent units, ranging in the following geographical areas: The Canadian east coast; the West Greenland area; the East Greenland-Iceland-Jan Mayen area; and the Svalbard-Norway-British Isles area (IWC, 1977a). The two latter stocks were later renamed the Central and the Northeastern stocks, respectively (IWC, 1981). This classification was based on segregational patterns by sex and length, distributions of catches, sightings and mark returns (IWC, 1977b).

Minke whales in the North Atlantic have been exploited by Norway, Denmark (i.e. Greenland), Iceland and Canada. Norwegian catchers have participated regularly in the minke whale fishery on all the stocks mentioned above, with the exception of the Canadian east coast, and have been alone on utilizing the Northeastern minke whales. The Norwegians started the fishery in the 1920s and catch statistics exist from 1938 and onwards. These statistics form the data basis for the work presented in this thesis together with data collected through sightings surveys in 1987 and 1988.

Since the Northeastern stock of minke whales have been exploited exclusively by, and thus been a special responsibility of, Norway, most of the analyses included here have been focused on that stock. the main objectives of the work presented in this thesis can be summarized as follows:

i) to assess the long-term trends of the Northeastern stock of minke whales based on analyses of catch per unit of effort (cpue) and length distributions;

ii) to provide information on distribution and absolute abundance of minke whales in the Northeast Atlantic.

The following six papers are included in this thesis:

I. Øien, N., Jørgensen, T. and Øritsland, T. 1987. A stock assessment for Northeast Atlantic minke whales. Rep.int.Whal.Commn 37: 225-236.

II. Øien, N. 1987. Multispecies catches by Norwegian small-type whalers with special reference to the significance of bottlenose catches for the Barents Sea minke whale cpue indices. Paper IWC/SC/39/Mi 12 presented to the IWC Scientific Committee, June 1987.

III. Øien, N. 1988. Length distributions in catches from the Northeastern Atlantic stock of minke whales. Rep.int.Whal.Commn 38: 289-295.

IV. Øien, N. 1988. Sighting estimates of Northeast Atlantic minke whale abundance from the Norwegian shipboard survey in July 1987. Paper IWC/SC/40/Mi 9 presented to the IWC Scientific Committee, May 1988 (revised and accepted for publication in Rep.int.Whal.Commn 39).

V. Øien, N. 1989. Sightings surveys in the Northeast Atlantic in July 1988: Distribution and abundance of cetaceans. Paper IWC/SC/41/O 4 presented to the IWC Scientific Committee, May 1989.

VI. Øien, N. 1989. Estimates of g(0) for minke whales based on an independent observer experiment during the Norwegian sightings surveys in July 1988. Paper IWC/SC/41/NHMi 2 presented to the IWC Scientific Committee, May 1989 (revised).

SUMMARY OF PAPERS

I. A stock assessment of Northeast Atlantic minke whales

The analyses presented in this paper are based on the compulsory catch reports introduced in the Norwegian small-type whaling in 1938. Prior to 1976, these reports only give information on whales caught. From 1976 onwards, also the number of days at sea are given in addition to some weather information. For a full utilization of the data in an extended cpue time-series, the 'catch per net catcher day -1' index with corrections for effort changes, time periods and areas, was applied. Cpue indices were calculated separately for the Barents Sea, the Vestfjord and the North Sea areas. Within each of these areas the participating vessels were assumed to be relatively homogenous, also with respect to equipment and strategy (Christensen and Øien, 1989). Throughout the catch history about 50% of all minke whales taken from the Northeastern minke whale stock have been caught in the Barents Sea area and 30% in the Vestfjord area. The Vestfjord area was the more important whaling ground up to around 1950, but the relative importance of coastal catches decreased with the expansion of whaling to the Barents Sea, and since the 1970s about 90% of the catches have been taken there.

The cpue indices calculated for the Barents Sea area increase rapidly for a few years after 1945, show a decreasing trend through the 1950s, an increasing trend through the 1960s and decrease again through the 1970s, a trend that is reinforced after 1980. Through the period 1952-1983 there is an overall non-significant decrease of 0.4% per year, while the last period of years 1973-1983 shows a significant average decrease of 3.3% per year. The cpue indices for the Vestfjord area show a significant decrease of 2.8% per year over the period 1946-1983. Possible factors that may have influenced these trends - the introduction of quotas, the spatial expansion to East Greenland and Iceland and the exclusion of Norwegian whalers from the economic zones of other countries - are discussed.

Based on a variety of assumptions, a simple population model was fitted to the Barents Sea cpue series and to mark-recapture estimates of recruited stock sizes. For many assumptions the fitting procedure proved to be difficult, requiring unrealistic parameters. The fit seemed to improve when higher recruited stock sizes than implied by the mark-recapture experiments were applied. When fitting the model to the Barents Sea indices for the period 1952-1983, the stock size in 1986 was estimated to be in the range of 44-73% of the initial (1938) stock. Given the large fluctuations in the Barents Sea cpue indices, current (1986) annual replacement yields were calculated based on only the cpue series for the last decade (1973-1983), giving estimates in the range of 129-629 whales.

II. The influence of multispecies catches on the Barents Sea minke whale cpue indices

One of the critisisms raised about the Barents Sea cpue indices calculated in Paper I is that they may be confounded by by-catches of bottlenose whales. Although several previous analyses indicate that the multispecies character of Norwegian small type whaling, comprising bottlenose, killer and pilot whales in addition to minke whales, has negligible effects on the whaling effort for minke whales, more convincing arguments were required. In each season a participating vessel may have taken any combination of the listed species, and this paper summarizes these combinations for all vessel during the years for which catch data are available. The number of vessels that have caught both minke and bottlenose whales within any season turns out to be small, and the simple approach of deleting these vessels completely from the analyses when calculating the Barents Sea cpue indices was followed. This revised series is only marginally different from the original one and does not alter the conclusions reached in Paper I.

III. Length distributions in catches from the Northeastern Atlantic stock of minke whales

The compulsory catcher log books introduced in 1938 hold information on the estimated length and sex of the whales caught. The mean lengths of the total catches show a decrease during the Second World War but then increase rapidly and level out during the 1970s. In the most recent years with individual quotas (from 1984 onwards), the reported mean lengths again raise sharply to exceed 24 feet. The catch statistics show a distinct spatial segregation by length and sex. The largest mean lengths are found in the Barents Sea area and in the North Sea, and the smallest lengths in the coastal areas from Møre to Lofoten. Females generally dominate in catches in the Barents Sea, while males dominate elsewhere. The increasing trends of mean lengths in the total catches therefore appear to follow changes in spatial allocation of the minke whaling effort, especially the expansion to the Barents Sea area.

Length frequency curves based on total catches show transitions from a distribution peaked at small lengths in the early years, through a more uniform distribution over length groups 17-27 feet, to end up in the 1980s with a distribution peaked at 22-23 feet, near the mean length for these later years. When broken down by smaller areas, the catch curves are of three main types: those skewed to the left around 17 feet which are typical for the coastal areas from Møre to Lofoten; those with an approximately symmetrical distribution as in the Barents Sea; and finally, those skewed to the right as in the North Sea. It is evident that segregational behaviour would influence the length distributions of the total catches according to the relative importance of different whaling grounds through the years, and confound possible effects of changes in productivity and mortality. For example, when the whaling effort was transferred to the Barents Sea, the declining trend of the cpue series for this area through the 1970s (Paper I) was followed by a significant change in the length distribution of the total catches from a uniform to a peaked distribution around the means.

The length distributions have been investigated in more detail for two of the areas which have contributed most to the total catches: the Vestfjorden area where mean lengths have increased during the catch history, and the southeastern Barents Sea where no trend in mean lengths or changes in the length distributions have been detected. Vestfjorden is known as the area where calves previously spent most of the summer, but the length distributions may indicate a decreased availability of young animals there. On the other hand, the length distributions from the southeastern Barents Sea do not seem to be correlated with the observed decline in the Barents Sea cpue indices. More detailed analyses, looking more specifically at the availability of different length groups, therefore are needed to investigate how changes during the seasons and changes in whaling regulations between seasons might affect the length distributions and relative indices.

IV. Sightings estimates of minke whales in the Northeast Atlantic in 1987.

As part of an international effort to cover North Atlantic waters by simultaneous cetacean surveys, three Norwegian vessels surveyed the Barents, Greenland and northern Norwegian Seas in July 1987. The coastal waters west of Spitsbergen and northern Norway, believed to be high density areas, received little effort from the shipboard survey since aerial surveys were planned to cover these areas. The coverage was rather low, ranging from 0.2% to 0.8% with the lowest values for the Barents and Greenland Seas. The two main purposes of the survey, to record the distribution of different species of whales and to estimate their abundance, could therefore only be partly fulfilled.

The survey was conducted by alternating on an equal share basis two different modes, viz. a closing mode where the ship diverts from trackline for identification when a whale is sighted, and a passing mode where the ship continues on the predetermined trackline upon sighting a whale. The main reasons for closing with sightings are to ensure some reliability both to the identification of species and to school size estimations. This, however, leads to problems with the data analysis, because the limited set of primary sightings is reduced to two smaller subsets. The effective search half-width estimated by fitting sightings data to a hazard-rate detection function for closing mode observations was about half of that of the passing mode observations. For two of the survey blocks the half-width estimates based on the two different modes were similar; for the other two they were rather different but not covariated. When all estimates were pooled prior to fitting, an effective search half-width of 0.27 nautical miles was obtained, giving a total estimate of approximately 18,000 minke whales in the surveyed areas excepting the northern Barents Sea. This estimate is not statistically different from those based on separate analyses of passing and closing mode data. It was further concluded that in most of the surveyed areas species identification was not a serious problem and that minke whales usually occur as single individuals. For this species a modified passing mode therefore might be the most effective way of conducting a survey.

The areas covered contribute both to the Central and the Northeastern stocks of minke whales; the contributions were estimated to be about 4,500 and 12,500 whales, respectively. A Faroese vessel surveyed the southern part of the Norwegian Sea, and a pooled provisional estimate for the Northeastern Atlantic minke whale stock of approximately 19,000 whales (c.v. 0.16) was agreed at the 1988 meeting of the IWC Scientific Committee (IWC, 1989a:86). This estimate is not corrected for whales missed on the trackline (see Paper VI), nor does it include all areas of potential minke whale abundance (i.e. most of the Barents Sea and the North Sea).

V. Sightings estimates of cetaceans in the Northeast Atlantic in 1988

The low coverage in the 1987 survey led to difficulties in estimating minke whale abundance. The survey in 1988 was therefore dedicated to increase coverage by increasing the total effort and limit the survey to areas of expected high minke whale densities which had also been covered by Norwegian vessels in 1987. Survey blocks were designed taking into consideration IWC minke whale stock boundaries. The survey was run in a modified passing mode. The following review concentrate on results for minke whales, although abundance estimates for other cetaceans are also presented in the paper.

Although the survey areas were selected because of expected high minke whale densities, local concentrations were observed within the blocks. All primary sightings were pooled over blocks prior to fitting a hazard-rate detection function. The resulting half search-width, 0.28 nautical miles, is similar to that found for the pooled 1987 data. The total estimate of minke whale abundance from the 1988 survey is 25,600 individuals, which is not statistically different from the estimate for the larger surveyed area in 1987. The higher total estimate in 1988 may be ascribed to large uncertainties in the estimates for the area off the Kola coast (the southeastern Barents Sea).

Contributions from the total estimate to the Central and Northeastern stocks of minke whales are about 2,200 (c.v. 0.26) and 23,400 (c.v. 0.16) individuals, respectively. Although the total estimate for 1988 is comparable to that from the 1987 survey, the proportional contributions to the two stocks are very different for the two surveys. There are at least two explanations for this: one being that restratification of data was not necessary for the 1988 analysis, the other that the blocks west of Spitsbergen and Lofoten, both within the Northeastern stock area, were not covered separately by shipboard surveys in 1987, as in 1988.

Although neither of the surveys completely covered the potential summer distribution of the Northeastern stock of minke whales, the two surveys do indicate that shifts in distribution may have significant effects on abundance estimates within limited areas. This in turn may cause problems for estimates of stock size from surveys which are not conducted within reasonable time limits.

VI. Estimates of g(0) for minke whales

Most of the minke whales in the Northeast Atlantic are detected by sightings of the body (see Papers IV and V) which is exposed when the animal surfaces, a process that makes them visible in 2-3 seconds per surfacing. Surfacings may vary individually at rates of 16-66 per hour (Joyce et al.,1989; Øien et al., 1989). The body cue is not as prominent to the observer as for example the blow which is conspicuous in other areas (e.g. in the Antarctic), and the probability of seeing a minke whale in the Northeast Atlantic decreases rapidly with increasing distance from the trackline. This has raised the question of whether the assumption in general line transect theory that all objects on the trackline are seen, formulated in terms of the detection function as $g(0)= 1$, has been severely violated during the Norwegian surveys.

During the survey in 1988, an independent observer platform experiment therefore was conducted to try to answer this question by comparing sightings from the masthead barrel to sightings from an additional independent observer platform (IOP) on the roof of the wheelhouse. Basically, the data were analyzed by the 'product integral method', but asymetries and obstruction of the forward view from the IOP were considered, too. A simple 'direct procedure' was also applied, taking advantage of modelling the detection functions for the barrel and IOP sightings by flat functions, as seems justified by the truncated data. Whatever method is used, the detection function for the barrel sightings evaluated on the trackline, $g(0)$, seems to be somewhat lower than 0.6 with standard errors that make them significantly lower than 1.

Although critisism has been raised towards the unconditional independence assumption underlying the 'product integral method', which introduces a positive bias in the estimates of $g(0)$, this IOP experiment indicates that standard line transect estimates for minke whale abundances in the Northeast Atlantic are underestimates in this respect and need to be corrected for whales missed on the trackline. However, this experiment is based on a small data sample and does not exclude the possibility that the correction factor may be both vessel and stratum dependent.

GENERAL DISCUSSION

The recognition of self-sustained biological units for which immigration and emigration are negligible compared to recruitment and mortality, is important for a proper management of whale populations. The Scientific Committee of the International Whaling Commission usually defines the management units ('stocks') on a geographical basis if there is no contradictory information available, and these stock units therefore may comprise one or more biological populations or only part of one population.

The population structure of North Atlantic minke whales has been debated in recent years and doubts have been expressed about the 1976 decision to divide the minke whales in this area into four management units (IWC, 1977a). Coherence of catch and effort series for the West Greenland and Central stocks may indicate substantial mixing between these (Holt, 1985), and the original arguments for the separation of these two stocks does not seem to be valid (Larsen and Øien, 1988). A review of available mark-recapture data from the North Atlantic was not found to justify any revision of the present stock boundaries (IWC, 1986a). However, the sightings surveys conducted in recent years have provided new information also on the distribution of minke whales in the Northeast Atlantic. The sightings suggest that the discontinuous distributional pattern indicated by catch positions should be replaced by a continuum over the Norwegian Sea, and that the separation between the Central and Northeastern stocks therefore is dubious (Øritsland et al., 1989). Unfortunately, the sightings do not provide definite clues to solve these stock boundary questions. Methods that are suited to investigate such problems exist or are being developed; these include radio- and satellite tracking and molecular approaches to reveal genetic relationships, either through DNA sequencing or biochemical genetics. Such research has already been given priority in the 'Marine Mammal Research Program' established by the Norwegian Fisheries Research Council (Anon., 1988). Pending results from this research which will be very important for the interpretation of other data, the discussion here is based on the established stock divisions.

The cpue series presented in Paper I show trends for the Northeastern stock of minke whales that are difficult to explain by variations in abundance, and multispecies catches do not confound the series. However, the results from the recent sightings surveys suggest that additional explanations might deserve further studies: The cpue analyses presented here are based on catch data, which de facto have been used to establish the present stock divisions, whereas the sightings data suggest a continuum over the Norwegian Sea. While the cpue analyses attempt to account for shifts in abundance within the Barents Sea, other studies must be made to account for the possibility that a variable proportion of the total stock enters this area during the feeding season. The moderate success of correlation analyses with the North Sea cpue indices (Rørvik, Øien, Øritsland and Christensen, 1985) may be explained if the minke whales observed in the Norwegian Sea during the sightings surveys are a part of the total stock that contributes to the Barents Sea whaling grounds. Unfortunately there is no information, neither qualitative nor quantitative, on historical distributions or on proportions in the Norwegian Sea as compared to the Barents Sea since the whalers have not operated in the Norwegian Sea. However, the recent sightings surveys may give some guidance, and studies have been initiated to analyze how possible variations in migration through the Norwegian Sea may account for changes in availability in the Barents Sea.

One may also speculate whether the availability of minke whales in the Barents Sea is related to the distribution and abundance of Norwegian spring-spawning herring (Clupea harengus), since herring appears to be an important food item for these whales, especially in coastal waters (Jonsgård, 1982; Øritsland and Christensen, 1982; Nordøy, Mathiesen and Blix, 1989). While the nursery areas of this herring stock comprise all the main whaling grounds for minke whales in the Barents Sea in addition to Norwegian coastal waters, the main summer feeding areas of adult herring have been in the Norwegian Sea until the stock collapsed around 1968/69 (Dragesund, Hamre and Ulltang, 1980). If the Norwegian Sea is an important part of the potential summer feeding area of minke whales as indicated by the sightings surveys, the Barents Sea cpue series calculated in Papers I and II may be interpreted as composed of two series, one prior to and one following the breakdown of the herring stock. This interpretation implies that both periods show declines in the cpue with a change in cpue levels around 1970. The change could be a consequence of a depleted food resource in the Norwegian Sea which made it necessary for the minke whales to search for food in other areas. Capelin (Mallotus villosus) is known to be important in the diet of minke whales, in fact, examinations of stomach contents have revealed that capelin has increased in importance for the Barents Sea minke whales in the 1970s with 40% of food items by volume, as compared to 16% in the 1950s (Øritsland and Christensen, 1982). Capelin was an abundant resource (Anon., 1987) when herring was depleted, and may therefore account for the increase in minke whale availability in the Barents Sea around 1970.

It still remains to see whether the trends in abundance indicated by cpue series reflect changes in total abundance or changes in local abundance only (i.e. availability on whaling grounds). It is difficult to resolve this question without a fairly good knowledge of the population structure of minke whales in the North Atlantic and how they recruit to the grounds. It should be noted that for all stocks and areas in the North Atlantic for which a cpue series is available, a negative trend is generally indicated; this applies also to the Central stock (Øien and Christensen, 1985; IWC, 1985) and to the West Greenland stock (Øien and Christensen, 1985; Kapel, 1985; IWC, 1985).

Traditionally, a linear relationship has been assumed between cpue and abundance, but for example examination of shoaling pelagic fishes showed no significant correlation between cpue and stock size (Ulltang, 1980). Analyses of whale cpue (Cooke, 1985) show that changes in abundance do not generally cause proportionate changes in cpue, as cpue tends to decrease slower than abundance. In addition, cpue series have large coefficients of variation, implying that for example changes in operating patterns may have a greater influence on cpue than abundance changes. Tentative modelling of the minke whale fishery in the Barents Sea (Cooke and Christensen, 1983) indicates a non-linear relationship, although the authors conclude that further studies are necessary to identify which are the most crucial parameters for the model and derive suitable parameter values. Since the interpretation of cpue indices depends critically on this relationship between indices and abundance, forthcoming analyses should try to elucidate both operational factors and other external factors that may influence the indices.

In the absence of information on absolute abundance and net recruitment, the Scientific Committee of the International Whaling Commission has used simple sustainable yield population models as a basis for assessments and management advice. Although the natural rate of increase in principle is determined by a few biological parameters such as age at maturity, pregnancy rate and natural mortality rate, it has been difficult to estimate these parameters, in particular the natural mortality rate, and assessments therefore are open to dispute. Biological data in addition to those which have already been presented (Jonsgård, 1951; Christensen, 1975;1980;1981) are therefore needed to throw further light on the question of minke whale productivity.

The present management procedure of the International Whaling Commission (IWC, 1989b) requires that stocks are classified according to their current status in relation to their initial ('virgin') size, with protection coming into force if the stock is more than 10% below its maximum sustainable yield level (MSYL), arbitrarily defined as 60% of the initial level. The Northeastern Atlantic stock of minke whales has repeatedly been assessed by the Scientific Committee (IWC, 1985;1987;1988) and was classified by the Commission as a Protection Stock in 1985 (IWC, 1986b). There has been some development of the models used in these assessments, but the basic data have been a population estimate from mark-recapture experiments (Beddington et al., 1984) and the cpue series presented in Paper I.

In its most extensive assessment (IWC, 1987), the Scientific Committee was unable to give an unanimous conclusion because the available data were not accepted by all members as sufficient to provide a basis for assessments. However, the Committee expressed some concern that a large proportion of the catch from Vestfjorden was of calves or yearlings and that the recent drop in the cpue series from the Barents Sea could be a result of this catch. Rørvik and Øien (1988) used an age-structured model to examine this effect and found that the cpue decrease could not be explained by high historical catches of calves in Vestfjorden, although the replacement yield is reduced when these catches are taken into account. Jonsgård (1962) warned that there had been a decrease in the catches of calves and an increase in the catches of matures which he ascribed to a failing recruitment and an appreciable reduction in total stock size. Age-structured models therefore merit more attention in future studies. Unfortunately, only length data exist from the catch reports, and the only age-length key for Northeast Atlantic minke whales has been derived from material collected during the 1970s. This may introduce some problems if growth is density-dependent or varies with time.

An additional potential problem relates to under-reporting of catches after the introduction of a quota system in 1976. Rørvik (1987) found indications of such under-reporting and also that the assessments are sensitive to increased under-reporting over the years. Such problems should be examined and data collected to correct for possible bias.

It has been mentioned above that the assessments so far have been based on population estimates from mark-recapture experiments (Beddington et al., 1984). Several problems, for example mark shedding and marking of selected portions of a stock for which segregational migration has been established, have complicated these estimates. In the most recent years substantial progress has been made in abundance estimation from sightings surveys. In addition to the surveys in 1987 and 1988 which are included in this thesis, an even more comprehensive survey, covering practically the whole summer distribution area of the Northeastern Atlantic stock of minke whales, was conducted in 1989. However, problems are also associated with estimates from these surveys, especially the evaluation of a correction factor to account for whales missed on the track-line (g(0)). In Paper VI a correction factor of approximately 2 is indicated, but further analyses of this problem are expected from parallell ship experiments conducted during the summer of 1989 (Schweder, pers. comm.). As the surveys in 1987 and 1988 covered only parts of the Northeastern stock area, an additional challenge is to find a reasonable way of combining data from several surveys in a single estimate.

As part of its Comprehensive Assessment, the Scientific Committee of the International Whaling Commission has given priority to minke whale stocks in the North Atlantic and in the Southern Hemisphere for its 1990 meeting. Although reasonable abundance estimates appear to be available for the assessment, the only way of estimating productivity of the stocks seems to be a reanalysis of catch data, since the time series of independent relative abundance data, for example from surveys, is not yet extensive enough for such analyses. Another problem arising is how to monitor the Northeastern stock of minke whales in the future. With no or low expected catches the only obvious alternative today is to collect sightings data. However, funding for large-scale surveys like those which have been conducted in the last few years can not realistically be expected, so an adaptation to lowcost monitoring is necessary. Adaptive cluster sampling (Thompson, 1989) could be investigated as a method to make the surveys more efficient in terms of reducing the variance in the estimates. Another approach could be to select from previous data key areas that could be used as indicator areas to provide relative indices of abundance.

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SC/38/Mi1

A Stock Assessment for Northeast Atlantic Minke Whales

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ABSTRACT

Catch reports for minke whales taken by Norwegian small-type whalers in the North Atlantic from 1938 to 1985 have been transferred to computer format. Total catches of minke whales from the Northeast Atlantic stock increased rapidly after the Second World War to a level of about 3,200 whales per year during the 1950s with a peak catch in excess of 4,300 in 1958. Catches then decreased and since 1965 1,700-1,800 whales have been taken each year until the annual quota was reduced to 635 whales in 1984. The proportion of females in the catch levelled off at about 50% during the 1950s, but increased to about 60% around 1970 and has since remained at this level.

About 50% of all minke whales taken in the Northeast Atlantic stock unit area during 1938-1985 have been caught in the Barents Sea, including coastal and offshore waters at Finnmark and Svalbard, and about 30% in the coastal Vestfjord area. However, the location of whaling activities has shifted considerably, both within the stock unit area and to whaling grounds outside the area, while the number of vessels participating has decreased and vessel efficiency increased through the years.

The catch data have been used to calculate annual indices of catch per net catcher day −1 for assessment of the status and potential yield of the Northeast Atlantic stock.

The indices for the Barents Sea area increase rapidly for a few years after 1945, show a decreasing trend through the 1950s, an increasing trend through the 1960s and decrease again through the 1970s, a trend that is reinforced after 1980. Omitting the build-up phase after the Second World War and the last two seasons with severely reduced quotas which were allocated to individual vessels, and consequential operational changes, the Barents Sea indices show an overall average decrease of 0.4% per year through the period 1952-1983. For the latter part of the period, 1973-1983, the trend is clear with an average decrease of 3.3% per year. Indices for the coastal Vestfjord area show an overall downward trend of 2.8% per year for the period 1946-1983.

Fitting a simple population model directly to the Barents Sea indices for 1952-1983 by alternative *a priori* assumptions, indicates a present stock level in the range 44-73% of its initial level. Difficulties in parameter estimation and interpretation are discussed.

Because of the marked decline in Barents Sea indices in recent years, the current replacement yield is estimated from the trend in these indices through 1973-1983. Under different assumptions these estimates vary between 129 and 629 whales in 1986.

INTRODUCTION

In 1976 the Scientific Committee recognized four stock units of minke whales (*Balaenoptera acutorostrata*) defined by areas in the North Atlantic: (1) the Canadian East Coast Stock, (2) the West Greenland Stock, (3) the Central North Atlantic Stock (East Greenland-Iceland-Jan Mayen) and (4) the Northeast Atlantic Stock (British Isles-North Sea-Norwegian Coast-Barents Sea-Svalbard). Geographical separation and differences in size and sex composition of catches were considered in defining the stock units. It is recognized that the factual basis is rather weak, but for management purposes the adopted separation into stock units is still considered useful.

Recent recaptures of marked minke whales have not led to revisions of stock unit boundaries in the North Atlantic, mainly because both markings and recaptures have been made within a rather restricted area in the Barents Sea (IWC, 1985b). However, the recaptures have not indicated any interchange between the Central and the Northeast Atlantic stocks, and so far markings therefore do not contradict the assumed separation of these two stocks.

Assessments of minke whales in the North Atlantic are traditionally based upon indices of catch per unit of effort (CPUE). Recent studies of factors affecting the indices have led to increasing demands for accuracy and appropriate corrections. Vessel efficiency has increased through increasing size and engine power, while the geographical distribution of catches has changed and the duration of trips has increased. Adjustments are therefore required, but the interpretation of CPUE time series may still be questionable, and in some cases doubt has even been raised as to whether trends in CPUE series do represent trends in whale abundance (Rørvik, Øien, Øritsland and Christensen, 1985; IWC, 1985b).

The present situation is, however, that no realistic alternative to CPUE indices exists for stock assessments of minke whales in the Northeast Atlantic. Markings in 1974-1976 and in 1978 add up to little more than 300 whales, and about 30 of these have been recaptured. Alternative stock size estimates from these recaptures, based on different assumptions about age–composition, marking mortality, mark shedding etc. (Christensen and Rørvik, 1983; Beddington, Cooke, Christensen, Øritsland, Øien and Rørvik, 1984; IWC, 1985b), imply that these estimates have very wide confidence limits. Such single-point estimates from markings and recaptures give no indication of population trends, but have been used to calibrate population models, and could also be used to calculate replacement yields, provided that estimates of recruitment rate were available.

Ship– or airborne sighting surveys in principle could provide both an absolute estimate of population size and an alternative database to the CPUE indices. A series of repeated and comparable surveys might yield relative indices of population trends. Methodological problems still exist, but survey indices have the advantage of being independent of catch statistics and any change in hunting technology or strategy. Shipborne sighting surveys of minke whales in the Barents Sea were attempted in 1984 and 1985, but the results were unsatisfactory, mainly because of difficult weather conditions and consequent incomplete coverage (Øien and Christensen, 1985b; 1985c).

Rørvik *et al.* (1985) analysed the Northeast Atlantic minke whales using CPUE data. Their analysis showed an overall average decreasing trend in CPUE indices for the Barents Sea of 0.3% per year through the years from 1954 to 1983. However, with correction for the non-linear relationship between CPUE and stock size (Cooke and Christensen, 1983; IWC, 1984), the series included periods of increase (80% through the 1960s) and decrease (-70% from 1970 to 1983) which can hardly be attributed to biological factors. Attempts were made to adjust for non-biological factors like competition between ships and also for changes in recruitment to the Barents Sea whaling grounds. The statistical basis for these adjustments was weak, and the Scientific Committee only accepted the use of the adjusted CPUE series as one of several alternatives in the assessments. The adjusted indices showed less variation than the unadjusted series, without any average trend over the full period from 1959 to 1983, but a decreasing trend through 1970-1983 remained, at about half the magnitude of the trend in the unadjusted series.

In 1985 Holt (1985a; 1986) presented estimates for Northeast Atlantic minke whales based on the CPUE indices calculated in 1984 and alternative mark-recapture estimates of stock size. Holt's model was a general production model without age-structure, based on a recruitment function developed by Pella and Tomlinson (1969). Holt fitted the model to trends in CPUE indices, corrected for non-linearity, and calibrated his projections by a mark-recapture estimate of stock size in 1978. The main conclusion from these estimates was that the Northeast Atlantic stock of minke whales should be classified as a Protection Stock according to the management procedures of the International Whaling Commission (IWC, Schedule paragraph 10).

The present report presents catch statistics and CPUE indices for the Northeast Atlantic stock unit area for all years since compulsory catch reports were introduced in conjunction with the licencing system for whaling vessels in 1938. In order to illustrate possible changes in recruitment to different whaling grounds, data for the two most important areas – the Barents Sea and the coastal Vestfjord area – are considered separately. Attempts are made to fit population models to time series of CPUE indices in order to assess the current stock in relation to initial stock level for classification of the stock in accordance with IWC policy. Finally, the report includes yield estimates.

MATERIAL AND METHODS

Available data

The basic data available for assessments of the Northeast Atlantic stock are catch reports for each individual minke whale caught by Norwegian small-type whalers since 1938. These reports on forms submitted by whalers have now been transferred to a computerized data file at the Institute of Marine Research, Bergen.

The data file has been searched to locate and correct obvious errors. Discrepancies in coding have also been corrected. Errors may still occur, but it is believed that their character and magnitude are such that they do not appreciably influence the results of analyses. However, some detailed information is lacking from a few of the catch reports. For older reports the deficiencies apply mainly to catch positions, but also to dates of catches and vessel characteristics. Recent reports occasionally lack notes on weather conditions (wind and visibility).

In the early years two or more vessels frequently cooperated in catching one whale. For some years during the 1940s, when catches in the Barents Sea were still small, such cooperative whaling accounted for an appreciable part of the total catch, but the numbers of whales taken by cooperating vessels have been insignificant in more recent years. All data on whales caught in this manner have been excluded from the analyses.

Whaling areas

Divisions by area in the present analysis are the same as in previous reports (Rørvik *et al.*, 1985). Whaling vessels, techniques and strategies are roughly comparable throughout the Barents Sea, including the coastal waters of Svalbard and Finnmark, so that all whaling grounds within this larger area may be analysed together. Statistical Areas 1-6 (Fig. 1) are therefore incorporated as factors in the combined analysis of the data for the Barents Sea. This should account for shifts in area over time, assuming that no obvious trend occurs in the shifts, an assumption which has so far not been investigated in detail. Our analyses also include the most important coastal whaling ground in the Vestfjord area (Statistical Area 7). However, the characteristics of the whaling operations, e.g. size of vessels, duration of trips etc., in this area differ so markedly from offshore operations in the Barents Sea, that data from the two areas cannot be combined. The Vestfjord data are therefore analysed separately.

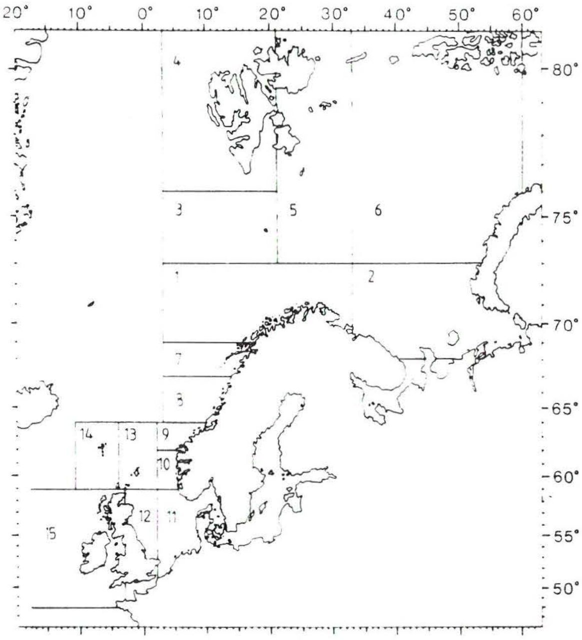

Fig. 1. Statistical areas used in statistics of the Norwegian minke whale fishery in the Northeast Atlantic. For convenience, the following terms have been adopted in the text: Barents Sea: Areas 1-6; Vestfjord: Area 7; North Sea: Areas 9-15.

Methods

Methods for calculating two alternative CPUE indices applicable to Norwegian small-type whaling, are described by Rørvik *et al.* (1985). The catch per shipday index is based on logbooks from all participating vessels, which include information on weather conditions for all days at sea in addition to the data for all whales caught. This index can only be calculated for the years from 1976 onwards for which detailed logbooks are available. The allocation of individual ship quotas from a reduced total quota in 1984 and 1985, obviously eased the competition between ships.

According to the skippers this permitted them to spend time on selecting large whales. Because of this change in strategy, the series of catch per shipday indices cannot be extended, and we refer to results and evaluations presented in 1984 (Rørvik *et al.*, 1985).

For the years prior to 1976 the catch reports contain only data for whales caught and no information is available for days at sea without a catch. Full utilization of all available catch reports in an extended time-series therefore must be based on the alternative catch per net catcher day -1 index (Rørvik *et al.*, 1985).

In an attempt to adjust the Barents Sea indices for competition between vessels, measured as the number of participating vessels, and availability of whales, measured as CPUE for the North Sea (Rørvik *et al.*, 1985), a multiple regression was carried out, using the formula:

$$Y = a + b^*X1 + c^*X2$$

where Y is catch per net catcher day (C/NCD) for the Barents Sea, X1 the corresponding index for the North Sea, and X2 the number of participating vessels in the Barents Sea. Because the North Sea index for 1983 was nil, the regression was calculated only for the years 1946-82.

According to IWC management procedures, whale stocks are to be classified on the basis of current status in relation to their maximum sustainable yield level, at present considered to be 60% of the initial (unexploited) stock level. The necessary estimates can be made by simulations of a population model which can be fitted to known parameters. One such model, the BALEEN program which was originally developed for sperm whales (Allen, 1973; Allen and Kirkwood, 1977) has previously been applied to Antarctic minke whales (IWC, 1981). On the basis of biological parameters and a series of effort and catch data, the BALEEN program minimizes the squared deviations between calculated expected and recorded catches. The best fit gives estimates of stock size and trends. However, the BALEEN program has not been used lately, possibly because the applied parameters are poorly known.

An alternative simplified model, not structured by age, has been proposed recently (Holt, 1985). The model estimates corresponding values of natural mortality and a second parameter termed the resilience in a recruitment function (considered to be an expression of the ability of the stock to respond to changes in density by changes in recruitment). The model is sex-specific to account for the possible effects of excessive catches of females through several years.

The model is defined by:

$$N(f)_i = (N(f)_{i-1} - C(f)_{i-1})e^{-M} + r_{i-t} N(f)_{i-t}$$

$$N(m)_i = (N(m)_{i-1} - C(m)_{i-1})e^{-M} + r_{i-t} N(f)_{i-t}$$

$$r_{i-t} = (1-e^{-M})[1 + A(1 - (N_{i-t}/N_0)^n)]$$

$$N_i = N(f)_i + N(m)_i$$

where the symbols are:

N : recruited stock size
f : index for females
m : index for males
M : instantaneous rate of natural mortality
A : resilience-parameter
n : density-dependent exponent, describing the form of the stock production curve (n = 2.39 corresponds to MSYL at 60% of initial stock size)
r : gross recruitment rate
i : index for year
t : age at sexual maturity.

The model assumes equal numbers of females and males in the initial stock.

As interpreted by Holt (1985), the maximum value of the resilence parameter A is 1/n without super-compensation. Super-compensation takes place if the absolute number of recruits at a stock size lower than the unexploited level is greater than it is at the unexploited level. The gross recruitment rate, r, in the model is defined by Holt (1985). It is based on a derivation from a stock production curve ascribed to Pella and Tomlinson (1969) and reformulated by Shepherd (1982).

The model is fitted to the CPUE data by linear regression techniques through a population estimate for the late 1970s. However, the available longer time series shows upward and downward trends which fit a linear regression rather poorly. An alternative fitting to the CPUE data may be performed according to the model:

$$CPUE_i = q\, N_i^c \exp(v_i) \qquad (1)$$

(Cooke, pers. comm.) where CPUE is the C/NCD-1 index for year i, q is the catchability coefficient, c is the catchability exponent, v is a normally distributed random error variable, and N is calculated from the iterative population model above. The catchability exponent amounts to the inverse value of the non-linearity factor (Cooke and Christensen, 1983). In logarithmic form equation (1) changes to:

$$\log(CPUE_i) = \log(q) + c \log(N_i) + v_i$$

The adjustment of the model to the calculated series of CPUE indices over a period of years in terms of the laps of N, may be made by minimizing over that period the objective function

$$OBJ = Var(\log(CPUE)) + c^2 Var(\log(N)) - 2c\, Covar(\log(CPUE), \log(N))$$

with respect to the resilience parameter A and the natural mortality rate M; given that the trajectory is restricted to a certain population level in a target year, which also in this context will be taken to be the mark-recapture estimates for 1978.

RESULTS

Catches and regulations

Catch reports on file from the Northeast Atlantic stock unit area are summarized in the catch statistics shown in Table 1. Some deviations from previous statistics (e.g. Rørvik *et al.*, 1985) are apparent. In most cases the discrepancies are small, anywhere from a couple of whales up to a few tens in individual years, but a more substantial deficiency of 219 whales (6.9%) appears in the 1962 statistics. However, also the official statistics (Fiskeridepartementet, 1962) show a lower figure (3,061) for 1962 than reported by Rørvik *et al.* (1985), indicating that some of the deficiency for this year may be explained by erroneous areal classification in the previous report. Some of the minor discrepancies can probably be attributed to the fact that catch reports without positions are excluded from the present Table 1, e.g. 11 whales without reported positions in 1962.

The Norwegian small-type minke whale fishery started around 1930, and developed gradually up to 1938 when

Table 1

Norwegian catches of minke whales in the Northeast Atlantic stock unit area 1938-1985, with sex compositions and catches in the larger Barents Sea area (Statistical Areas 1-6, Fig. 1)

Year	Total catch	Sex composition: Males	Females	Not known	% females	Catches in the Barents Sea: n	%
38	1345	698	550	97	44.1	233	17.7
39	915	453	402	60	47.0	33	3.6
1940	539	274	236	29	46.3	23	4.5
41	2109	1108	945	56	46.0	118	5.6
42	2133	1206	916	11	43.2	150	7.2
43	1612	931	661	20	41.5	111	9.6
44	1348	703	637	8	47.5	27	3.3
1945	1782	1002	762	18	43.2	44	3.2
46	1883	1050	815	18	43.7	408	23.9
47	2556	1424	1106	26	43.7	505	22.3
48	3487	1862	1570	55	45.7	1167	34.8
49	3840	1884	1912	44	50.4	2437	65.3
1950	1990	951	1020	19	51.8	803	41.0
51	2751	1408	1326	17	48.5	892	32.8
52	3324	1470	1833	21	55.5	2004	60.5
53	2433	1229	1196	8	49.3	1168	48.4
54	3499	1741	1737	21	49.9	1605	47.1
1955	4309	2039	2243	27	52.4	1702	40.5
56	3654	1808	1829	17	50.3	1628	44.6
57	3624	1648	1955	21	54.3	1649	45.7
58	4338	1984	2327	27	54.0	2068	48.7
59	3062	1621	1417	24	46.6	1634	53.4
1960	3233	1519	1702	12	52.8	1602	49.6
61	3092	1428	1633	31	53.3	1547	50.1
62	2975	1352	1584	39	54.0	1334	45.0
63	3059	1436	1620	3	53.0	1802	59.3
64	2463	1183	1269	11	51.8	1118	45.6
1965	2114	1018	1088	8	51.7	983	47.2
66	1902	846	1050	6	55.4	1040	55.1
67	1758	886	861	11	49.3	860	49.2
68	1986	1166	804	16	40.8	1104	56.1
69	2014	1002	1003	9	50.0	1355	67.3
1970	1890	881	1000	9	53.2	1109	58.8
71	1799	853	925	21	52.0	1083	60.8
72	2172	790	1368	14	63.4	1733	79.7
73	1558	645	909	4	58.5	1140	73.9
74	1410	526	876	7	62.5	1008	72.0
1975	1426	598	827	1	58.0	1015	71.1
76	1884	615	1263	6	67.3	1590	84.4
77	1698	710	983	5	58.1	1477	86.9
78	1383	470	910	3	65.9	1234	89.3
79	1786	760	1011	15	57.1	1570	87.8
1980	1807	779	1009	19	56.4	1621	89.7
81	1770	757	1001	12	56.9	1546	87.4
82	1782	629	1137	16	64.4	1592	89.4
83	1688	608	1063	17	63.6	1582	93.8
84	630	335	293	2	46.7	569	90.3
1985	634	320	309	5	49.1	497	78.4

licensing combined with compulsory reporting of catches was imposed (Jonsgard, 1955). Rørvik (1981) in his simulations assumed a development of the fishery which implies a total catch of 4,910 minke whales from the Northeast Atlantic area through 1930-1937. No further regulation was enforced during the first dozen years after 1938, and catches increased through the 1950s to a maximum total catch of 4,338 minke whales taken in the Northeast Atlantic area in 1958. A mid-season catch-stop from 1 to 21 July was introduced in 1950, and in 1952 the season was limited to six months from 15 March to 15 September with a further limitation in 1955 (Table 2)*. Catches decreased towards the mid 1960s, and have since amounted to 1,700-1,800 whales per year until quotas were reduced in 1984. A series of regulations restricting the whaling areas and the season were imposed through the 1970s in order to reduce the proportion of females in the catches.

* Table 2 is found on p. 236.

Table 3

Sex compositions in Norwegian catches of minke whales in the Northeast Atlantic 1938-1985, by Statistical Areas (Fig. 1)

Area	Catch	% of tot. catch	Males	Females	Not known	% females	% of tot. females
01	10602	10.0	6214	4321	67	41.0	7.9
02	22003	20.7	8079	13754	170	63.0	25.1
03	5967	5.6	2248	3692	27	62.2	6.7
04	6560	6.2	1706	4827	27	73.9	8.8
05	2249	2.1	759	1483	7	66.1	2.7
06	6712	6.3	2061	4621	30	69.2	8.4
07	30078	28.3	16156	13593	329	45.7	24.8
08	3885	3.6	2330	1507	48	39.3	2.7
09	6105	5.7	3363	2648	94	44.1	4.8
10	4160	3.9	2750	1343	67	32.8	2.4
11	1481	1.4	592	871	18	59.5	1.6
12	1272	1.2	737	523	12	41.5	1.0
13	2900	2.7	1949	914	37	31.9	1.7
14	1127	1.1	756	362	9	32.4	.7
15	1345	1.3	906	435	4	32.4	.8
Total	106446		50606	54894	946	52.0	

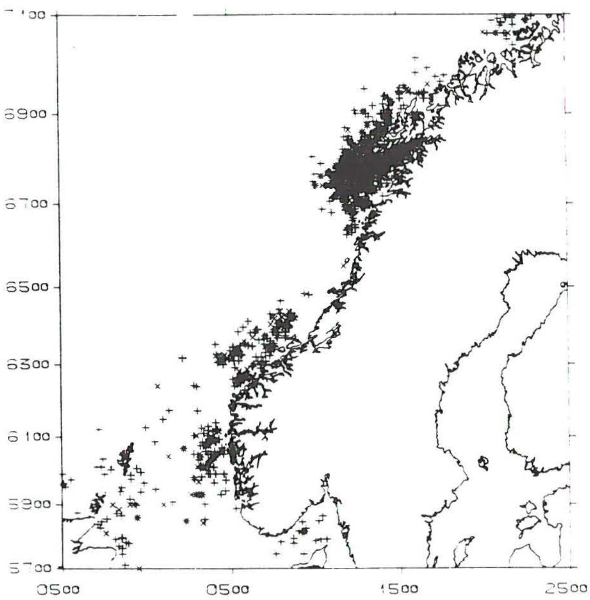

Fig. 2. Positions of minke whales caught by Norwegian small-type whalers in Norwegian coastal waters and the North Sea in 1948.

Spatial distribution of catches

Throughout the period with recorded catches from 1938 to 1985, the most important whaling grounds for minke whales have been located in the southeastern Barents Sea and the Vestfjord area on the coast of Northern Norway (Statistical Areas 2 and 7, Fig. 1). These two areas account for 49% of all catches on file as indicated in Table 3. This table also shows that excessive catches of females have mainly been taken in Areas 2-6 in the Barents Sea, where the females make up an average 66% of the total accumulated catch.

Recorded catch positions show significant shifts in whaling grounds through the years. During the first years after 1938, most of the whales were taken in Norwegian coastal waters, mainly in the Vestfjord area, at Møre and on the southern west coast (Fig. 2). Up to the outbreak of the Second World War some additional catches were taken at Bjørnøya and the west coast of Svalbard, and whaling on

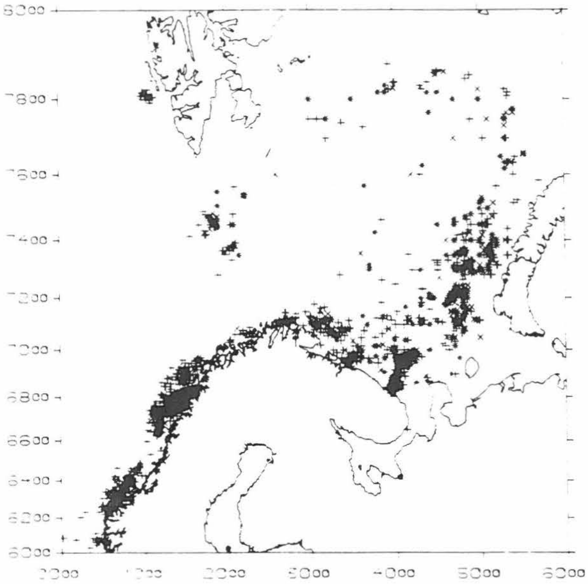

Fig. 3. Positions of minke whales caught by Norwegian small-type whalers in the Northeast Atlantic in 1952.

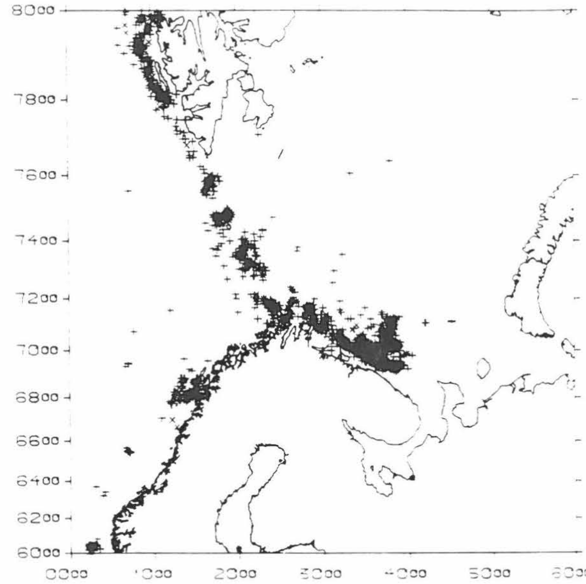

Fig. 4. Positions of minke whales caught by Norwegian small-type whalers in the Northeast Atlantic in 1980.

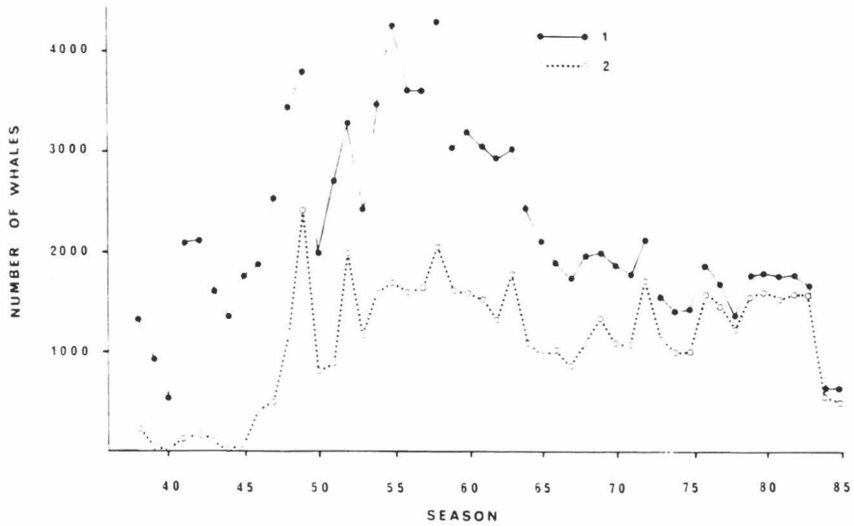

Fig. 5. Norwegian catches of minke whales in the Northeast Atlantic 1938-1985. (1) Total catches, (2) catches in the larger Barents Sea area (Statistical Areas 1-6, Fig. 1).

these grounds was resumed after 1945. Whaling on the coast of Finnmark expanded to the East, and the southeastern part of the Barents Sea to Novaya Zemlya was one of the most important whaling areas during the 1950s and the early 1960s (Fig. 3). The west coast of Svalbard was established as a regular whaling ground from the mid 1950s, and gained importance as catches in the eastern Barents Sea, particularly off Novaya Zemlya, decreased. Very few catches were taken at Svalbard (Area 4, Fig. 1) from 1972 to 1979, but in the 1980s whaling has mainly been concentrated within a rather narrow strip from the mouth of the White Sea, along the Murman and Finnmark coasts and across to Bjørnøya and the west coast of Svalbard (Fig. 4).

Catches taken in the larger Barents Sea area (Statistical Areas 1-6) are listed separately in Table 1. An average 50.5% of all recorded catches in the Northeast Atlantic stock unit area through the years have been taken in this larger area. As demonstrated by the table, the proportion taken in the Barents Sea increased rapidly after 1945 to 45-50% of the total through the 1950s, 60-70% towards the end of the 1960s and 85-90% from the mid 1970s. The number of whales taken in the Barents Sea increased to a level of about 1,700 per year towards the late 1950s, decreased to about 1,000 per year in the late 1960s and later increased to about 1,600 per year around 1980.

The relative importance of coastal catches decreased with the expansion of whaling in the Barents Sea. However, catches in the Vestfjord area remained nearly constant for some years, until they were gradually reduced through the 1960s from an annual level of about 1,000 to a couple of hundred per year from around 1970.

Table 4

Participation and catches in the Norwegian minke whale fishery in the Northeast Atlantic 1938-1985, with data for the larger Barents Sea and the Vestfjord areas (Statistical Areas 1-6 and 7, Fig. 1) given separately. Only complete catch reports with vessel characteristics are included. Whales caught by cooperative effort of two or more vessels are excluded (Excl.). Cooperative catches have not been reported since 1975

	Total stock unit area			Barents Sea			Vestfjord		
	No. of	No. whales		No. of	No. whales		No. of	No. whales	
Year	vessels	catch	Excl.	vessels	catch	Excl.	vessels	catch	Excl.
1938	253	1297	0	46	215	0	104	503	0
39	158	886	0	13	33	0	79	453	0
1940	76	528	0	5	23	0	35	252	0
41	253	2081	15	30	114	0	123	1176	[illegible]
42	317	2047	79	45	147	4	181	1399	26
43	251	1217	395	38	111	44	150	752	222
44	250	960	386	18	27	17	168	701	240
1945	212	1481	288	18	43	13	129	1090	169
46	240	1672	210	71	408	42	141	769	132
47	226	2239	316	82	504	65	146	1046	134
48	287	3246	225	101	1167	32	171	1417	157
49	338	3562	196	190	2410	23	162	751	137
1950	199	1886	96	67	801	13	104	715	54
51	224	2566	167	70	892	7	127	1190	116
52	220	3173	138	82	2002	3	129	790	114
53	169	2316	106	55	1163	10	92	820	89
54	185	3269	181	49	1602	6	99	865	152
1955	191	4019	201	54	1664	3	101	1376	177
56	196	3428	221	68	1623	5	97	780	177
57	196	3372	244	69	1649	5	90	716	210
58	188	4012	284	76	2066	12	97	860	241
59	184	2882	165	63	1626	0	79	406	139
1960	181	3069	163	58	1602	0	89	585	148
61	178	2869	223	70	1547	1	94	800	209
62	161	2708	267	55	1334	5	87	723	213
63	149	2833	226	70	1802	16	71	383	176
64	138	2220	243	52	1118	5	71	558	187
1965	127	1853	261	45	983	16	66	487	205
66	106	1745	156	45	1040	7	54	298	140
67	114	1507	251	54	860	6	56	332	212
68	117	1871	115	58	1104	8	46	210	100
69	109	1992	21	54	1354	1	26	130	19
1970	111	1824	66	59	1109	0	40	301	64
71	98	1752	47	46	1083	1	40	242	43
72	92	2155	17	56	1733	0	23	101	16
73	96	1512	46	62	1140	11	27	165	35
74	73	1360	50	40	1008	7	28	160	35
1975	77	1405	21	47	1015	0	34	198	21
76	80	1884	-	62	1590	-	26	107	-
77	86	1698	-	72	1477	-	20	103	-
78	86	1383	-	72	1234	-	21	62	-
79	84	1786	-	73	1570	-	34	139	-
1980	87	1807	-	77	1621	-	43	105	-
81	88	1770	-	73	1546	-	42	151	-
82	79	1782	-	65	1592	-	34	115	-
83	78	1688	-	61	1582	-	22	62	-
84	49	630	-	44	569	-	12	20	-
1985	49	634	-	41	497	-	24	67	-

Whaling grounds at the British Isles, Shetland and the Faeroe Islands have never been very important to Norwegian small-type whalers, and no catches have been recorded in these waters since the late 1970s.

Catches of females

In the 1950s the proportion of females was stabilized at about 50% of the total annual catch, but increased to about 60% during the 1970s (Table 1). Regulatory measures imposed to reduce catches of females do not appear to have worked, except perhaps to halt a further increase. The catch reports for 1984 and 1985 indicate catches of females below 50% of the totals, but data collected by inspectors and scientific observers cast some doubt on these figures. The latter data suggest that the proportion of female whales may have been as high as 72.1% and 57.8% of totals in each of these two years respectively, but since the material collected by inspectors represents only a minor fraction of the total catch, they may not be valid.

Participation

Annual figures for the number of vessels participating in whaling in the Northeast Atlantic stock unit area are given in Table 4 with figures for the larger Barents Sea and the Vestfjord areas shown in separate columns.

The average number of vessels whaling in the Barents Sea has remained at about 60 per year from 1950 to 1985, with somewhat lower numbers through a period from the mid 1960s. Participation increased again in this area in 1976 when quotas were imposed.

Vessel characteristics

The increase in size of Norwegian small-type whaling vessels participating in the Barents Sea minke whale fishery from 1938 to 1985 is illustrated in Fig. 6. Average registered lengths increased from 45-50 to 65-70ft up to about 1960. The curve levels off during the 1960s and increases again through the early 1970s. After a temporary low in 1976, the vessels again increase in size until the average lengths drop in 1984 and 1985. These recent temporary declines probably were caused by smaller coastal vessels moving from the Vestfjord whaling grounds to the Barents Sea when quotas were imposed in 1976 and reduced in 1984. Table 4 shows that the number of vessels increased in the Barents Sea area from 47 in 1975 to 62 in 1976. A corresponding increase in relative numbers of vessels occurred from 1983 to 1984.

The continuously increasing average engine power of the Barents Sea whaling fleet is illustrated by the second curve in Fig. 6. The effects of the shift of coastal vessels to the Barents Sea in 1976 and 1984 is evident also here.

Changes in the average size and engine power of whaling vessels in the Vestfjord area are illustrated in Fig. 7. These graphs show that vessel size increased at rates comparable to those in the Barents Sea, but engine power lagged behind until the 1960s.

Catch per unit of effort

C/NCD-1 in the Barents Sea are tabulated in Table 5 and illustrated in Fig. 8. This index has been calculated for all years from 1946 to 1983. In 1984 and 1985 the reduced total quota was allocated to individual vessels, which permitted the whalers to change their tactics as a result of eased competition. Data for the last two seasons therefore have been omitted from further analyses. The series comprises all vessels from 50 to 95ft in length and the season from 21 May to 30 June, and therefore includes both the majority of all participating vessels and the most important part of the whaling season each year.

Notwithstanding the large variations between years, the Barents Sea index shows a rapid increase during the first few years after 1945, a downward trend through the 1950s, an increase through the 1960s and, finally, a decreasing trend through the 1970s which continues up to 1983. Calculated trends in the series are given in Table 6.

C/NCD indices for the Vestfjord area are illustrated in Fig. 9 and tabulated in Table 5. Indices for 1938-1945 are disregarded in the analysis because of the special circumstances which influenced all Norwegian fisheries during the Second World War. Fig. 9 indicates a general downward trend through all postwar years, calculated in Table 6.

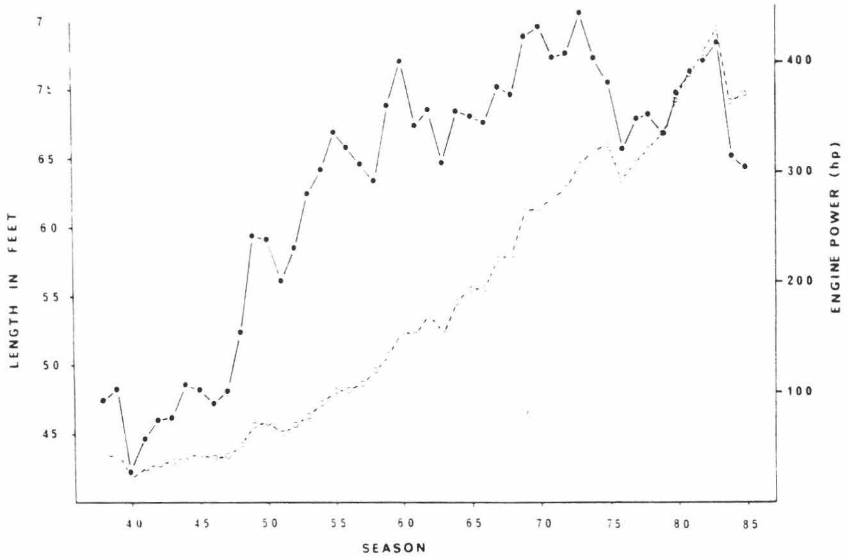

Fig. 6. Characteristics of Norwegian vessels whaling for minke whales in the larger Barents Sea area (Statistical Areas 1-6, Fig. 1) through 1938-1985. Closed circles: average registered lengths; open circles: average engine power.

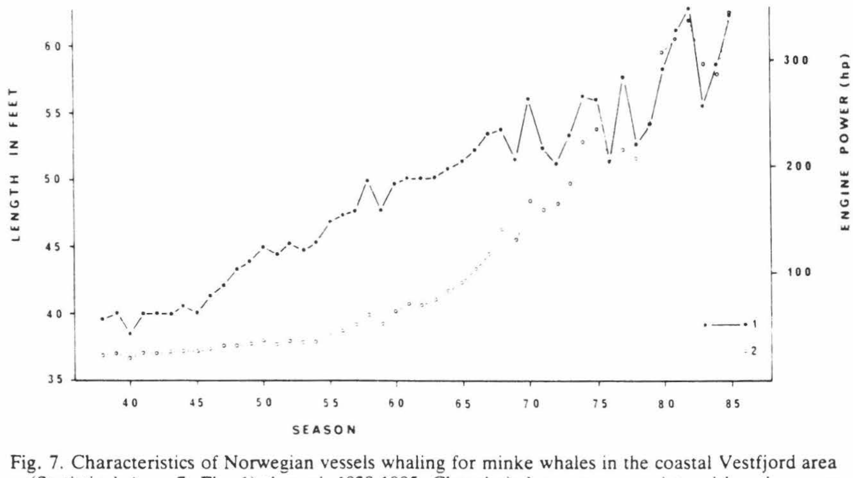

Fig. 7. Characteristics of Norwegian vessels whaling for minke whales in the coastal Vestfjord area (Statistical Area 7, Fig. 1) through 1938-1985. Closed circles: average registered lengths; open circles: average engine power.

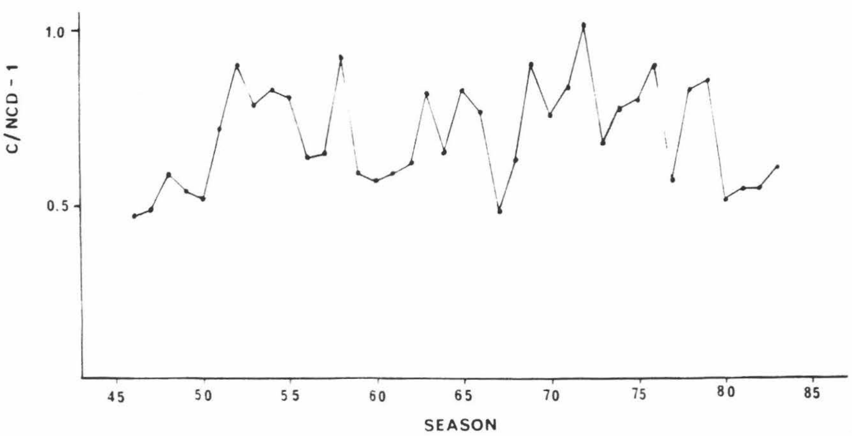

Fig. 8. Catch per net catcher day −1 in Norwegian whaling for minke whales in the larger Barents Sea area (Statistical Area 1-6, Fig. 1) through 1946-1983.

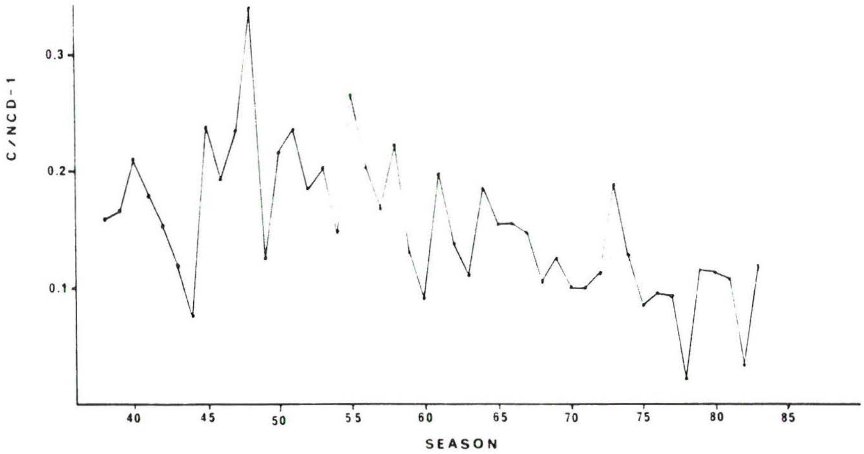

Fig. 9. Catch per net catcher day −1 in Norwegian whaling for minke whales in the Vestfjord area (Statistical Area 7, Fig. 1) through 1938-1984.

Table 5

Catch per net catcher day −1 for Norwegian catches of minke whales in the larger Barents Sea and the coastal Vestfjord area (Statistical Areas 1-6 and 7, Fig. 1) 1938-1983. The Barents Sea indices contain catches from 21 May to 30 June each year, taken by 50-94 feet long vessels. The Vestfjord indices contain catches from 21 March to 20 September, taken by 25-94 feet long vessels

Season	Catch per net catcher day - 1			Adjusted index
	Barents Sea	Vestfjord	North Sea	
1938	-	0.1596	-	
1939	-	0.1661	-	
1940	-	0.2089	-	
1941	-	0.1778	-	
1942	-	0.1535	-	
1943	-	0.1185	-	
1944	-	0.0762	-	
1945	-	0.2365	-	
1946	0.4713	0.1940	0.1505	0.510
1947	0.4883	0.2357	0.1919	0.655
1948	0.5917	0.3406	0.1364	0.777
1949	0.5425	0.1243	0.2789	0.916
1950	0.5153	0.2155	0.1688	0.644
1951	0.7204	0.2357	0.1624	0.856
1952	0.9046	0.1853	0.2108	1.080
1953	0.7922	0.2025	0.4453	0.990
1954	0.8276	0.1478	0.2189	0.967
1955	0.8089	0.2655	0.3376	0.986
1956	0.6386	0.2031	0.2561	0.810
1957	0.6466	0.1681	0.3520	0.841
1958	0.9253	0.2236	0.2196	1.103
1959	0.5948	0.1298	0.2157	0.758
1960	0.5709	0.0895	0.2095	0.724
1961	0.5879	0.1979	0.1975	0.756
1962	0.6175	0.1379	0.2478	0.766
1963	0.8213	0.1088	0.2080	0.989
1964	0.6526	0.1856	0.2454	0.799
1965	0.8256	0.1552	0.1243	0.935
1966	0.7670	0.1547	0.1892	0.892
1967	0.4782	0.1465	0.1555	0.605
1968	0.6313	0.1062	0.4102	0.837
1969	0.9040	0.1249	0.4304	1.103
1970	0.7587	0.0999	0.2541	0.919
1971	0.8436	0.0988	0.2856	0.993
1972	1.0174	0.1119	0.0970	1.139
1973	0.6818	0.1864	0.0950	0.814
1974	0.7752	0.1280	0.2900	0.919
1975	0.7984	0.0838	0.3208	0.962
1976	0.8997	0.0951	0.1818	1.054
1977	0.5694	0.0937	0.5085	0.823
1978	0.8267	0.0221	0.0755	0.967
1979	0.8612	0.1153	0.0882	1.010
1980	0.5103	0.1133	0.5661	0.787
1981	0.5476	0.1064	0.5878	0.821
1982	0.5478	0.0328	0.4104	0.764
1983	0.6054	0.1197	0.0014	0.711

Table 6

Estimated trends in alternative series of C/NCD-1 for Norwegian catches of minke whales in the Northeast Atlantic. P is the probability that C/NCD-1 is stable or increasing

Series	Trend in % per year		P
	In mid year	In 1983	
Barents Sea			
1952–1983	- 0.4	- 0.4	0.17
1973–1983	- 3.3	- 4.0	0.046
1952–1959	- 3.4		0.096
1960–1969	+ 2.3		0.84
1970–1979	- 0.6		0.38
1970–1983	- 3.2	- 4.0	0.009
Barents Sea, adjusted			
1973–1983	- 2.0	- 2.2	0.05
Vestfjord area			
1946–1983	- 2.8	- 5.9	<<0.001

The comparison by multiple regression of catch per net catcher day indices (Y) for the Barents Sea with indices for the North Sea (X1) and participation in the Barents Sea (X2) gave the following coefficients:

$$a = 0.875050$$

$$b = -0.256579 \text{ (SE } 0.1842)$$

$$c = -0.001733 \text{ (SE } 0.0011)$$

None of these coefficients are significant at the 95% level. Only about 12% of the total variation in Y was explained by X1 and X2, and the regression was not significant ($F=2.303$, $\alpha>0.10$). An adjusted series of C/NCD indices for the Barents Sea is included in Table 5 and the trend for this index through 1973-1983 is calculated in Table 6.

Population models

Results of simulations to fit trends in various unadjusted series of C/NCD-1 for the Barents Sea to the simplified population model (Holt, 1985) are given in Table 7. These simulations were performed using the linear regression trends taken from Table 6. As seen from the tables, 1952 is used as a starting year. In preliminary runs we tried to fit the population model to the whole series from 1946 onwards but did not get any convergence. This is further

Table 7

Results from model simulations of the Northeast Atlantic stock of minke whales using trends calculated from linear regressions of alternative C/NCD-1 series from the larger Barents Sea area (Table 6). Simulations have been carried out for various estimates of the recruited stock in 1978. Factor refers to correction of the given trend owing to non-linearity. M is natural mortality, A is resilience, asterisks indicate parameters which give the best fit when other parameters are fixed. P gives the estimated current (1986) stock as a percentage of the estimated initial (1938) stock and RY is estimated replacement yield in 1986. [1] Alternative fit to trend in the ten mid-years of the period (1963-1972)

CPUE-series	Trend	Recruited stock	Factor	M	A	Initial stock	Stock 1986	P	RY
1952–83	–0.4	22000	1.0	0.10	no fit				
1952–83	–0.4	22000	2.0	0.10	0.785*[1]	49507	21837	44.1	1287
1952–83	–0.4	30000	1.0	0.10	0.736*[1]	55927	31019	55.5	1455
1952–83	–0.4	30000	2.0	0.10	0.851*	52853	31853	60.3	1570
1973–83	-3.3	22000	1.0	0.10	0.202*	68009	17116	25.2	629
1973–83	-3.3	22000	2.0	0.01*	0.418	105862	12056	11.4	129
1973–83	-3.3	30000	1.0	0.10	0.003*	84940	23255	27.4	398
1973–83	-3.3	30000	2.0	0.10	no fit				

referred to in the discussion section. Although the validity of the mark–recapture estimates is much debated (IWC, 1987), values of 22,000 and 30,000 were used as alternative estimates of recruited (available) stock size in 1978. These values correspond to estimates of 44,000 and 60,000 whales for the total stock (IWC, 1985b). A multiplicative factor of 2.0 is used for the trends where they are corrected for non-linearity, because this was considered to be the most likely figure for the relationship between C/NCD-1 and abundance for the Barents Sea fishery at the 1983 and 1984 meetings of the Scientific Committee (IWC, 1984; 1985b). A value of 0.10 is applied for natural mortality rate whenever this is used as an input parameter to the model.

Results of the alternative fitting of the model by equation (1) to the C/NCD-1 index for the Barents Sea for the years 1952-83 (taken from Table 5) are given in Table 8. The results must be discussed in relation to the parameter estimates, because it is quite apparent that a compromise must be made between high resilience values (allowing for super-compensation), high natural mortality rates, and stock estimates for the late 1970s which are considerably higher than 44,000 and 60,000, presently considered to be the best alternative estimates for 1978.

Replacement yields

Replacement yields, calculated by the simple population model directly from catches and year by year stock size estimates corrected for survival, are given in Table 7.

DISCUSSION

Catch per unit of effort

The C/NCD index has not been explicitly corrected for changes in weather conditions through the season. However, the basic units of effort, the catcher days, which are days with recorded catches, imply an indirect correction for weather because conditions must necessarily be tolerable or good for any whale to be taken at all. In 1982 for example, 96% of all whales were taken in winds at or below moderate breeze (Beaufort 4).

Catches are influenced not only by weather and the availability of whales, but also by the efficiency of vessels and crews. The catch reports contain data on the size and engine power of the vessels. Rørvik *et al.* (1985) found that vessel length is a sufficient expression of efficiency, and registered lengths therefore have been used as the only correction for vessel efficiency in the C/NCD index, as described in that paper. Obviously also other factors like equipment and gear or the experience of skipper and crew are important. It has not been possible, however, to quantify such factors for inclusion in the analyses.

Recently, it has been suggested that catches of bottlenose whales in conjunction with the minke whale fishery may have distorted the C/NCD-1 indices for the years up to 1970 (IWC, 1987). Until a thorough analysis of the relationship between bottlenose and minke whaling can be carried out, this hypothesis cannot be rejected, but there are indications in the literature that this is a minor problem. Rørvik and Christensen (1981) concluded from an investigation of factors affecting CPUE in the Norwegian minke whale fishery that by-catches of a small number of odontocetes are of little relevance to CPUEs in Norwegian minke whaling.

C/NCD indices for the Barents Sea through 1946-1983, illustrated in Fig. 8, show trends which could not be fitted to the population model with convergence and acceptable values of natural mortality rate (M) and resilience (A). This suggests either that the model is insufficient to describe the catch history, or that the index is influenced by factors other than those directly related to stock size or availability. Increasing indices during the first years after the Second World War probably are related to the reconstruction of the fleet and the expansion during those years of the area exploited by Norwegian small-type whalers.

In the larger Barents Sea area both the number of participating vessels and the catches increased rapidly until the season was limited by opening and closing dates in 1952 (Table 2). Catches continued at a stable level up to the early 1960s while the CPUE indices declined. This discrepancy probably is related to the renewal and increasing efficiency of the fleet during the 1950s,

Table 8

Fitting of the model to C/NCD-1 for the Barents Sea for the years 1952-83 by minimizing an objective function based on equation (1). The simulations have been carried out for various alternatives of the recruited stock size in 1978. c is the catchability exponent. M is natural mortality, A is resilience, asterisks indicate parameters which give the best fit when other parameters are fixed. P gives the estimated 1986 stock as a percentage of the estimated initial stock (1938)

Recruited stock	c	M	A	Initial stock	1986 stock	P
22000	1.0	0.10	0.778*	49897	21741	43.6
22000	0.5	0.10	0.778*	49897	21741	43.6
30000	1.0	0.10	0.893*	51984	32093	61.7
30000	0.5	0.10	0.747*	55829	31067	55.6
40000	1.0	0.10	0.724*	63562	42155	66.3
40000	0.5	0.10	0.566*	68830	40784	59.3
50000	1.0	0.10	0.622*	74717	52156	69.8
50000	0.5	0.10	0.434*	82161	50208	61.1
60000	1.0	0.10	0.540*	86173	62008	72.0
60000	0.5	0.10	0.370*	93762	60002	64.0
22000	1.0	0.33*	0.418	31890	23282	73.0
22000	0.5	0.24*	0.418	37936	22699	59.8
30000	1.0	0.24*	0.418	44059	31380	71.2
30000	0.5	0.18*	0.418	50567	30670	60.7
40000	1.0	0.20*	0.418	56162	41620	74.1
40000	0.5	0.14*	0.418	65016	40668	62.6
50000	1.0	0.16*	0.418	69938	51666	73.9
50000	0.5	0.11*	0.418	80090	50439	63.0
60000	1.0	0.14*	0.418	82077	61768	75.3
60000	0.5	0.09*	0.418	94601	60172	63.6

illustrated by the rapidly increasing size of the vessels during these years (Fig. 6).

During the 1960s catches in the Barents Sea decreased while the C/NCD increased. An explanation may be that Norwegian whaling expanded to the west with the start of whaling at East Greenland and Iceland in 1960 (Øien and Christensen, 1985a). The transfer of some vessels to the Central stock unit area eased competition (Table 4) and thus may have affected the CPUE in the Barents Sea. Barents Sea catches increased again during the 1970s to a level comparable to catches in the 1950s, with a corresponding decline in CPUE. During this period extensions of the Icelandic fisheries zone excluded Norwegian vessels from important western whaling grounds and corresponding British regulations had a similar if much smaller effect (Table 2). The introduction of quotas in 1976 also led to a transfer of vessels to the Barents Sea where chances to compete for a share of the total quota were better than in coastal waters further to the south.

The observations above suggest that participation may affect the C/NCD index for the Barents Sea through competition. The low correlations between CPUE indices for the Barents Sea, indices for the North Sea and participation in the Barents Sea, probably are influenced by the fact that throughout the recorded history of Norwegian small-type whaling, the fleet has only been congregated in the Barents Sea for the last few years. Catches in the North Sea have always been low, particularly through the last decade. CPUE indices for this area therefore show very wide variations between years with correspondingly large uncertainties in estimates of trends. Most of the catches in the North Sea have also been taken after the peak summer season in the Barents Sea, ie. in late July and August.

The characteristics of vessels and strategies employed in the North Sea make whaling in this area comparable to coastal whaling in for example the Vestfjord area, with correspondingly low CPUE indices. This of course increases the uncertainties in the estimates. The possible influence of competition upon CPUE indices for the Barents Sea therefore should be investigated and quantified by other methods than the one attempted here.

As mentioned above, coastal whaling in the Vestfjord area has been characterized by smaller vessels and different strategies from those employed in offshore whaling in the Barents Sea. In particular the short trips, with only one whale caught and landed per trip, produce low indices which are sensitive to changes in whaling practices. Even though variations between years are large and some reservation must be made for low catches during the last few years, the Vestfjord C/NCD indices (Fig. 9) show a significant decrease over the full period from 1946 to 1983 (Table 6). The trend in these indices, which represent about 30% of total Northeast Atlantic catches through all years, should be taken into account in evaluations of this stock.

Indications of overexploitation were also found when catches were at their highest level in the late 1950s. Jonsgård (1974) points out that the number of calves caught in Norwegian coastal waters had declined gradually since 1948, probably as a result of overexploitation in the Barents Sea where catches included excessive numbers of pregnant females.

The present analyses do not preclude the possibility that changes and trends in CPUE have been caused or influenced by periodic variations in climate and the distribution of prey.

Population models and trends

Attempts at simulations by the BALEEN model did not succeed because of difficulties in fitting the model to series of CPUE indices and choosing reproductive parameters to the model. Data are not available to demonstrate changes in fertility or age at first parturition for North Atlantic minke whales. Apparent changes in sexual maturity of Antarctic minke whales have been found to be probable statistical artefacts inherent in sampling (IWC, 1985a). As these parameters are not available from observation or from analogy, the BALEEN model could not be used.

Even the simplified model cannot be fitted to some of the observed trends in CPUE with reasonable values for resilience and natural mortality. Particular problems arise in attempts to fit the model to the strongly negative trends which result from application of a non-linearity factor of 2.0. That factor is derived from considerations of a model for the Barents Sea for which only preliminary results have been presented (Cooke and Christensen, 1983). Accordingly the linear factor should be used with some caution and is not directly applicable to other fisheries. The problems which have appeared therefore could mean either that the non-linearity factor is unrealistically high or that the observed trends are unrealistic. The fit is improved if it is assumed that the recruited stock in 1978 is significantly higher than calculated from mark-recaptures. As indicated in Table 7, the stock in 1986 would be at 10-30% of its initial (1938) level if the assessments were to be based only on the trend in Barents Sea indices for 1973-1983.

The database for such an assessment is considerably expanded by including the full series of Barents Sea indices for 1952-1983 in the simulations. Problems arise, however, in fitting the simple population model to the full series, because this produces an unrealistically high resilience parameter and a correspondingly poor fit. Fitting by linear regression over the whole period therefore proved to be impossible. As a tentative alternative approach the model was fitted by linear regression to the ten mid-years of the period (1963-1972), which suggested a present stock at 44-55% of the initial level (Table 7). Fitting the simple model directly to the full series of Barents Sea indices for 1952-1983, indicates a present stock level of 44-62% of the initial stock when M = 0.10 is used as input and resilience is estimated (Table 8). Using a resilience factor (A) of 0.418 (corresponding to the highest value of A without super-compensation) as input, and estimating natural mortality, gives a present level of 61-73% (Table 8). However, these attempts at fitting give unrealistically high values of A and M with currently accepted stock estimates as input. An improved fit with acceptable values of A and M may be achieved by increasing the estimated size of the recruited stock in 1978 to a level above 50,000. This implies a higher present stock level in relation to the initial stock than indicated above.

During the early years of the Norwegian small-type minke whale fishery, both sexes were caught in about equal numbers, but the proportion of females has increased in later years. The rate of pregnancies is very high (Christensen, 1981), and catches of mature females therefore have a particularly strong impact on recruitment in North Atlantic minke whales. On this background the change in strategy, which is based on the allocation of individual quotas the last two seasons, may lead to unfortunate consequences. Minke whale females are larger than the males, and when the whalers select for large whales, this may result in an excessive pressure on mature females. Females reach sexual maturity at a length of about 23ft (7m) (Christensen, 1981), and females at or above this length made up 65.1% and 84.5% of all females caught in 1984 and 1985 as compared to about 50% in previous years. We therefore wish to emphasize the obvious fact that the exploitation of mature females has a relatively greater impact on the stock than the total catch.

Alternative replacement yields have been calculated from the population model fitted to linear regressions, and are given in Table 7. The table shows that the RY level depends mainly on the selection of time series of CPUE indices to be used in the calculations. Arguments for selecting the extended series as a basis for the evaluation of current and initial stock size and thus for classification of the stock, may not apply to an evaluation of present permissible exploitation rates. As discussed above, several unexplained peculiarities arise in connection with the full C/NCD-1 series. The recent drop is a striking feature of the series. Although under-reporting may have relevance to this drop as discussed by Rørvik (1987), care should be taken in estimating current yields until this has been fully investigated. One possible cautious approach would be to base the calculations on the last ten year period of the C/NCD-1 indices for the Barents Sea, which gives current replacement yields ranging from 129 to 629 whales as indicated in Table 7. The recent trend suggests that the RY will decrease over the next few years because the mature productive segment will continue to decrease until the stock has stabilized.

The simple model may also be used to calculate current and maximum sustainable yields (SY and MSY). Both are proportional to the product of resilience and natural mortality, and SY will necessarily be lower than current RY.

CONCLUSION

The analyses and evaluations of Northeast Atlantic minke whales presented in this report are all based on catch per net catcher day (-1) indices which are calculated from the compulsory catch reports submitted by the whalers. Particular emphasis is put on the indices for the larger Barents Sea area which accounts for slightly more than 50% of total catches in the Northeast Atlantic stock unit area through all years for which catch reports are available, and more than 85% of the total catches during the last decade.

The Barents Sea indices show periods of increase and decrease which are not completely explained by regulatory measures, changes in catch levels or spatial and temporal changes in effort.

Since catch quotas were imposed in 1976, nearly all whaling effort has been directed to a rather narrow strip of water covering about 250,000km^2 of the western Barents Sea. From then on the declining trend which is just discernible in the early 1970s, gains momentum and accelerates. This would appear to indicate a declining abundance of whales in the Barents Sea. In the most recent years, however, information has appeared to suggest that the catch reports do not include all whales taken (IWC, 1986). Under-reporting of catches would imply that calculated CPUE indices are biased downwards. Calculated trends also could be incorrect, in particular if the rate of under–reporting has increased since 1976. In turn this would result in an underestimate of the replacement yield, even if the harvest has been larger than assumed in the estimate. The effects of under-reporting on the conclusions that can be drawn, are investigated by Rørvik (1987).

In the absence of alternative data, eg. from sighting surveys, the calculated CPUE indices must nevertheless be accepted as the best available basis for an evaluation of the status of the stock and the permissible catch. However, the scientific basis for any conclusion is impaired by unexplained variations in the C/NCD-1 indices, problems with fitting the model, possible under-reporting of catches and uncertainties in the mark-recapture population estimates. Hence, we meet difficulties in applying the strict criteria for classification adopted from the Whaling Commission's current management procedures. Estimates of replacement yields depend heavily upon the selection of the time series. In this context we feel that recent trends should be decisive.

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Table 2. National and international measures regulating Norwegian small-type minke whale fisheries in the North Atlantic 1938–1985

Season	Regulatory measures
Pre 1938	No regulation.
1938	Licencing system combined with compulsory catch reports. 381 licencees.
1950	301 licencees. Summer closure 1 - 21 July.
1952	246 licencees. Six months whaling season from 15 March to 14 September with summer closure maintained.
1955	203 licencees. Whaling season North of 70°N and East of 0°, 15 March - 30 June, with other areas as in 1952.
1958	202 licencees. Iceland's fisheries zone to 12 naut. miles closed for Norwegian whaling.
1961	190 licencees. Whaling season 15 March - 30 June also South of 70°N in the area East of 25°E (southeastern Barents Sea).
1972	123 licencees. Whaling season 15 March - 15 July in all areas North of 65°N and East of 15°W (season actually closed this year on 27 June). Other areas as in 1952. Icelandic fisheries zone, closed for Norwegian whaling, expanded from 12 to 50 naut. miles.
1973	118 licencees. Whaling season 1 April - 30 June in areas North of 70°N and East of 0°, as well as south of 70°N in the area East of 25°E. Season in other areas 1 April - 31 August with summer closure 1-21 July. Maximum quantity of meat 70 tons per vessel.
1974	100 licencees. Whaling season 1 May - 30 June North of 70°N in waters East of 20°W and South of 70°N in the area East of 25°E; 15 April - 31 August in the other areas East of 44°W (Kap Farvel, Greenland); 15 May - 31 August with closure 1-21 July West of 44°W.
1975	91 licencees. Icelandic fisheries zone, closed to Norwegian whalers, expanded from 50 to 200 naut. miles.
1976	93 licencees. Total quotas for North Atlantic minke whales imposed upon IWC decision: 2,000 whales East of Kap Farvel, 550 whales West of Kap Farvel.
1977	93 licencees. IWC minke whale quotas: Northeast Atlantic 1790 (all Norway), Central North Atlantic 320 (Norway 120), West Greenland 325 (Norway 75) and Canadian East Coast 48 (Norway 0). Summer closure suspended at East Greenland - Iceland - Jan Mayen and at West Greenland. EEC fisheries zones closed to Norwegian whalers during the season.
1978	91 licencees. IWC minke whale quota at West Greenland: 397 (Norway 75). Quotas in other areas as in 1977.
1979	91 licencees. IWC quotas as in 1978. Whaling season 15 May - 15 July North of 70°N East of 20°W and South of 70°N East of 25°E; 15 April - 31 August with closure 1-21 July in Norwegian coastal waters, and Norwegian zone of the North Sea South of 70°N; 15 May - 31 August at West Greenland South of 71°N and East of Canadian zone.
1980	92 licencees. IWC quotas: 385 at West Greenland (Norway 75), no change from 1977 in other areas. Whaling season: 28 May - 15 July East of 33 E; 16 May - 15 July North of 70°N between 5°W and 33°E and South of 70°LN between 25°E and 33°E; 15 April - 31 August with closure 1-21 July as in 1979 and 100 whales reserved for coastal whaling after 21 July in Norwegian coastal waters South of 70 N and in the Norwegian North Sea zone; 25 July - 31 August in the Central North Atlantic area (East Greenland - Jan Mayen outside the Icelandic fisheries zone); 16 May - 31 August at West Greenland South of 71 N and East of the Canadian fisheries zone.
1981	91 licencees. IWC quotas: Canadian East Coast 0, West Greenland block quota 1778 over 5 years, max 444 per year (Norway 75), no change from 1977 in other areas. Whaling season: 3 August - 30 September at East Greenland - Jan Mayen; 16 May - 30 September at West Greenland; no change from 1980 in other areas, but whaling in the Barents Sea was closed on 8 July.
1982	88 licencees. IWC quotas as in 1981. Whaling season 28 May - 31 August East of 33°E; 16 May - 31 August North of 70°N between 5°W and 33°E and South of 70°N between 25°E and 33°E; 15 April - 31 August as in previous years but without a summer closure in Norwegian coastal waters and the Norwegian North Sea zone south of 70°N; 1 August - 10 September at East Greenland - Jan Mayen; 16 May - 10 September at West Greenland.
1983	88 licencees. IWC quotas: Northeast Atlantic stock 1690 whales (decided by Norway upon advice from IWC Scientific Committee); Central stock 300 (Norway 112); West Greenland 444 of five year block quota as in 1981 (Norway 75). Closing dates for whaling in Norwegian coastal waters and the North Sea South of 70°N changed to 10 October and at West Greenland to 20 September; whaling season at East Greenland - Jan Mayen 30 July - 22 August; other areas as in 1982.
1984	55 licencees. IWC quotas: Northeast Atlantic stock 635 whales, Central stock 291 whales (Norway 104); West Greenland 300 whales (Norway 70). As a new measure, quotas were allocated between individual licencees on the basis of their average catches through the last five years. Whaling season 28 May - 31 August as in 1981-1982 East of 33°E; 21 May - 18 September North of 70 N between 5°W and 33°E and South of 70°N between 25°E and 33°E; 21 May - 18 September on the coast and in the North Sea South of 70°N; opening dates 18 June at East Greenland - Jan Mayen and 15 July at West Greenland.
1985	53 licencees. IWC quotas: Central stock 242 whales, no change for other stocks. Norway was allocated 85 whales at East Greenland - Jan Mayen and 52 whales at West Greenland. Whaling season: 21 May - 1 August in the Norwegian economic zone South of 69°N; 28 May - 1 August in the Norwegian zone North of 69°N and the Soviet zone in the Barents Sea; 3 June - 1 August in the Svalbard zone. Opening dates 28 May at East Greenland - Jan Mayen and 15 July as in 1984 at West Greenland.

MULTISPECIES CATCHES BY NORWEGIAN SMALL-TYPE WHALERS WITH SPECIAL REFERENCE TO THE SIGNIFICANCE OF BOTTLENOSE CATCHES FOR THE BARENTS SEA MINKE WHALE CPUE INDICES

ABSTRACT

A C/NCD-1 series for the Barents Sea area has been calculated excluding vessels that have caught one or more bottlenose whales during the season. This series is not different from that calculated previously including all catch records, thus indicating that other factors than a possible distortion by bottlenose catches have caused the apparent increase in the series in the 1960s. Catches of other small whale species, i.e. killer and pilot whales, are also discussed, but seem to be quite irrelevant to the Barents Sea C/NCD-1 index.

INTRODUCTION

At the 1986 IWC Scientific Committee meeting, concern was raised about the possible influence of bottlenose catches on the Norwegian minke whale CPUE series, espescially during the 1960s (IWC, 1987). This problem has been discussed on several occasions. It was recognized as a major difficulty in evaluating CPUE for the minke whale fishery by Bertrand (1977), who pointed out that in fact three other species (bottlenose, killer and pilot whales) might have played a significant role in the overall fishing effort. He pointed out that from 1938 to 1950 the minke whale catch was always greater than 90% of the total small whale catch, but from 1959 to 1971 the take of bottlenose, killer and pilot whales varied between 11 and 28% of the total fishery.

Christensen (1975) has given summaries of small whale catches in the North Atlantic both as totals and as catches in sub-areas. From these tables it is evident that in certain periods considerable numbers of bottlenose whales have been taken in addition to minke whales, also in the Spitsbergen-Barents Sea region which is of most interest to the Barents Sea CPUE indices. However, he gives no indications of effort allocations for different species. Detailed information on each vessel that has caught a bottlenose whale and the catch by month is given by Christensen (1976), but that paper does not ascribe the catches to whaling grounds.

Mitchell (1975) has given catch statistics for the bottlenose whales by area, year and month, but there is no information on effort. His tables indicate that the peak month of bottlenose catches in the

Spitsbergen-Barents Sea area has been May, but in more western areas (Shetland, Iceland, Greenland, Jan Mayen) June may have been the more important catching month.

Rørvik and Christensen (1981) discussed the multispecies character of the minke whale fishery. They found that the peaks of the catches of minke and bottlenose whales were in May-June, while killer whales were taken more continuously through a longer season, and pilot whales exclusively in August. However, when considering only the Northeast Atlantic stock area, excluding the Faroe Islands and the British Isles, in the peak months May and June the dominance of minke whales in the total catches in those areas from 1952 to 1975 have varied between 89.6% and 99.9%. The average by-catches over that period have been 1.4% bottlenose whales, 0.9% killer whales and 0.1% pilot whales. In addition, most of those bottlenose whales were not taken by minke whale catchers. Their conclusion was that by-catches in the Northeast Atlantic minke whale fishery hardly affected the effort directed towards minke whales.

Benjaminsen (1972) gives some relevant data on the localities where the bottlenose whales were caught: In the 1960s most of the catches were taken at Iceland, although considerable numbers were also caught in the Svalbard area. However, at Svalbard the deep water bottlenose grounds do not overlap the minke whale grounds, which are in the adjoining shallow waters.

MATERIALS AND METHODS

These analyses are based on computerized catcher logbook forms. For bottlenose and killer whales these are believed to be complete, perhaps with insignificant minor errors, and they seem to be in good agreement with catch statistics published by the Bureau of International Whaling Statistics (BIWS). However, for pilot whales the catcher forms we have at hand are definitely not complete, and we are lacking all forms concerning pilot whales from 1964 onwards. According to BIWS, 643 pilot whales have been caught during the period 1964 to 1970. The minke whale database is the same as described in Øien, Jørgensen and Øritsland (1987), with the addition of a few catcherforms from the early 1960s.

The method for calculating catch per net catcher day indices for the Barents Sea area is as described previously (Rørvik, Øien, Øritsland and Christensen 1985, Øien et al. 1987).

RESULTS

In Table 1 the number of vessels that participated in Norwegian small type whaling on any of the North Atlantic whaling grounds have been tabulated according to composition of total catches in each season, neglecting whether there have been separate trips for different whale species or not.

In the following CPUE analysis all vessels that have caught at least one bottlenose whale in any particular season, regardless of when or where, have been excluded when selecting data for the GLIM analysis. The resulting C/NCD-1 series for the Barents Sea calculated exactly as the series presented by Øien et al. (1987), is given in Table 2. A visual picture of the series is given in Fig. 1. Calculated trends for the full series and for ten-year periods within the series are given in Table 3 together with the corresponding results for the previous series.

DISCUSSION

During discussions of the Scientific Committee (IWC, 1987), the strange behaviour of the Barents Sea C/NCD-1 series as presented by Øien et. al. (1987), was debated and several suggestions were put forward to explain special features of the series, of which the apparent increase during the 1960s is particularly difficult to interpret. One suggestion was to reject the series for all years prior to 1970, because the series for those years may have been distorted by bottlenose catches mixed up with minke whale catches. As is seen from Tables 2 and 3 and Fig. 1, exclusion of the bottlenose catches makes virtually no difference to the Barents sea indices and therefore invalidates that argument. The differences observed are possibly derived from the fact that most of the bottlenose whales were caught by relatively few vessels (Rørvik and Christensen, 1981) which also were efficient minke whale catchers, and thus a considerable number of minke whale catches have been excluded from the underlying raw data.

It is seen from Table 1 that only on a few rare occasions any vessel has been catching only one of the by-catch species (bottlenose, killer or pilot whales) during a particular season. It is also seen that the most frequent patterns on a seasonal basis are either a by-catch of bottlenose whales or of killer whales. In the Northeast Atlantic, pilot whales have mostly been caught at Shetland and the Faroe Islands (Christensen, 1975), and they have been taken almost exclusively in August (Rørvik and Christensen, 1981). Thus the pilot whale catches cannot have affected the Barents Sea C/NCD-1 index.

According to Rørvik and Christensen (1981), the peaks in catches of both minke and bottlenose whales in the period 1952-1975 occurred in May and June for both species, while killer whales have been caught more continuously throughout the year. In addition killer whales have mostly been caught in the Vestfjord and Møre areas, with only a few sporadic catches in the Barents Sea (Jonsgård and Lyshoel, 1970) as defined for the purposes of calculating the C/NCD-1 series (Øien et al. 1987). Hence, there is no indication of a distortion of the Barents Sea CPUE indices by the killer whale cathes.

Referring to Table 1, we may conclude that on a seasonal basis, the number of vessels that have caught bottlenose whales are insignificant compared to those that have caught minke whales only. The by-catches have mostly been either bottlenose or killer whales, of which the bottlenose whales have been shown to have no effect on the Barents sea C/NCD-1 indices, and the killer whales have been taken in other areas than the Barents Sea.

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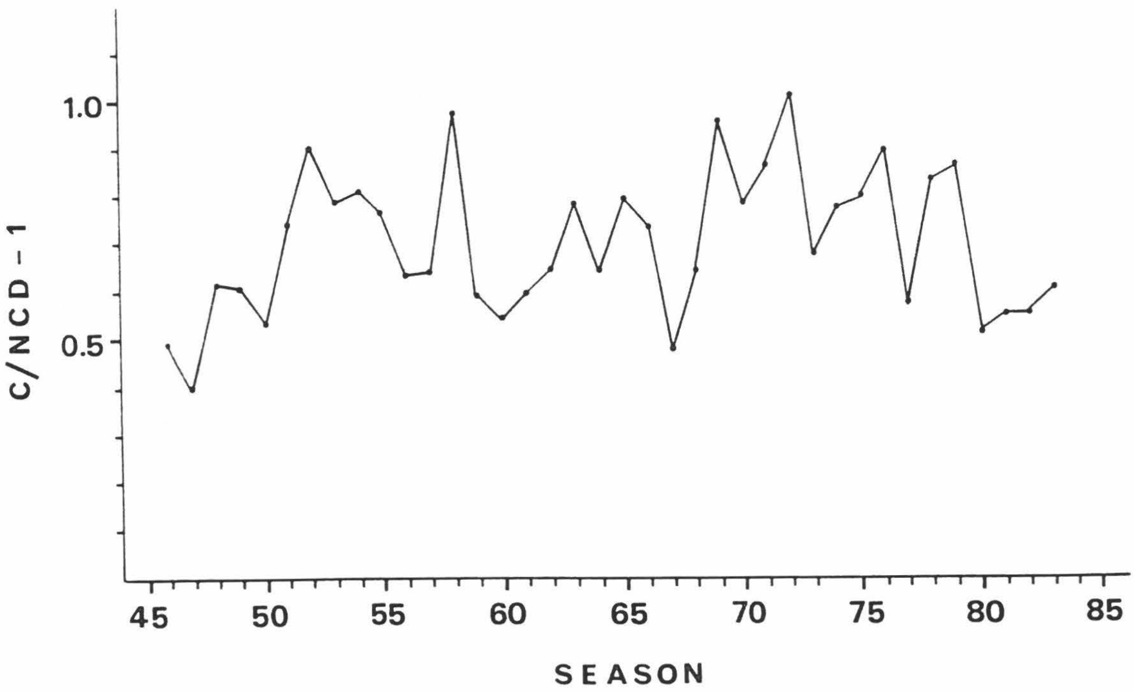

Fig. 1. 'Catch per net catcher day - 1' in the larger Barents Sea area through 1946-1983 as calculated when all vessels that have caught at least one bottlenose whale are excluded from the analysis.

Table 1. A summary of the number of participating vessels in Norwegian small type whaling on North Atlantic whaling grounds according to any combinations of total catches in each season since 1938. B= bottlenose; K= Killer whales; P= Pilot whales. Data on pilot whales from 1964 onwards are lacking.

		Minke whales and:							Minke not involved:				
	Minke only	B	K	P	B+K	B+P	K+P	B+K+P	B	K	P	B+P	Totals
1938	219	15	25	0	5	0	0	0	0	0	0	0	264
1939	150	4	9	6	3	2	1	1	3	1	0	0	180
1940	74	4	2	0	0	0	0	0	0	0	0	0	80
1941	234	7	10	4	0	0	0	0	2	0	0	0	257
1942	287	4	30	1	0	2	0	0	0	2	1	0	327
1943	245	11	9	1	4	3	0	0	3	0	0	1	277
1944	234	16	18	3	1	0	0	0	3	0	0	0	275
1945	204	11	10	3	0	1	1	0	4	0	0	0	234
1946	218	5	20	1	2	0	0	0	0	0	0	0	246
1947	201	12	12	0	4	3	0	0	1	0	0	0	233
1948	251	18	15	1	7	0	0	0	0	0	0	0	292
1949	269	50	21	4	3	1	0	0	4	0	0	0	352
1950	179	15	5	1	1	1	0	0	0	0	0	0	202
1951	203	10	15	1	0	1	0	1	1	0	0	0	232
1952	208	6	7	1	1	1	0	0	0	0	0	0	224
1953	151	9	8	1	0	0	0	0	0	0	0	1	170
1954	165	10	10	0	1	0	0	0	1	0	0	0	187
1955	167	6	9	4	6	1	0	0	0	0	0	0	193
1956	160	13	18	1	6	0	0	0	0	0	0	0	198
1957	142	12	21	12	2	2	3	2	0	0	0	0	196
1958	148	8	22	2	2	6	0	1	0	0	0	0	189
1959	148	11	12	2	3	2	2	5	0	0	0	0	185
1960	129	6	21	8	5	5	1	6	0	0	0	0	181
1961	131	7	21	6	3	4	3	3	0	0	0	0	178
1962	124	5	25	3	5	2	0	4	0	0	0	0	168
1963	111	7	19	7	4	2	0	4	0	0	0	1	155
1964	115	3	16	-	9	-	-	-	1	0	-	-	144
1965	111	4	11	-	11	-	-	-	0	0	-	-	137
1966	72	4	26	-	12	-	-	-	0	0	-	-	114
1967	102	5	6	-	6	-	-	-	0	0	-	-	119
1968	99	5	9	-	12	-	-	-	0	0	-	-	125
1969	80	9	16	-	7	-	-	-	0	1	-	-	113
1970	82	11	20	-	5	-	-	-	1	0	-	-	119
1971	88	6	9	-	2	-	-	-	0	0	-	-	105
1972	94	0	4	-	1	-	-	-	0	0	-	-	99
1973	97	1	1	-	0	-	-	-	0	0	-	-	99
1974	79	-	3	1	-	-	-	-	-	0	-	-	83
1975	78	-	1	-	-	-	-	-	-	0	-	-	79
1976	83	-	0	-	-	-	-	-	-	0	-	-	83
1977	84	-	3	-	-	-	-	-	-	0	-	-	87
1978	66	-	20	-	-	-	-	-	-	0	-	-	86
1979	62	-	23	-	-	-	-	-	-	0	-	-	85
1980	76	-	12	-	-	-	-	-	-	0	-	-	88
1981	82	-	7	-	-	-	-	-	-	0	-	-	89
1982	80	-	-	-	-	-	-	-	-	-	-	-	80
1983	80	-	-	-	-	-	-	-	-	-	-	-	80
1984	55	-	-	-	-	-	-	-	-	-	-	-	55
1985	53	-	-	-	-	-	-	-	-	-	-	-	53
1986	53	-	-	-	-	-	-	-	-	-	-	-	53

Table 2. 'Catch per net catcher day - 1' for Norwegian catches of minke whales in the Barents Sea (statistical areas 1-6) 1946-1983, when all vessels that have caught one or more bottlenose whales during the season have been excluded. This index includes catches from 21 May to 30 June taken by 50-94 feet long vessels each year.

Season	C/NCD	Season	C/NCD	Season	C/NCD
1945	-	1960	0.5465	1975	0.7988
1946	0.4937	1961	0.5968	1976	0.8986
1947	0.4000	1962	0.6482	1977	0.5725
1948	0.6173	1963	0.7858	1978	0.8309
1949	0.6096	1964	0.6438	1979	0.8683
1950	0.5328	1965	0.7945	1980	0.5135
1951	0.7409	1966	0.7386	1981	0.5519
1952	0.9033	1967	0.4788	1982	0.5515
1953	0.7893	1968	0.6424	1983	0.6068
1954	0.8113	1969	0.9558		
1955	0.7633	1970	0.7862		
1956	0.6339	1971	0.8641		
1957	0.6404	1972	1.0135		
1958	0.9781	1973	0.6760		
1959	0.5920	1974	0.7784		

Table 3. Estimated trends in the Barents Sea C/NCD-1 series when bottlenose catchers are excluded from the raw data. In parentheses the corresponding trends calculated from the full series as given in Øien *et al*. (1987). P is the probability that C/NCD-1 is stable or increasing.

Series	Trend in % per year		P
	in mid. year;	in 1983	
1952-1983	- 0.3 (- 0.4)	- 0.3 (- 0.3)	0.23
1952-1959	- 2.9 (- 3.4)		0.16
1960-1969	+ 2.8 (+ 2.3)		0.89
1970-1979	- 0.8 (- 0.6)		0.34
1970-1983	- 3.2 (- 3.2)	- 4.1 (- 4.0)	0.007

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Length Distributions in Catches from the Northeastern Atlantic Stock of Minke Whales

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ABSTRACT

Length distributions from the Northeastern [Atlantic] stock of minke whales are presented and discussed. Annual mean lengths in the total catches show an increasing trend over the whole period 1938–1983, but with a levelling off since the 1970s. The trends are ascribed to segregation of the whales by sex and size and changes in the relative importance of different whaling areas. However, some changes in the shape of the length distributions from the northeast Atlantic minke whales have occured, although these are not revealed by changes in annual mean lengths. Examples are given of a subarea with both an increase in mean length and a change in the length distribution, and a subarea where neither mean length nor distribution have changed. Changes in catching season regulations may be an additional complicating factor in analyses of length distributions from the Norwegian small-type whaling for minke whales.

INTRODUCTION

Changes in age distributions in catches are generally believed to reflect changes in the structure of populations and the status of stocks. The only published age data from the northeast Atlantic minke whales (called the 'Northeastern' stock by the International Whaling Commission) was presented by Christensen (1981). The material was collected from catches in the Barents Sea area in May and June during the whaling seasons 1972–77. Relationships between numbers of bullae growth layers and lengths were tentatively established from those data using von Bertalanffy equations, but these showed discrepancies which may be ascribed to the lack of data for the youngest and oldest age groups and considerable variations in lengths at age. We therefore have only a limited knowledge of growth rates for northeast Atlantic minke whales, and for consideration of historical catches, we are left with the recorded lengths as relative measures of age. In this paper some length distributions in catches from the Northeastern Atlantic stock of minke whales are discussed as potential indicators of stock condition.

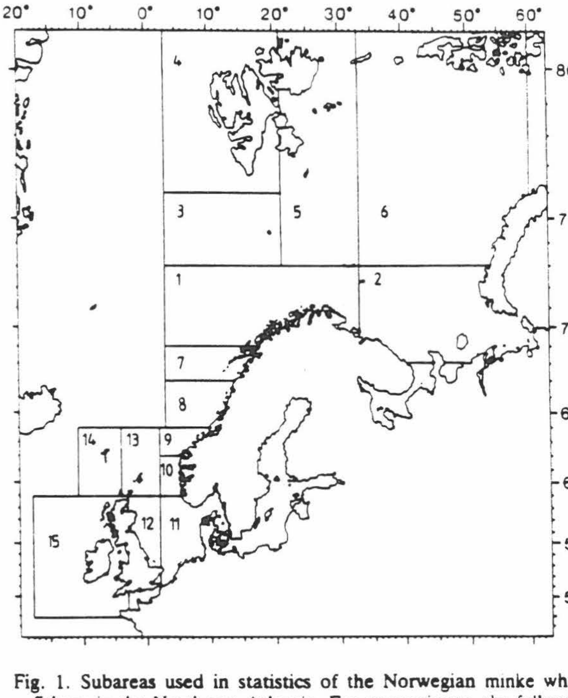

Fig. 1. Subareas used in statistics of the Norwegian minke whale fishery in the Northeast Atlantic. For convenience, the following terms have been adopted in the text: Barents Sea: Areas 1–6; Vestfjord: Area 7; North Sea: Areas 9–15 (from Øien *et al.*, 1987)

DATA SOURCE

The lengths used are those reported by the whalers in the compulsory forms which are submitted for each whale caught according to the licensing system introduced in 1938. Although it is prescribed in the original directions that this measurement is to be taken by tape measure which all ships are obliged to have on board, most of the lengths have been estimated by eye. These estimated lengths are given to the nearest foot and are believed to be quite accurate, as they are estimated by experienced whalers comparing whale lengths to known measurements on the ship. However, no formal analysis of their reliability has been made. Jonsgård and Lyshoel (1970) found deviations up to ± 2ft between estimated and measured lengths of several species (including minke whales, Christensen, pers. comm.) but also that the estimated lengths were generally correct or almost correct.

Previous divisions of the Northeastern stock area into sub-areas are maintained for the present analysis (Fig. 1).

RESULTS

Annual mean lengths through the years 1938–85 for the total catches of females and males from the Northeastern stock (Areas 1–15) are plotted in Fig. 2. They show a distinct downward trend during the Second World War, but rise quickly after 1945 and have shown an increasing trend since, with a sharp peak in 1984 and 1985. Since the late 1950s, the mean lengths have been larger than the means for the compiled period 1938–85. Linear regressions over the periods 1938–83 (i.e. excluding 1984 and 1985) give regression coefficients that are significantly different from zero (at a significance level of $\alpha=0.01$) of 0.066

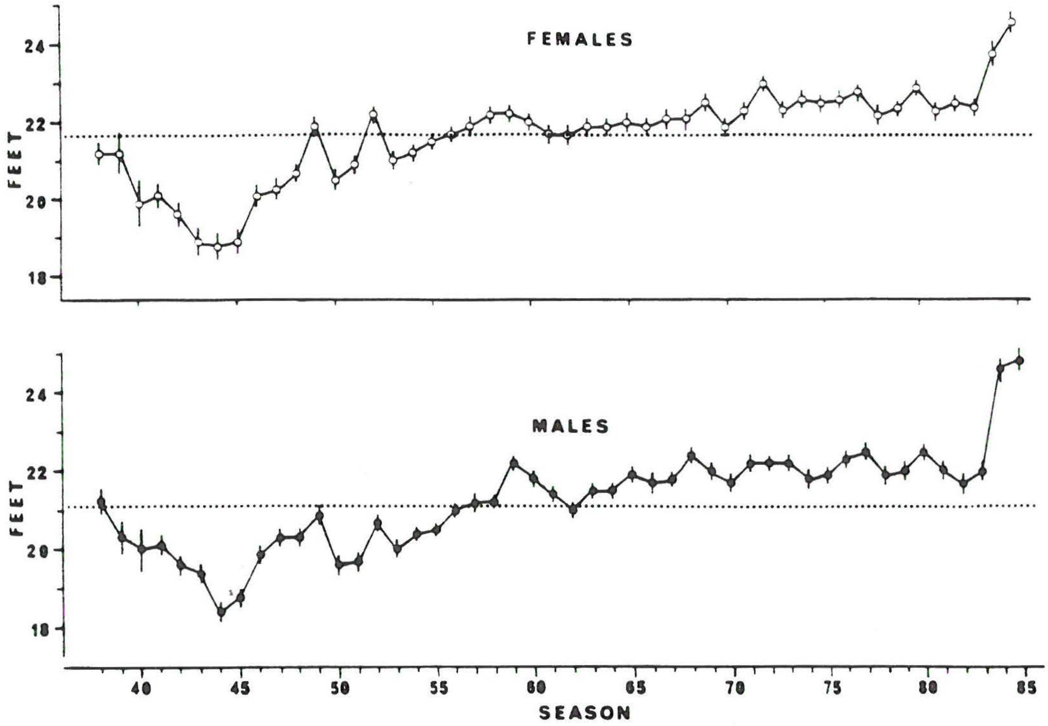

Fig. 2. Annual mean lengths in total catches for the period 1938–1985 for the Northeastern stock. The bars indicate approximate 95% confidence intervals for the means. Upper half: females; lower half: males. The dashed lines are the average lengths in the total samples.

(SD=0.0072) and 0.065 (SD=0.0066) for females and males respectively. However, the increase seems to have levelled out during the 1970s, as corresponding regressions over the period 1970–83 give regression coefficients of 0.011 (SD=0.0199) and 0.000 (SD=0.018), neither significantly ($\alpha=0.05$) different from zero by a t-test.

Fig. 3 shows length distributions and Table 1 gives the mean lengths and sample sizes in the reported catches from the entire Northeastern stock area for different selected years. The overall impression is that the relative catch load has been transferred from smaller to larger length-groups from 1940–85. Simultanously the extremes, i.e. the very small and the very large whales, have gradually reduced their shares of the total catches. Around 1960 the length distribution changed from a peak at small lengths to a nearly equally shared load on all length-groups in the range 17–27ft. This change is revealed as an increase in mean lengths in Fig. 2 and Table 1, and is further confirmed by a Kolmogorov-Smirnov two-sample test (Sokal and Rohlf, 1981) leading to the conclusion that, for example, the 1940 and 1960 total samples illustrated in Fig. 3 come from populations with highly different distributions ($D=0.269 \gg D_{0.01}=0.076$). By 1970 the length distributions started to show a peak around mean lengths, i.e. at about 22–23ft, a tendency that has been strengthened since. Although this is not seen as a significant difference in mean lengths between the 1960 and 1970 total samples, the K-S test shows there is a significant ($\alpha=0.01$) difference between those two distributions ($D=0.058 > D_{0.01}=0.047$). Although the further changes in mean lengths (Fig. 2, Table 1) appear less convincing, the K-S test gives a significant difference ($\alpha=0.01$) between the total length distributions from 1970 and 1975 ($D=0.079 > D_{0.01}=0.057$), and between 1975 and 1980 ($D=0.083 > D_{0.01}=0.058$). The catch distribution for 1985 has a rather sharp peak at 24–26ft, a feature that will be discussed later.

Table 1

Mean lengths, and their standard deviations (L, SD), in total catches from the Northeast Atlantic stock of minke whales for selected years. n = sample size. The totals may add up to more than the number of males + females because some catch data lacks information on sex

	Males			Females			Total		
Season	L	SD	n	L	SD	n	L	SD	n
1940	20.0	0.26	256	19.9	0.30	232	19.8	0.19	525
1950	19.6	0.12	948	20.5	0.13	1,018	20.0	0.09	1,977
1955	20.5	0.08	2,039	21.5	0.08	2,240	21.0	0.06	4,300
1960	21.8	0.09	1,519	22.0	0.10	1,702	21.9	0.07	3,232
1965	21.9	0.11	1,018	22.0	0.12	1,088	22.0	0.08	2,114
1970	21.7	0.10	880	21.9	0.11	1,000	21.8	0.08	1,888
1975	21.9	0.12	598	22.5	0.11	827	22.2	0.08	1,426
1980	22.5	0.10	776	22.9	0.10	1,006	22.7	0.07	1,782
1985	24.9	0.13	320	24.6	0.13	309	24.8	0.09	629

Length distributions and sex compositions for each of the sub-areas, based on the total catches for the full period 1938–85, are shown in Fig. 4, while the trends in two sub-areas, Area 7 (Vestfjorden) and Area 2 (southeastern Barents Sea) are illustrated in Figs 5 and 6 respectively. Mean lengths for the distributions shown in Figs 4–6 together with their standard deviations and sample sizes are given in Tables 2 and 3. Table 2 shows that the mean lengths of females and males are different in most areas as judged by approximate 95% confidence limits around the means. The exceptions are found in Vestfjorden (Area 7) and on the Finnmark coast (Area 1). North of this zone

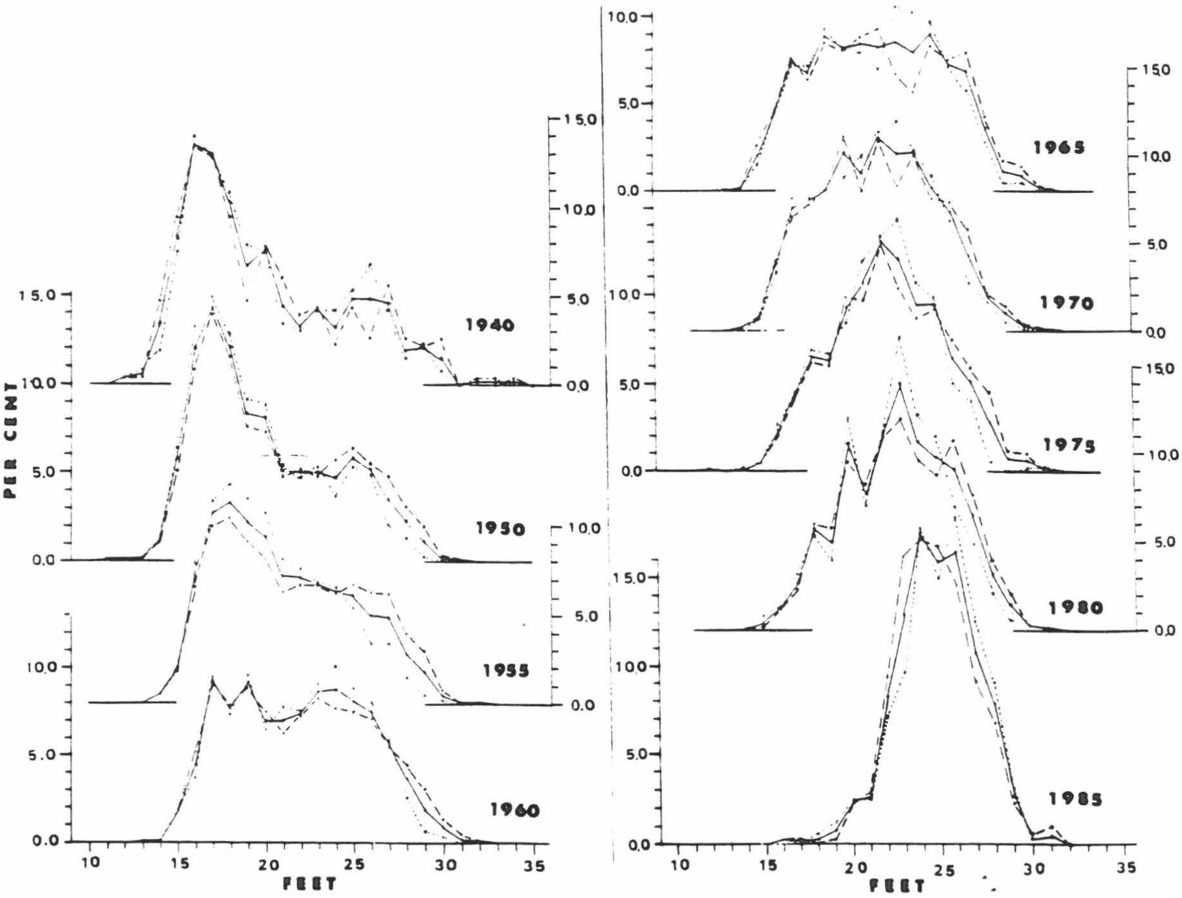

Fig. 3. Length distributions in total catches from the Northeastern stock for selected years. Legend: solid line, totals; dashed line, females; dotted line, males.

Table 2

Mean lengths, and their standard deviations (L, SD), in statistical areas 1–15, all catches in the seasons 1938–85 compiled. n = sample size. The totals may add up to more than the number of males + females because some catch data lacks information on sex

	Males			Females			Total		
Area(s)	L	SD	n	L	SD	n	L	SD	n
01	22.5	0.04	6,195	22.4	0.06	4,309	22.5	0.03	10,540
02	22.3	0.03	8,071	22.8	0.03	13,747	22.6	0.02	21,938
03	22.6	0.06	2,248	23.2	0.05	3,692	23.0	0.04	5,952
04	22.8	0.06	1,706	23.6	0.04	4,826	23.4	0.03	6,551
05	22.4	0.11	759	23.8	0.08	1,481	23.3	0.07	2,245
06	22.8	0.07	2,059	24.3	0.05	4,621	23.8	0.04	6,707
01–06	22.5	0.02	21,177	23.2	0.02	32,814	22.9	0.01	54,215
07	19.1	0.03	16,120	18.9	0.03	13,566	19.0	0.02	29,906
08	20.3	0.09	2,323	18.8	0.09	1,505	19.7	0.06	3,866
09	20.0	0.07	3,358	19.0	0.07	2,645	19.6	0.05	6,079
10	21.6	0.06	2,744	20.9	0.10	1,342	21.4	0.05	4,135
11	23.6	0.11	591	24.4	0.12	871	24.1	0.09	1,472
12	23.1	0.12	735	24.5	0.17	523	23.7	0.10	1,269
13	22.1	0.07	1,947	21.5	0.12	913	21.9	0.06	2,892
14	21.9	0.12	756	20.8	0.18	362	21.5	0.10	1,126
15	22.2	0.10	906	22.6	0.18	435	22.3	0.09	1,345
01–15	21.1	0.02	50,518	21.7	0.02	54,838	21.4	0.01	106,023

(Areas 2–6) the females are on an average the largest, and south of this zone the males have the largest average lengths with a few exceptions in the North Sea (Areas 11 and 12) where the females caught have the largest mean lengths when all areas are considered. The percentages of females in the catches are highly dependent on area as seen by a G-test (G=6563, 14 df, P<<0.001).

Table 3

Mean lengths, and their standard deviations (L, SD), for selected years in catches from statistical areas 7 (Vestfjorden) and 2 (southeastern Barents Sea). n is sample size. The totals may add up to more than the number of males + females because some catch data lacks information on sex

Area	Males			Females			Total		
Season	L	SD	n	L	SD	n	L	SD	n
Area 07									
1945	18.0	0.13	686	18.6	0.15	569	18.3	0.10	1,262
1950	17.8	0.13	425	17.8	0.16	330	17.8	0.10	763
1955	19.4	0.11	831	19.1	0.12	717	19.3	0.08	1,552
1960	18.7	0.15	364	18.2	0.14	366	18.4	0.10	733
1965	20.1	0.19	349	19.7	0.21	342	19.9	0.14	692
1970	19.9	0.23	207	19.0	0.26	157	19.6	0.17	365
1975	20.3	0.30	130	20.6	0.45	89	20.4	0.25	219
1980	23.1	0.47	75	18.3	0.55	24	21.9	0.43	99
Area 02									
1950	21.8	0.40	45	22.6	0.27	121	22.4	0.23	168
1955	22.0	0.16	292	22.8	0.17	330	22.5	0.12	623
1960	23.1	0.18	269	22.9	0.18	343	23.0	0.13	613
1965	22.0	0.31	84	22.3	0.29	113	22.1	0.21	201
1970	21.5	0.30	48	22.4	0.19	207	22.2	0.16	257
1975	22.4	0.14	213	22.9	0.15	386	22.7	0.11	599
1980	22.0	0.16	299	22.8	0.13	528	22.5	0.10	827

Fig. 5 may give an impression of a change in the length distributions in Area 7 during the 1960s, changing from one to several peaks. The corresponding mean lengths in the total catches given in Table 3 show a significant increasing trend during the years (regression coefficient b=0.0967,

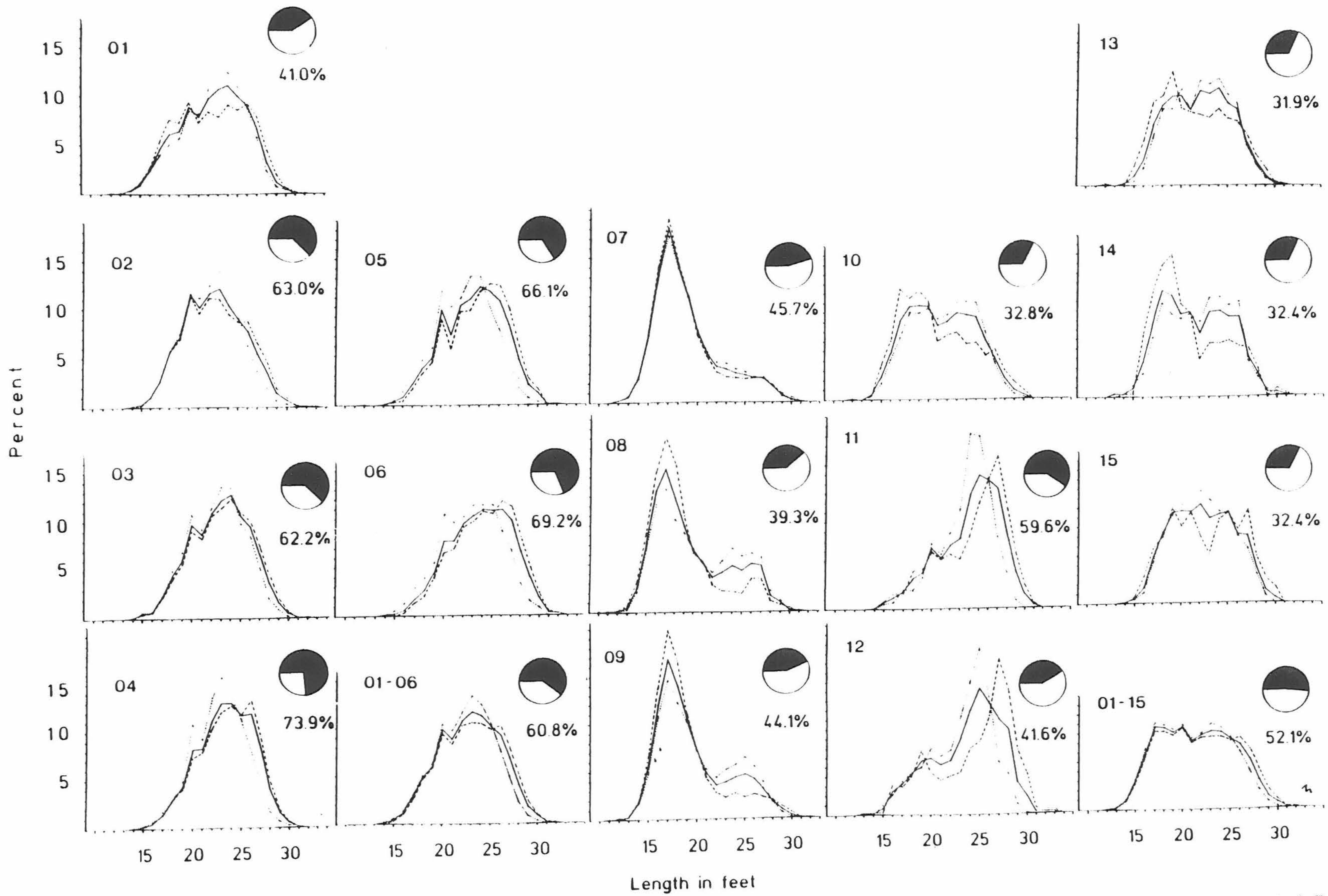

Fig. 4. Length and sex distributions of minke whales in statistical areas 1–15, all catches during 1938–1985 compiled. Black sectors of circles represent percentages of females in the catches. Legend as in Fig. 3.

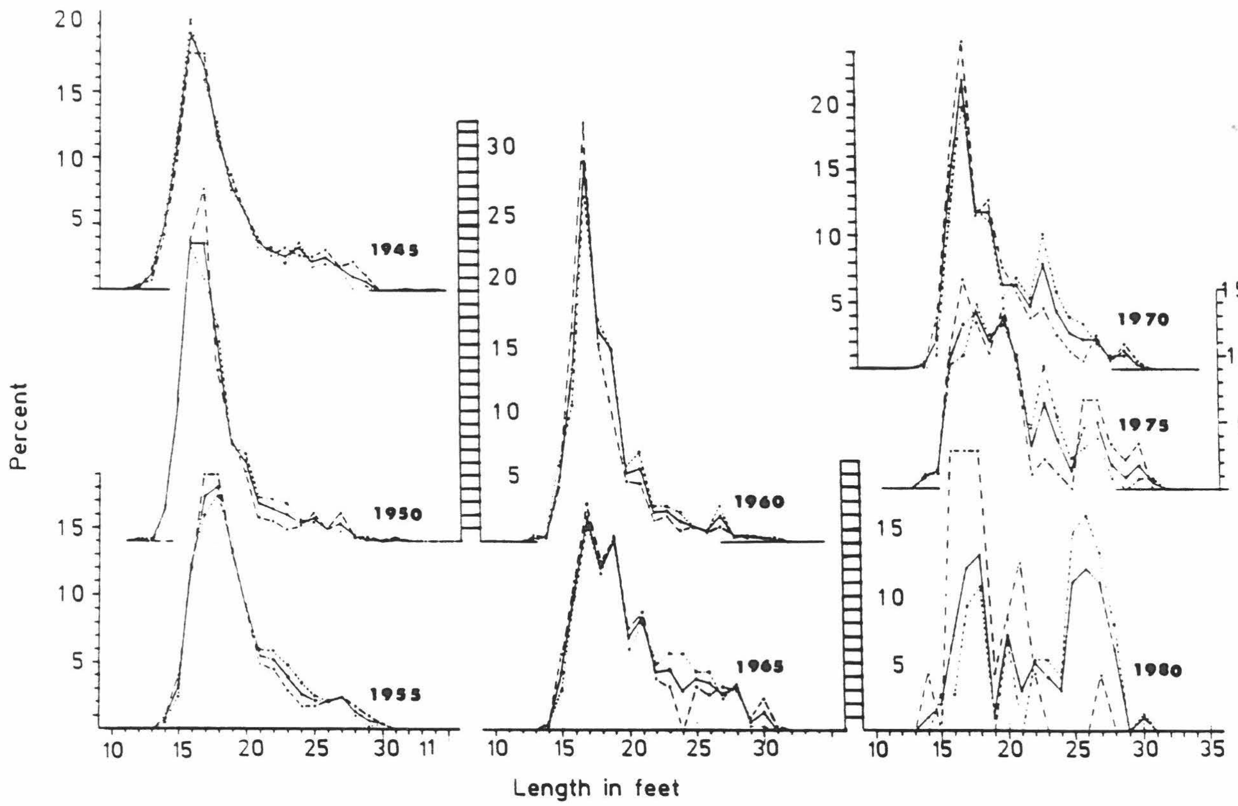

Fig. 5. Length distributions for selected years in total catches of minke whales from Area 7 (Vestfjorden). Legend as in Fig. 3.

SD=0.0199, P<0.01) even when leaving out the high 1980-figure (b=0.0750, SD=0.0207, P<0.02). No trend is apparent in the mean lengths of the total catches from Area 2 (Fig. 6, Table 3) as judged by a linear regression (b=-0.0007, SD=0.0125, P>>0.05), and a K-S two-sample test applied to the length distributions from two widely separated years with the same mean lengths, 1955 and 1980, does not indicate any significant difference between the distributions ($D=0.039 < D_{0.05}=0.072$).

DISCUSSION

It has been noted that the whale lengths used in this study were estimated by eye by the whalers and that no formal experiments have been carried out for testing their validity; thus no information on error structure or correction factors is available. However, Christensen and Rørvik (1981) found, by means of chi-square tests, no significant differences at the 95% confidence level between relative length distributions of age samples measured by standardized methods and catches with estimated lengths from the same area and seasons. This suggests that the estimated lengths from the catch data can provide some information on changes in these areas, especially given the large amount of material available.

Cooke (1984) concluded from simulation studies that depletion of baleen whale stocks through exploitation will not lead to significant changes in mean lengths of catches unless the stock is close to extinction, and that other factors may also affect the length distributions. This may be the case for the length distributions presented here. The annual mean lengths in the catches (Fig. 2) show a decrease during the war that may be easily explained by a shortage of fuel and restrictions on leaving nearshore waters. The whalers therefore had to operate within a short distance from port where they were more likely to catch small whales, as in area 7 (Fig. 5 vs Fig. 6).

The increasing trend in the mean annual lengths since 1945 may be explained by geographical expansion and changes in spatial allocation of the whaling effort for minke whales. The trend follows quite closely the increasing percentage of catches taken in the Barents Sea area, as given by Øien, Jørgensen and Øritsland (1987, Table 1). This is further emphasized by the fact that in two of the early years, 1949 and 1952, exceptionally high percentages of the total catches were taken in the Barents Sea area; for those years the mean annual lengths differ conspicuously from the general early years trend.

Although changes are apparent in the total catches from the Northeastern stock, with a relative displacement from smaller to larger length-groups, there is no straightforward conclusion to be drawn on how this may have affected the stock. The reduced shares of the smallest (<15ft) and largest (>31ft) whales may have some significance, but it must be remembered that the absolute numbers representing these length-groups in the catches have been rather small.

When discussing the length distributions for the total stock area, it is necessary to consider the segregational behaviour of minke whales by sex and length, as illustrated in Fig. 4 and in Table 2. The percentages of females in the catches depend on area, and females dominate catches in the Barents Sea with the notable exception of the Finnmark coast (Area 1), and in Area 11 in the North Sea.

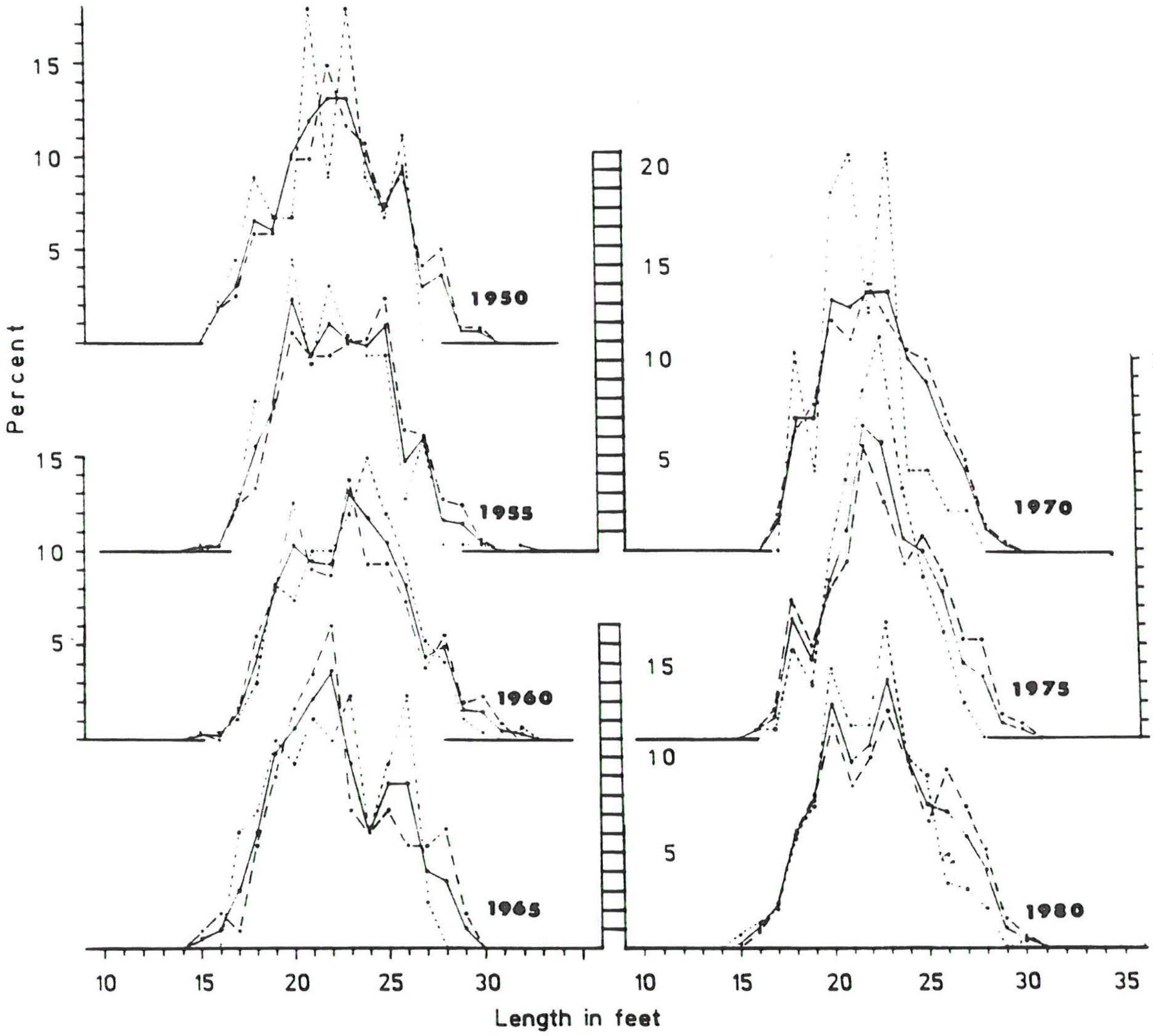

Fig. 6. Length distributions for selected years in total catches of minke whales from Area 2 (southeastern Barents Sea). Legend as in Fig. 3.

Otherwise males predominate in the catches around the British Isles and on the Norwegian coast including Finnmark. The length distributions fall into three main types; those peaked at around 17ft, which are typical for the coastal areas from Møre to Vestfjorden (Areas 7–9, Fig. 4b); those with a more or less symmetrical distribution as in the Barents Sea and the area west of the British Isles; and finally those skewed to the right, as in the North Sea (Areas 11–12, Fig. 4). Consequently, the total length distributions in the catches from the whole stock area will be heavily influenced by the distribution of catches between areas. As shown by Øien *et al.* (1987), changes have occured in the distribution of catches with time. Since the beginning of the 1970s the major catches have been taken in the Barents Sea, suggesting that this is the main reason for subsequent length distribution changes shown in Fig. 3.

Fig. 4 also shows that in general the length distributions of females are displaced slightly to the right compared with the males, but according to Table 2 it appears to be a general tendency that in areas where the females tend to dominate the catches, they also have the largest mean lengths and vice versa.

The length distributions in Fig. 3 show an apparent concentration on whales of average lengths since the 1970s. No apparent change in mean lengths in the catches has been found, but the shoulders of the length distributions have disappeared and changed the shape of the distributions significantly as revealed by the K-S tests. This could mean a decline of older and younger animals and an increased mortality in the stock. However, segregational patterns, both areal and seasonal, may also have changed to confound this interpretation.

It is therefore of interest to examine more closely two of the most important whaling areas in the Northeast Atlantic: viz. Vestfjorden (Area 7, Fig. 5 and Table 3) and the southeastern Barents Sea (Area 2, Fig. 6 and Table 3). Since the 1970s, catches in Vestfjorden have been rather small (Øien *et al.*, 1987), which may explain the fluctuating length distributions in later years. The youngest age groups have always been predominant, although the absolute number of whales caught in this area has decreased considerably. However, the older age groups have become more important in this area over the years as indicated by the increasing trend of mean lengths, and this might indicate a decreased availability of the youngest age-groups in Vestfjorden, which is well-known as the area where calves previously spent most of the summer (Jonsgård, 1951).

In the southeastern Barents Sea, no statistically significant trends or distribution changes have been revealed. However, Fig. 6 suggests that the relative frequency of the largest whales may have decreased, but this apparently took place already in the early 1960s, and therefore is not directly correlated to the change in the Barents Sea CPUE indices (Øien *et al.*, 1987).

The conclusion from these preliminary considerations is that it will probably be necessary to study length distributions also in smaller areas during a season to gain insight into whether segregation in time might affect the distributions, since there have been changes in catching season regulations (Øien *et al.*, 1987).

Finally it seems appropriate to comment upon the length distribution for 1985 presented in Fig. 3: the catch statistics for 1984 and later years are of limited value for analysis, because the reduced and allocated quotas imposed since then have implied incentives for changing catch strategies to maintain economic yields, one of them being the searching for larger whales.

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SIGHTING ESTIMATES OF NORTHEAST ATLANTIC MINKE WHALE ABUNDANCE FROM THE NORWEGIAN SHIPBOARD SURVEY IN JULY 1987

ABSTRACT

Estimates of minke whale abundance in the area covered by Norwegian ships as part of the July 1987 North Atlantic Sightings Survey (NASS-87) are presented. The survey area, covering the Norwegian, Greenland and Barents Seas, was divided into five blocks of varying expected minke whale density. No confirmed primary sightings were made in the block comprising the northeastern part of the Barents Sea, but coverage in that area and also in the Greenland Sea block was very low. Effective search half-widths have been calculated by fitting a hazard-rate model to the perpendicular distance data. The survey alternated between closing and passing modes, and the total abundance estimates based on pooling perpendicular distances over blocks for the area surveyed are 17,382 (c.v. 0.304) and 22,774 (c.v. 0.235) minke whales, respectively. Pooling the perpendicular distances also over modes prior to fitting the hazard-rate model, results in a combined minke whale abundance estimate of 17,918 (c.v. 0.228). The data from the area surveyed by Norwegian vessels have been stratified with respect to the present IWC minke whale stock boundaries in the North Atlantic to relate the abundance to these. The estimated contribution to the Central stock is 4,461 (c.v. 0.273) animals, and to the Northeastern stock 12,459 (c.v. 0.293) minke whales. None of the estimates presented here have been corrected for possible deviations from the assumption g(0)=1 (i.e. all animals on trackline detected) since relevant information is not available at present.

INTRODUCTION

The two main objectives of the 1987 North Atlantic Sightings Survey (NASS-87) were to map the simultaneous distribution of whale species and to estimate their abundance (Anon., 1987). Compared to earlier surveys (Øien and Christensen, 1985), the area covered by Norway was greatly extended by including the Barents Sea to the northern ice edge, the Greenland Sea to the western ice edge and the northern Norwegian Sea. The southern and western parts of the Norwegian Sea were covered by Faroese and Icelandic vessels (Sigurjónsson, Gunnlaugsson and Payne, 1988).

Øritsland et al. (1988) reports on the sightings surveys conducted by Norway as part of NASS-87, including information on distribution of sightings by species. This paper deals with estimation of abundance of minke whales from the Norwegian shipboard survey.

ESTIMATION OF ABUNDANCE

Survey block boundaries

The total area surveyed by the Norwegian vessels was divided into five blocks (A, B1, B2, C1 and C2) as shown in Fig. 1. The blocks were covered by three vessels; Asbjørn Selsbane (block A), Veslekari (blocks B1 and B2) and Arnt Angel (blocks C1 and C2). Block areas have been calculated using outer coastlines and ice edges, as evaluated from the July 1987 monthly mean sea ice chart from the Norwegian Meteorological Institute, as borderlines where appropriate. Supplementary aerial surveys were intended at blocks west of Svalbard and in costal waters of northern Norway (Øritsland et al., 1988; Hiby, Ward and Lovell, 1988). These blocks, believed to be high density areas, received little effort from the shipboard surveys and then as parts of the larger blocks B2 and A, respectively.

Search effort

The primary sighting platform was a barrel mounted in the foremost masthead on each vessel. The transects were run with two experienced whalers as topmen when in primary searching mode.

The search effort was alternated between closing mode (ship diverts from trackline when sighting a whale) and passing mode (ship continues on the predetermined trackline upon sighting a whale), ideally on an equal share basis. This was accomplished by alternating modes between legs, or dividing longer legs into sections. The runned transects in each mode are shown in Figs 2 (closing mode) and 3 (passing mode). An additional transect was run at the continental shelf west of Spitsbergen to find whales for blow-rate experiments. The data from this transect have not been included in the other transect data and have therefore been dealt with separately.

During closing mode, sightings where species identification and/or school size were uncertain, were approached immediately.

Sighting rate

Only primary sightings recorded as confirmed with respect to species identification have been used for estimation of sighting rates. The main sighting cue was the body, which accounted for 91% of passing mode and 96% of closing mode primary sightings. Primary sightings were made by the topmen in the barrel (76% of total in passing mode and 82% in closing mode, respectively), by observers located on the wheelhouse roof (11% / 7%) and by observers located in the wheelhouse (11% / 11%). All these have been used in the fitting procedures, but a few sightings were left out after truncation of data.

No confirmed primary sightings of minke whales were made during the survey of block C2, although 245.7 n. miles and 329.7 n. miles were run with primary effort in closing mode and passing mode, respectively. In this block one minke approached the ship while drifting and one 'like-minke' was observed in passing mode. It follows from this that no abundance estimate is available for that block from the 1987 survey.

Coefficients of variation for the sighting rates have been calculated from truncated data using daily variation, with the exception of the result from the transect surveyed in connection with the blow-rate experiments at Spitsbergen (Table 1), which is based on variation between legs of the transect. The sighting rates compared between modes are not significantly different.

Mean school size

Mean school sizes (s) were calculated from all sightings made in closing mode where school sizes were recorded as confirmed. For blocks A and B2 all minke whale sightings with confirmed school sizes were of single animals although a few observations of schools of two whales were recorded as unconfirmed in those areas. The mean school size estimated from data pooled over blocks is 1.27 (c.v. 0.119).

Effective search half-width

As decided at the joint post-cruise meeting (Anon., 1988), effective search half-widths have been estimated by fitting a hazard-rate model (Hayes and Buckland, 1983) with a detection function of the form $g(y) = 1\text{-EXP}(-(y/a)^{1-b})$ to estimated perpendicular sightings distance data y. Generally, the numbers of primary sightings in each surveyed block are too few to allow a proper analysis with respect to the two-parameter hazard-rate model. The data were therefore pooled over all strata by mode (Fig. 4), truncated at 0.5 n. miles and effective search half-widths calculated for each mode separately. These estimates are basis of calculations given in Table 1.

The closing mode and passing mode perpendicular sighting distance distributions shown in Fig. 4 were tested by the Kolmogorov-Smirnov two-sample test (Sokal and Rohlf, 1981) and not found to be significantly different at the 1% level, neither for untruncated data ($D=0.174 < D_{0.01} = 0.390$) nor data truncated at 0.5 n. miles ($D=0.257 < D_{0.01} = 0.410$). The data truncated at 0.5 n. miles were therefore also pooled over mode and fitted to the hazard-rate model, resulting in an effective search half-width of w=0.2701 (c.v. 0.088). Recalculations based on the pooled data are presented in Table 2.

The approximate coverages as calculated from the latter effective search half-width are for block A: 0.5%; block B1: 0.8%; block B2: 0.2%; block C1: 0.7% and block C2: 0.2%.

IWC stock boundaries

The blocks were not defined to fit the present IWC classification of minke whale stock boundaries in the North Atlantic (IWC, 1977).

However, a compilation of abundance estimates referring to these boundaries, outlined in Fig. 1, has been made by rearranging the basic data from the two blocks concerned, i.e. blocks A and B2, into a Central stock component and a Northeastern stock component. The results are summarized in Table 3.

DISCUSSION

During sightings surveys in 1984 and 1985 (Øien and Christensen, 1985), the areas along the Kola and Finnmark coasts, and from Finnmark through Bear Island area to and including the west coast of Spitsbergen, were covered. These areas were thought to be the most important areas of minke whale distribution, based on previous knowledge from incidental sightings and catch distributions. However, the expansion of the study area in the present study has revealed a significant contribution to the abundance estimates of minke whales also from the northern Norwegian Sea area.

The survey in block B2, the Greenland Sea, was less successful with regard to abundance estimation as only one primary sighting was recorded in closing mode and eight in passing mode. However, coverage was very low in this block. The parts of the planned transect surveyed in closing mode were evenly distributed over the block as shown in Fig. 2, in contrast to the parts surveyed in passing mode (Fig. 3), mainly in the Jan Mayen area (76%). In the latter area all primary sightings were made in passing mode. It therefore seems unlikely that the density of minke whales from passing mode data as calculated in Table 1 is representative of the entire block B2.

In the northeastern Barents Sea (block C2) no primary sightings of minke whales were made. This area received some coverage in 1984 (Øien and Christensen, 1985) with no primary sightings made. Catch distributions, at least in the 1980's (Øien, Jørgensen and Øritsland, 1987), seem to confirm a present low abundance of minke whales in this area for parts of the year where information is available.

Passing mode was alternated with closing mode to ensure reliability both to species identification and school size estimations. It has been realized that the sighting rates in these areas are too low to allow such a data collection procedure with the present effort put into the surveys. The experience from this survey is that species identification is a minor problem in most of the areas covered. The exception is primarily the Norwegian Sea area which has the greater species diversity (Øritsland et al., 1988) with species that are prone to erroneous identification. Regarding school sizes, the minke whales were mostly seen in these waters as single individuals with a pooled average of 1.27 (c.v. 0.119) as compared to 1.20 (c.v. 0.111) in the 1984 survey and 1.42 (c.v. 0.224) in 1985 (Øien and Christensen, 1985). For minke whale abundance estimation, a passing mode survey with delayed closure (diverting from course at approximately 90^0 to the sighting) when needed for confirming species identification or school size could therefore be the most successful approach.

None of the estimates of abundance calculated in Table 1 by pooling perpendicular distance data over blocks prior to fitting the hazard-rate model, are significantly different by mode. They are very similar for two of the blocks (A and B1) but rather different for block B2. The latter situation may be a result of the unequal distribution of effort in the two modes but it should be noted that no primary sightings of minke whales were made in closing mode in the Jan Mayen area, although all passing mode sightings were made there.

The perpendicular distance frequency distributions from the two modes appear to be very different as the passing mode distribution exhibits a shoulder while the closing mode distribution is more like an exponential one. Although this has to be investigated further, these two distributions are not statistically different and were thus pooled to give a single estimate of the effective search half-width. The sighting rates were also pooled over modes, resulting in a single combined estimate for each of the blocks (Table 2). For all blocks this pooling procedure made the abundance estimates lower than any weighted or unweighted mean of corresponding estimates in Table 1. The reason for this is that the separate pooling gives an estimate of closing mode half-width that is approximately half the passing mode half-width, while the pooled-over-mode half-width is similar to that based on passing mode data. This is not unexpected since 46 passing mode observations are included compared to 24 observations made in closing mode.

A transect was planned at the west coast of Svalbard to find whales for blow-rate experiments. Although the planned transect was intentional and thus invalid for unbiased abundance estimation, it is interesting to note that the density of minke whales as calculated from these data (0.2135 whales/sq. n. miles) is well in accordance with the density (0.248) found during the survey of that area in 1985 (Øien and Christensen, 1985). A separate block was designed for this area to be covered by aircraft during the 1987 survey (Øritsland et al., 1988). Results from that survey (Hiby et al., 1988) indicate a lower density than from shipboard surveys by a factor of about five. Whatever the reason for this discrepancy, the result seems to be contradictory to the reputation of the Svalbard coastal area as a high-density area in which considerable catches have been taken, especially during the last decade.

To get an estimate of the total contribution from this survey to the two IWC stock areas concerned, the data from blocks A and B2 were restratified, primarily to cope with the bias that might arise from the uneven distribution of sightings in block B2. This procedure lowered the total estimate for block B2 by approximately 1,000 minke whales (Table 3 compared to Table 2) while the estimate for block A remained the same. This illustrates the difficulties in calculating a valid estimate for block B2 and suggests that alternative procedures should be investigated, as for example by using the variable coverage prohability method described by Cooke (1987).

The contribution to the Central stock of minke whales has been calculated to 4,461 whales and to the Northeastern stock 12,459 minke whales. Areas southwards of the southern boundary (approximately 66^{0}N) of areas surveyed by the Norwegian vessels in 1987 also contribute to the Northeastern minke whale stock abundance. These areas were surveyed by a Faroese vessel and abundance estimates from this and the Icelandic vessels are given in Gunnlaugsson and Sigurjónsson (1988).

No correction factors have been applied to the abundance estimates presented in this paper, although particularly a correction for deviations from the assumption g(0)= 1, that is schools missed on the trackline, seems appropriate. However, since correction factors calculated for other surveys are inconclusive and not necessarily applicable to the present survey, the question of g(0) corrections remains unsolved until relevant experimental data have been collected.

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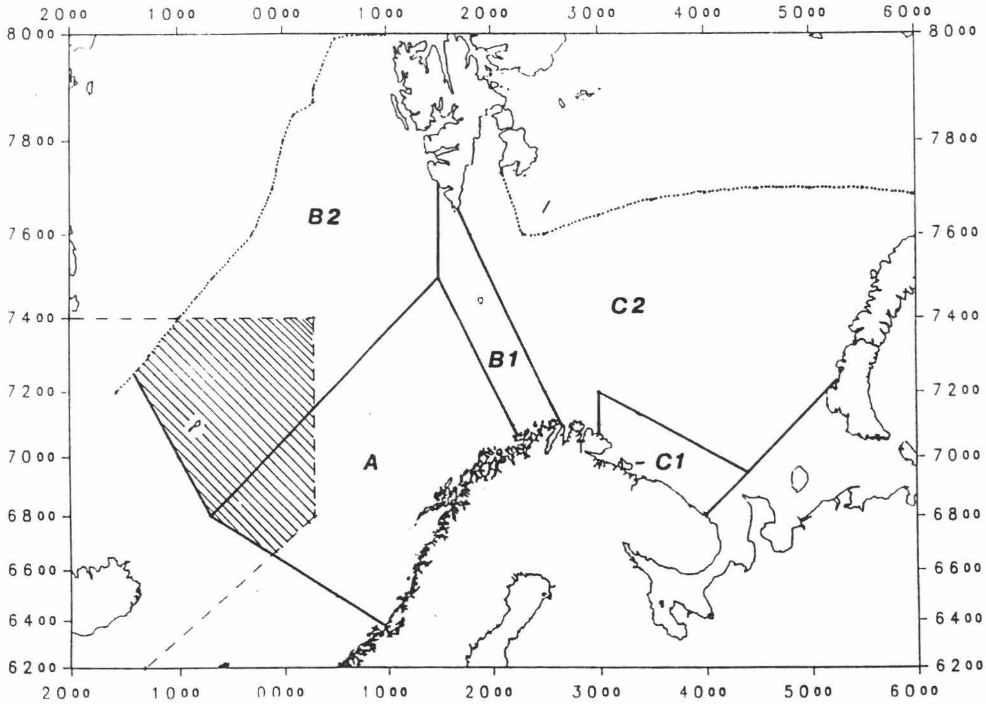

Figure 1. Boundaries between the five blocks A, B1, B2, C1 and C2 of the total area surveyed by Norwegian ships in July 1987. Punctuated lines indicate ice edges. The hatched area represents the parts of blocks A and B2 belonging to the Central stock of minke whales, as defined by IWC, while the remaining areas are considered as parts of the Northeastern minke whale stock area.

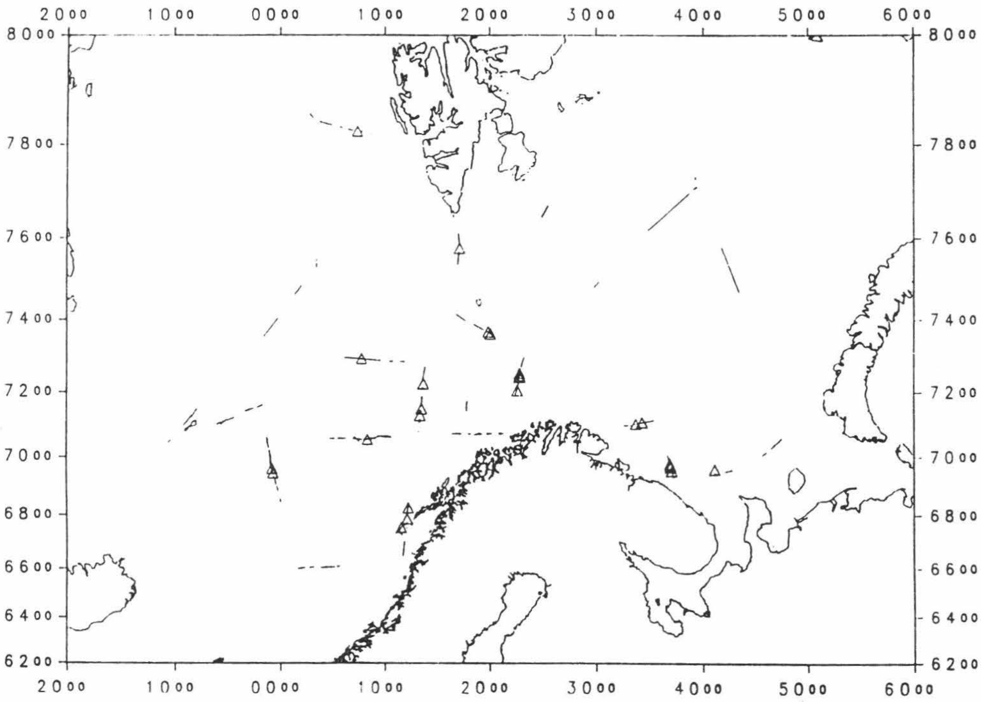

Figure 2. Surveyed closing mode transects. Primary sightings are indicated by triangels.

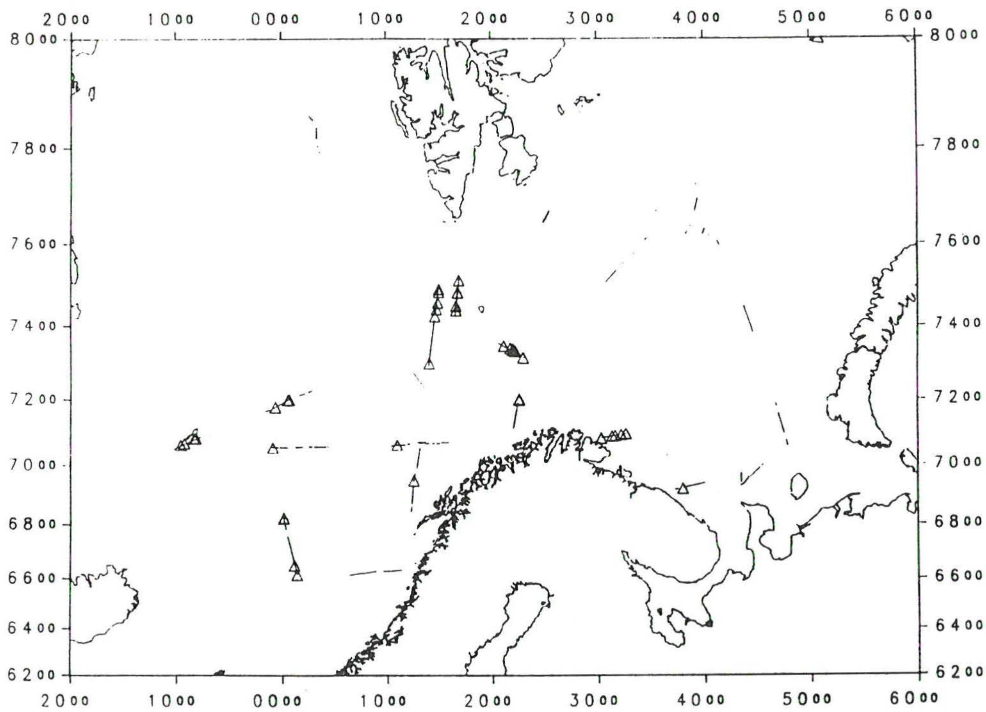

Figure 3. Surveyed passing mode transects. Primary sightings are indicated by triangels.

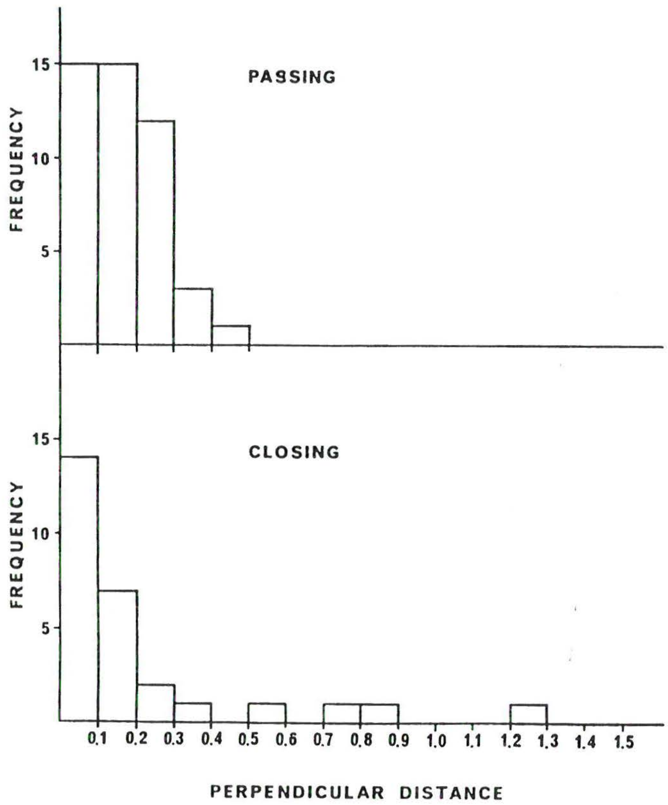

Figure 4. Frequency distributions of passing mode and closing mode perpendicular distances for primary sightings pooled over all surveyed blocks.

Table 1. Data used to estimate abundance of minke whales in the area surveyed by Norwegian vessels in July 1987 by blocks. No primary sightings were made in block C2. Effective search half-widths have been calculated separately, but pooled over blocks for closing and passing modes. Results from the searching for minke whales for blow-rate experiments at Svalbard are given separately. Figures in brackets are coefficients of variation.

Block	A - Northern Norwegian Sea		B1 - Bear Island		B2 - Greenland Sea		C1 - Kola coast		Exp. at Svalbard
Survey mode	Closing	Passing	Closing	Passing	Closing	Passing	Closing	Passing	Closing
Primary effort, L, n.miles	820.1	797.0	185.3	202.0	273.3	235.5	165.1	184.8	123.8
No. of schools, n	7	13	8	18	1	8	8	7	10
Sighting rate n/L	0.0085 (0.363)	0.0163 (0.391)	0.0432 (0.552)	0.0891 (0.385)	0.0037 (0.724)	0.0340 (0.330)	0.0485 (0.399)	0.0379 (0.812)	0.0808 (0.429)
Effective search half-width, w, n.miles	0.1671 (0.231)	0.3041 (0.103)	0.1671 (0.231)	0.3041 (0.103)	0.1671 (0.231)	0.3041 (0.103)	0.1671 (0.231)	0.3041 (0.103)	0.2233 (0.385)
Density of schools, Ds = (n/L) · (1/2w)	0.0255 (0.430)	0.0268 (0.404)	0.1293 (0.598)	0.1465 (0.399)	0.0111 (0.760)	0.0559 (0.346)	0.1450 (0.461)	0.0623 (0.819)	0.1809 (0.576)
Mean school size, s	1.00 (0)		1.86 (0.320)		1.00 (0)		1.18 (0.103)		1.18 (0.103)
Density of whales, Dw = Ds · s	0.0255 (0.430)	0.0268 (0.404)	0.2404 (0.679)	0.2725 (0.511)	0.0111 (0.760)	0.0559 (0.346)	0.1711 (0.472)	0.0735 (0.825)	0.2135 (0.586)
Area, (n.miles)^2	185,699		25,113		158,696		28,315		-
Uncorrected estimate of abundance	4,743 (0.430)	4,977 (0.404)	6,038 (0.679)	6,843 (0.511)	1,757 (0.760)	8,872 (0.346)	4,844 (0.472)	2,082 (0.825)	
Uncorrected total estimate	Closing: 17,382 (0.304)				Passing: 22,774 (0.235)				

Table 2. Uncorrected abundance estimates of minke whales in each of the survey blocks from data pooled over modes and truncated at 0.5 n. miles. Effective search half-width has been calculated from fitting the hazard-rate model to perpendicular distance data pooled over modes and blocks. Figures in brackets are coefficients of variation.

Block	A	B1	B2	C1
Primary effort, L. n.miles	1671.1	387.3	508.8	349.9
No. of schools, n	20	26	9	15
Sighting rate n/L	0.0124	0.0671	0.0177	0.0429
	(0.327)	(0.431)	(0.327)	(0.442)
Effective search half-width, w, n.miles		0.2701 (0.088)		
Mean school size, s	1.00	1.86	1.00	1.18
	(0)	(0.320)	(0)	(0.103)
Density of whales,	0.0230	0.2310	0.0328	0.0937
$D_w = (n/L) \cdot (1/2w) \cdot s$	(0.339)	(0.544)	(0.339)	(0.462)
Area, (n.miles)^2	185,699	25,113	158,696	28,315
Uncorrected estimate	4,263	5,802	5,200	2,653
of abundance by block	(0.339)	(0.544)	(0.339)	(0.462)
Uncorrected total estimate of abundance in survey area		17,918 (0.228)		

Table 3. Restratification of data collected from blocks A and B2 to fit the IWC minke whale stock boundaries. Uncorrected total contributions to the stocks from the survey area have been given by including B1 and C1 from Table 2 in the Northeastern estimate. Effective search half-width has been calculated as in Table 2 and sightings outside the truncation distance of 0.5 n. miles have been excluded. Coefficients of variation are given in brackets.

	Central		Northeastern	
Block	A	B2	A	B2
Primary effort, L. n.miles	259.4	323.9	1357.7	184.9
No. of schools, n	5	8	15	1
Sighting rate n/L	0.0193 (0.348)	0.0247 (0.334)	0.0110 (0.403)	0.0054 (0.447)
Effective search half-width, w, n.miles	0.2701 (0.088)			
Mean school size, s	1.0 (0)			
Density of whales, $D_w = (n/L) \cdot (1/2w) \cdot s$	0.0357 (0.359)	0.0457 (0.345)	0.0205 (0.412)	0.0100 (0.456)
Area, $(\text{n.miles})^2$	31,790	72,757	153,909	85,939
Uncorrected estimate of abundance	1,134 (0.359)	3,327 (0.345)	3,148 (0.412)	856 (0.456)
Uncorrected total contribution to stocks from survey area	4,461 (0.273)		12,459 (0.293)	

SIGHTINGS SURVEYS IN THE NORTHEAST ATLANTIC IN JULY 1988: DISTRIBUTION AND ABUNDANCE OF CETACEANS

ABSTRACT

A sighting survey was conducted in July 1988 in central parts of the distribution area of minke whales in Norwegian and adjacent waters. Distribution of sightings and line transect estimates of abundance in the area surveyed are given for several cetacean species. The estimates are not corrected for possible deviations from line transect assumptions, pending further investigations of these. Effective search half-widths have been calculated by fitting a hazard-rate detection function to perpendicular distance data. Uncorrected abundance estimates for the survey area, which includes parts of the Norwegian and Barents Seas as well as coastal areas off northern Norway, Kola and Spitsbergen, are: 25,600 (c.v. 0.144) minke whales, of which 23,400 contribute to the Northeastern stock of minke whales and the remaining 2,200 to the Central stock; 2,300 (c.v. 0.31) fin whales, of which 1,300 contribute to the East Greenland-Iceland stock and 1,000 to the North Norway stock; 1,100 (0.31) humpback whales; 2,500 (c.v. 0.27) sperm whales and 3,100 (0.63) killer whales.

INTRODUCTION

In 1987 coordinated multinational North Atlantic sightings surveys (NASS-87) were conducted with the aim to map simultaneously the distributions of cetaceans and collect data for abundance estimations (IWC, 1989). Although the information received on distributions were considered useful, the area coverage was rather low in all blocks surveyed by the Norwegian vessels, i.e. in the Norwegian and Barents Seas. This resulted in problems with the abundance calculations, even for the associated target species the minke whale Balaenoptera acutorostrata (Øien, 1989a).

As one important objective of the Norwegian minke whale research program is to get 'more precise estimates of stock size' (Anon., 1988), a survey especially dedicated to giving a high coverage of important summer distribution areas was conducted in July 1988. This paper presents and discusses the results and, where possible, associated uncorrected abundance estimates of cetaceans sighted during the survey. These include minke, fin (B. physalus), blue (B. musculus), humpback (Megaptera novaeangliae), killer (Orcinus orca), Northern bottlenose (Hyperoodon ampullatus), white (Delphinapterus leucas) and sperm (Physeter catodon) whales in addition to dolphins (Delphinidae). Further discussions of harbour porpoises (Phocoena phocoena) in Norwegian waters are given by Bjørge and Øien (1989).

MATERIAL AND METHODS

Survey block boundaries and design

The minke whale was defined as the target species of this survey. The total area to be surveyed was chosen with respect to previous experience from sightings surveys, especially that conducted in 1987 (Øien, 1989a), and catch distributions from earlier years (Øien, Jørgensen and Øritsland, 1987). To ensure a high coverage in the most densely populated areas, it was decided to limit the survey to the areas covered by Norwegian vessels in 1987. This inevitably implies that a considerable part of the Northeastern minke whale stock area, as defined by the International Whaling Commission (IWC, 1988), was not covered by the 1988 survey. Important areas comprise the southern part of the Norwegian Sea, which was however covered by a Faroese vessel in 1987 (Sigurjonsson, Gunnlaugsson and Payne, 1989), and the North Sea. Since previous surveys indicate a present low abundance of minke whales in the Greenland and the northeastern Barents Seas (Øien and Christensen, 1985; Øien 1989a), these areas were neither surveyed in the present study.

The survey area was divided into eight blocks (see Fig. 1) considering practicability, expected minke whale densities and IWC minke whale stock boundaries. The blocks were (in brackets, abbreviations as used throughout text and tables): The Kola coast (KO); the Finnmark coast (FI); the coastal areas between the Træna and Tromsøflaket fishing grounds, comprising Lofoten and Vesterålen (LO); the Bear Island area (BJ); the west coast off Spitsbergen (VS); the eastern (NØ) and western (NV) parts of the northern Norwegian Sea; the Jan Mayen area (JM). Of these blocks JM and NV are parts of the Central minke whale stock area while the remaining areas are parts of the Northeastern minke whale stock area (IWC, 1988).

The bottom topography of the surveyed area comprises shallow waters, mostly less than 300 meters in depth, in the Barents Sea (FI, KO and BJ); shelf areas west of Spitsbergen (VS) and around Lofoten (LO); and steep slopes running into the deep waters (more than 3,000 meters in depth) of the Norwegian Sea (NØ). Jan Mayen is surrounded by a small shelf area only.

Cruise tracks were designed in a saw-tooth pattern according to the principles outlined by Cooke (1987) and Cooke and Hiby (1987). Relatively more effort was put into expected high density blocks. The estimated available survey time within each block allowed planning of two transects (i.e. coverages) in all but two blocks (FI and NV). The first transect was expected to be fully completed, eventually waiting for acceptable weather conditions when necessary, while the second transect was run with adaptations to prevailing weather conditions.

Sightings procedures

The blocks were covered by six vessels: Landkjenning (block NØ), Ole Willassen (BJ), Rango (FI and KO), Vestflud (NV and JM) and Willassen Senior (VS), all combined fishing- and whaling vessels, and the expedition vessel Polarbjørn (LO) which also carried a helicopter to conduct special experiments and additional surveys (Jensen, 1989).

Intended speed during primary searching was 10 knots but in practice it varied somewhat around this value. A minimum meteorological visibility of 1.5 nautical miles and sea conditions not above four

Beaufort were defined as acceptable weather conditions for primary searching. Searching was conducted on a 24 hour basis when conditions permitted, with the observers and scientists organized in two shifts usually working six hours at a time. The observers were experienced whalers or in a few cases, ornithologists with experience in working at sea.

The survey was conducted in a modified passing mode (Anon., 1989) where sightings were closed on only in certain cases, and then by delay closing until the sighting was abeam. These special cases were when a sighting could not be identified but was thought to be of species other than small cetaceans, or if the school size for a minke whale sighting had to be determined. For each observation, position, species, school size, radial distance and angle with track line were notified. Angles were usually given as readings from angle boards mounted in the barrel and on the wheelhouse roof. Radial distances were estimated by eye; only in a few cases additional measurements were made by reading the height beneath the horizon by plastic rulers. Activity, weather and sightings conditions were continuously recorded.

The barrel, varying in heights by vessel from around 14 meters to 21 meters above sea level, was the primary sighting platform. However, observer platforms were also established on the wheelhouse roofs to accomodate scientists and other crew members. In primary searching mode (i.e. while on predetermined track-line), two observers were on duty in the barrel at a time, but alternating with a third one, which together with the scientist and crew made up additional, although less regular, survey effort.

Abundance estimation

Some of the sightings were classified in the field as 'unidentified', and others as 'like-' the supposed species. Both these categories have been excluded from sighting rate calculations and other analyses presented here. In the present paper, only identified sightings with estimable perpendicular distances have been termed 'primary'. Coefficients of variation for sighting rates have been calculated using daily variation.

Mean school sizes have been estimated from all sightings where species have been recorded and a best estimate of school size given.

Abundance estimates have been calculated by block using standard line transect methods (Burnham, Anderson and Laake, 1980), with abundance, N, equal to

$$N = (n/L) \cdot (1/2w) \cdot s \cdot A$$

where (n/L) is the sighting rate, 2w the effective search width, s the mean school size and A area of the block. This means that no correction factors, for example for the assumption that all whales on the trackline are seen, have been applied to the estimates.

Effective search half-widths, w, have been estimated by fitting a hazard- rate model with a detection function of the form $g(y) = 1 - \mathrm{EXP}(-(y/a)^{(1-b)})$ (Hayes and Buckland, 1983) to estimated perpendicular distance data, $y = r \cdot \sin\theta$, as calculated from radial distances, r, estimated by eye and angles, θ, usually read from an angle board.

SHORT NARRATIVE OF THE CRUISE

A pre-cruise meeting was held in Tromsø, the port of departure, to make all participants familiar with sightings procedures and conduct of experiments. The six vessels left Tromsø 4 July 1988 and returned to the same port 28 July. A post-cruise meeting was then held in Tromsø 29 July to report on results and experience.

A total of 7,634 nautical miles were cruised in primary searching mode (Fig. 1). This was somewhat more than the 7,401 nautical miles planned on the basis that 20% of total shiptime available would yield an effective survey time as experienced on previous cruises. The extra transects made were mainly due to better survey conditions than expected in block NØ. In all other areas most of the planned transects were completed.

Pauses in searching were mainly caused by either strong winds or fog. In some cases the demand on visibility was reduced, especially when fog patches were suspected to be local.

Cetacean sightings recorded during the survey have been listed by species and block in Table 1. Also other sea mammals were recorded, of which many observations were of harp seals (Pagophilus groenlandicus), mainly concentrated in the areas ranging from Bear Island northwards and along the west coast of Spitsbergen.

During the survey time was also dedicated to several experiments. Dive time experiments were attempted on an occasional basis from all vessels; some of these were successfully completed (Øien, Folkow and Lydersen, 1989). At Spitsbergen an independent observer experiment was conducted (Øien, 1989b), and at Jan Mayen it was attempted to collect whale tissues by biopsy sampling. The method used was biopsy darts shot from a cross-bow. The cross-bow was appearantly too weak to give a sufficient range, and only two samples, one from a minke whale and another from a humpback whale, were collected. In block LO, experiments were also made from a helicopter placed onboard Polarbjørn (Jensen, 1989).

RESULTS AND DISCUSSIONS

Minke whales

Distribution of sightings and sighting rates

All recorded observations of minke whales have been plotted in Fig. 2. Although the areas surveyed were selected because of expected high minke whale densities, the densities varied within this area, for example around Jan Mayen, in the eastern part of the Norwegian Sea, off the Kola coast and in the area between Bear Island and the southern part of the banks west off Spitsbergen, relatively large concentrations of minkes occurred.

The number of primary sightings recorded is given by block in Table 1. The equivalent numbers given in Table 2 are the data truncated at a perpendicular distance of 0.7 nautical miles (see below); these have been used in the sighting rate calculations also presented in Table 2.

The sighting rate in the Kola block was especially high compared to those observed in the other blocks (Table 2).

Of the total number of primary sightings of minke whales 87.0% were made by the topmen in the barrel. Of the remaining sightings 6.1% were made from the wheelhouse roof, 5.1% from the wheelhouse and 1.8% from 'other' places. All these primary sightings have been used in the abundance estimations, with the exception of truncation restrictions.

The most frequent sighting cue was the whale body, accounting for 90.3% of the cues. The blow was recorded as the main cue in 4.3% of the sightings and a combination of these in 1.5% of the cases. These percentages did not vary much between blocks, with the exception that blows seem to have been more important in block VS than in the other blocks, as 10% of the cues were coded as blows and an additional 10% as a combination of blow and whale body in that area.

Mean school size

The mean school sizes are given in Table 2. The mean over all blocks was 1.15 individuals/sighting (c.v. 0.029). Although school sizes ranged over the interval from 1 to 10 individuals/school, the overwhelming majority of the sightings (90.9%) were of single animals with a certain share of sightings with two animals (6.4%) and 2.7% of sightings of three or more animals. One secondary sighting of a school comprising 10 individuals was made northwest of Bear Island.

Effective search half-width

Perpendicular distances, y, have been calculated from radial distances, r, estimated by eye and angle from transect line, θ, usually measured by means of an angle board, by $y = r \cdot \sin\theta$. The relative positions of primary minke whale sightings pooled for all vessels participating in the survey are shown in Fig. 3. The radial distance estimates appear in groups, as distances evidently were rounded to the nearest 100-meter values (note: the whale spotters usually estimate short distances in meters, larger distances as fractions of nautical miles. For convenience, all length measures have been converted to nautical miles). Smearing techniques (Buckland and Anganuzzi, 1988) have been tentatively applied to the data but found to have only a minor influence on the results. Therefore, further examinations of the problems related to data collection have been postponed for future studies.

The frequencies of perpendicular distances grouped into intervals of 0.1 nautical miles are given, truncated at 0.7 nautical miles, by blocks in Table 3. The cell frequencies were tested for heterogenity between blocks by a G-test (Sokal and Rohlf, 1980) but deviations were found to be non-significant at the $\alpha = 0.05$ level. All perpendicular distance data were therefore pooled; the resulting distribution when grouped by 0.1 and 0.02 nautical mile intervals is shown in Fig. 4. Prior to fitting the detection function (to data grouped by 0.1 nautical miles), the perpendicular distance distribution was truncated at 0.7 nautical miles, thus leaving out 1.0% (4 out of 385) of the total number of primary observations. The fitted function has the form $g(y) = 1 - \mathrm{EXP}[-(y/0.210)^{(1-3.841)}]$ which gives an effective search half-width of 0.2792 (c.v. 0.0554) nautical miles. This value has been used in the estimations of abundance shown in Table 2.

Abundance estimates and stock boundaries

Density and absolute abundance have been calculated separately for each block based on the detection function derived from the pooled data, as explained above. The results are presented in Table 2.

The current stock boundaries for minke whales as defined by the IWC mean that the area surveyed in 1988 contributes both to the Central and the Northeastern Atlantic stock areas. The westernmost blocks JM and NV contribute to the Central stock area, while the others belong to the Northeastern stock area, as the boundary between the stocks follows the longitude 3^{0}E (IWC, 1988) through the survey area. The pooled estimates are also shown in Table 2; the estimates as rounded off are 25,600 (c.v. 0.144) minke whales in the total survey area, with 23,400 (c.v. 0.155) contributing to the Northeastern stock and 2,200 (c.v. 0.26) contributing to the Central stock.

Discussion

The estimated effective search half-width of 0.2792 nautical miles is not significantly different from that calculated from the data collected during the Norwegian NASS-87 survey in 1987 (0.2701 nautical miles, Øien, 1989a). The latter search width was derived from pooled data collected both in passing and closing modes. The pooled frequency distribution for the 1987 data seems to have the same relative appearance as the 1988 distribution given in Fig. 4. At a first glance, considering the 0.1 nautical mile intervals, the perpendicular distance distribution has a spiky appearance, a feature which has been attributed to problems with respect to data collection and whale behaviour (Hiby and Hammond, 1987). In this case, however, the spiky appearance seems to be a grouping artifact, as the 0.02 nautical mile grouping clearly reveals a shoulder. The frequency distribution in Fig. 4 therefore indicates that the detection probability of minke whales in these waters decrease rather quickly with increasing distances from the trackline, which is not unexpected given that blows are rarely seen. Gunnlaugsson and Sigurjónsson (1989) applied a correction to their minke whale abundance estimates for influence of sea state on sightability, as they found that sea state (as measured on Beaufort scale) affected sighting rates but not perpendicular distances. The Norwegian survey data have not yet been analyzed for such effects.

The school size grand mean, 1.15 whales/school, was somewhat less but not significantly so, than the corresponding value from the survey in July 1987 (Øien, 1989a) of 1.27. For the only comparable block, KO, the school size estimates were similar (1.22 in 1988 versus 1.18 in 1987). The mean school size in Icelandic waters based on data from the 1987 survey was 1.089, which is comparable to the values obtained in the Norwegian survey in 1988 in the eastern part of the Norwegian Sea and Lofoten area (blocks NØ and LO). Inspection of Table 2 reveals that school size tend to increase when entering the Barents Sea and coastal waters of Spitsbergen, which may be related to more dense prey concentrations there.

The total estimate of minke whale abundance in the surveyed areas in 1988 was 25,600 (c.v. 0.144), which is not different from the estimate of 17,900 (c.v. 0.228) for the surveyed areas in 1987 (Øien, 1989a).

Although the survey in 1987 covered a larger area, both surveys in practice covered much the same areas of high minke whale abundance. In 1988 the survey area was divided into smaller blocks, and the only block completely comparable between those two years is that off the Kola coast, KO. The estimate for this block is 8,900 (c.v. 0.33) in July 1988 and 2,700 (c.v. 0.46) in July 1987. Therefore, the larger total estimate in 1988 may predominantly be ascribed to a much higher abundance of minke whales off the Kola coast.

For the other blocks, the comparisons are only approximate. The block A in the 1987 survey matches parts of the block NØ in addition to LO in the 1988 survey; B1 in 1987 comprised a somewhat smaller area than blocks BJ and FI in 1988, while B2 (1987) comprised both VS, JM and parts of NØ and NV in 1988. If these differences in block divisions are taken account of, there are no conspicuous divergences between July 1987 and 1988 abundance estimates, with the exception of the KO block mentioned above.

The abundance contributions to the Central and Northeastern stocks of minke whales are 2,200 (c.v. 0.26) and 23,400 (c.v. 0.155), respectively, from the 1988 survey. The corresponding numbers from the 1987 survey were 4,500 (c.v. 0.27) and 12,500 (c.v. 0.293), respectively. Although the total estimates seem to share some resemblance as mentioned above, their contributions to stocks appear to be very different. This may merely be an artifact of data analysis, as the 1987 survey was not designed according to IWC stock boundaries, and a restratification of the data was necessary to get these estimates. In 1988 stock boundaries were taken care of already at the planning stage. An additional reason for discrepancies may be related to the fact that the areas west of Spitsbergen and Lofoten, areas of high local abundances, did not receive any additional coverage in 1987, since they were expected to be surveyed by aircraft.

The survey in 1988 covered only part of the anticipated summer distributional area of the Central and Northeastern stocks of minke whales. Additional areas of importance to the Northeastern stock are the southern parts of the Norwegian Sea, the North Sea, and possibly the northeastern Barents Sea. However, the surveys in 1987 and 1988 indicate that shifts in distribution may have significant effects on abundance estimates within limited areas. This makes it doubtful to get a valid estimate of total stock abundance without a complete coverage of the defined stock area within reasonable time limits.

At the 1988 meeting of the IWC Scientific Committee, the abundance of the Northeastern stock of minke whales was estimated to be 19,100 (c.v. 0.163), summarized from ship and aircraft surveys conducted in 1987 (IWC, 1989). In 1988, the contribution from the surveyed areas alone was higher than this, 23,400 whales (c.v. 0.155). The estimate based on 1987 surveys was considered preliminary, realizing both that part of the distributional range was not covered and that uncertainties with regard to the fullfillment of the underlying assumptions in line transect theory applied to shipboard surveys, had to be further investigated. One of these, the assumption that all whales on the trackline are seen, have been tested in an experiment at Spitsbergen, indicating that this condition is certainly not met with (Øien, 1989b).

Fin whales

Distribution

Fin whales were recorded in all but the two blocks KO and BJ (Table 1 and Fig. 5), and almost exclusively west of the slope separating the Barents and Norwegian Seas. A large bulk of the observations were recorded at the slopes of the bank south of Jan Mayen. Otherwise the fin whales seem to display an even although low density throughout the Norwegian Sea (Table 4) and at the slopes off the southern part of Spitsbergen.

The average school size for the observations from all blocks was 1.83 (c.v. 0.0738). 51.5% of the observations were of single whales, 30.1% of two whales. There were two observations at Jan Mayen of schools consisting of six animals.

Abundance

Of the primary sightings 91.5% were made from the barrel. At 72.9% of the incidences the main cue was the blow, while in an additional 16.9% of cases both animal and blow were recorded as observational cue. Several of the sightings were made at large radial distances, the largest recorded being 5,000 meters. The distribution of perpendicular distances collected from all blocks with primary sightings of fin whales is given in Fig. 6. The detection function fitted to the data truncated at 1.4 nautical miles is $g(y)= 1 -EXP[(- y/0.679)^{(1-5.123)}]$, which results in an effective search half-width of 0.8030 (c.v. 0.0952) nautical miles. This value has been used for the calculations presented in Table 4.

For two of the blocks, JM and NØ, sufficient data were available to fit separate detection functions to the perpendicular distance distributions. The effective search half-widths from these two blocks differed by a factor of two, the estimates being 0.9642 (c.v. 0.1335) (block JM) and 0.4719 (c.v. 0.4382) (block NØ). Nevertheless, the two distributions were not found to be significantly different at the α= 0.05 level by a chi-square test.

The total abundance estimate of fin whales in the survey area was 2,300 (c.v. 0.31), of which 1,300 (c.v. 0.46) could be ascribed to the East Greenland-Iceland stock and 1,000 (c.v. 0.41) to the North Norway stock.

Discussion

The northernmost records of fin whales during this survey are from west of the southern Spitsbergen (76^{0}46'N), but this species is known to be found up to ice edge, and in June 1930 catches were taken at 80^{0}42'N, 11^{0}E , i.e. northwest off Spitsbergen (Jonsgård, 1966). However, within the survey area west of a line between Finnmark and Spitsbergen, fin whales were seen regularly, taking no care of stock boundaries. At present the International Whaling Commission takes into account seven fin whale stocks in the North Atlantic (IWC, 1988; Rørvik and Jonsgård, 1981), of which three are of interest to this study. These are the East Greenland-Iceland stock, the North Norway stock and the West Norway-Faroe Islands stock. The JM and NV blocks contribute to the East Greenland-Iceland stock, while the remaining blocks contribute to the North Norway stock, with the exceptions of the southernmost tips of the blocks NØ and LO as the boundary separating the North Norway and the West Norway-Faroe Islands stocks is supposed to follow the 67^{0}N latitude while the 66^{0}N latitude is the southern boundary of LO. This difference has not been considered in Table 4, since it is supposed to be of marginal significance (comprising 30.2 nautical miles of survey effort in block NØ but no primary sightings, and 105 nautical miles and two primary sightings in block LO).

The estimates presented here show that in the 1988 survey area the central fin whale distributions were in the Norwegian Sea and at Jan Mayen, with about equal contributions to the East Greenland-Iceland and North Norway stocks. From the sightings surveys in 1987, the abundance of the East Greenland-Iceland stock has been estimated to be 11,563 (c.v. 0.261), including data from Icelandic survey vessels (Gunnlaugsson and Sigurjónsson, 1989), and an estimate from Norwegian vessels of 5,806 (c.v. 0.502) fin whales in the Jan Mayen - Norwegian Sea area (IWC, 1989). Previously, the recruited virgin size of the North Norway stock has been estimated to at least 2,034 animals, based on an assumed sustainable catch of 61 fin whales annually from 1948 to 1971 (when catching ended) and 6% yield at an MSY level of 50% of virgin stock (Rørvik and Jonsgård, 1981). Those considerations seem to bear some resemblance to the present estimate of the North Norway stock of 1,000 (c.v. 0.41) animals.

Blue whales

Blue whales were sighted at the bank south of Jan Mayen and west of Lofoten (Table 1 and Fig. 10). At Jan Mayen they seemed to occur in schools of two, while that observed at Lofoten was a single individual. With only two schools recorded as primary sightings at Jan Mayen, at perpendicular distances of 0.00 and 0.619 nautical miles, no attempts have been made to estimate abundance. However, in recent years an increasing number of observations of blue whales have been made in the Denmark Strait and at Iceland (Sigurjónsson and Gunnlaugsson, 1989).

During the North Atlantic Sightings Survey in 1987, blue whales were recorded from west of Spitsbergen (Øritsland et al., 1989), from the area between Iceland and Jan Mayen, and south of Iceland (Sigurjónsson, Gunnlaugsson and Payne, 1989), and even an upper bound of their abundance (442 individuals) in Icelandic waters has been given (Gunnlaugsson and Sigurjónsson, 1989). These observations at least suggest that blue whales at present are regular visitors to the Jan Mayen area.

Humpback whales

Distribution

Most of the humpback whales were seen in the eastern part of the Norwegian Sea (Table 1 and Fig. 7), and with the exception of the few observations off the Finnmark and Kola coasts, at or to the west of the continental slope between Spitsbergen and northern Norway (Figs 1 and 7). The open sea observations were at depths of about 3,000 meters.

The average school size for all observations was 1.48 (c.v. 0.1112), but varied from block to block (Table 5). Most of the sightings were of single animals (60.7%) or of two animals (25%). The largest school was observed north of Bear Island and comprised five animals.

A few fluke photographs were taken for identification of individual whales during the survey. On one occasion (at 22.20 hrs on 20 July) one individual of a school of five feeding humpbacks was photographed north of Bear Island ($75^{0}07$'N; $15^{0}44$'E) from Ole Willassen while off effort in block BJ. This individual seems to be the same as that photographed two days later (at 23.30 on 22 July) from Willassen Senior in block VS ($76^{0}09$'N; $15^{0}27$'E). The distance between these two positions is 62.1 nautical miles. On the latter occasion, the whale was feeding in close association with only one other whale.

Abundance estimates

The data used for abundance estimations are shown in Table 5. All primary sightings were made from the barrel. The most frequent sighting cue was the blow alone (72%) and in only 12% of the sightings the detection of the animal itself was recorded as the only sighting cue. The maximum radial distance to a sighting recorded was 5,000 meters. The perpendicular distance distribution of all primary sightings made is given in Fig. 8c. The fitted detection function has the form $g(y)=1 - EXP[(-y/0.508)^{(1-4.898)}]$. The estimated effective half search-width was 0.6032 nautical miles (c.v. 0.1633). The abundance estimate for all blocks is 1,100 (c.v. 0.31) humpback whales.

Discussion

Stock identification of North Atlantic humpbacks seem to be unclear and much debated (Mitchell and Reeves, 1983) and at present no stock boundaries have been defined by IWC. The estimates presented here therefore have to be considered as a first estimate of local humpback abundance in the areas surveyed.

The distribution observed seems to be in agreement with distributions given for comparable areas, based on incidental observations in the seasons 1973-1984 (Christensen, 1985), with the exception of the Norwegian Sea for which he does not give any records, while the highest survey density in fact was observed in that area. On the other hand, Christensen (1985) gives some information on areas outside that surveyed in 1988. These include a more eastern distribution both in the southeastern Barents Sea and off Spitsbergen to the Edge and Hopen Islands, in addition to observations farther south on the Norwegian coast (Trøndelag, approximately 64⁰N) and at Shetland (60⁰N).

Although Christensen (1985) concludes that the humpbacks in the Northeast Atlantic are increasing their numbers since they are seen in increasing numbers in what were known as their former distributional areas, no numbers have been associated with their abundance. However, Ingebrigtsen (1929) concluded from analyses of catch statistics that not more than 1,500 humpbacks could have been caught at Finnmark and Bear Island and that this catch entirely exterminated the stock or eventually changed its distributional range. His analyses were based on catches taken up to 1904; from that year whaling was prohibited along the Norwegian coast until it was reopened in 1918. Some catches were however still taken in the Bear Island-Spitsbergen area. During the period from 1918 until the IWC ban on humpback whaling in the North Atlantic in 1955, 32 humpbacks were caught in northern Norway and 15 off western Norway (Christensen, 1985). The estimates for the coastal blocks (LO, FI, KO) and the Svalbard area (BJ, VS) sum up to 360 (c.v. 0.38) humpbacks, which does not seem unreasonable in light of the analyses of Ingebrigtsen (1929) of Finnmark and Bear Island catches in the period from approximately 1880 to 1904 and incidental sightings during 1973-1984 (Christensen, 1985). The 1988 survey revealed a relatively high humpback whale density in the Norwegian Sea, resulting in a very large contribution of 700 (c.v. 0.45) animals to the total estimate of 1100 (c.v. 0.31) for the area surveyed. Literature gives no information on distribution in the deep waters of the Norwegian Sea, presumably because whalers considered them to be too far away from the land stations. During the North Atlantic Sightings Surveys in 1987 no humpbacks were recorded in the Norwegian Sea, but there were a few records from Svalbard and the Finnmark coast (Øritsland et al., 1989). The 1987 survey also revealed a high abundance around Iceland, giving a total estimate for those areas of 1,816 (c.v. 0.176) animals (Gunnlaugsson and Sigurjónsson, 1989). Since there are no comparable data available for 1988, any interdependence between humpback whale distributions around Iceland and in the Norwegian and Barents Seas remains speculative.

The photo identification observation made between Bear Island and Svalbard may indicate rapid movement between areas, thus increasing the probability of making double-sightings, especially near boundaries between blocks. However, little is known about humpback migrations neither in short nor long term, although rough outlines of their possible migration routes have been given by Ingebrigtsen (1929) and Christensen (1985). This might of course introduce bias in the estimates as the applied survey design could be less suitable for survey of humpbacks.

The observed variation in school sizes may be related to different availability of suitable food in the different areas. As indicated by the photo identification results mentioned above, the observed schools may not need to be tight associations of individuals. The average school size (1.48, c.v. 0.1112) is approximately the same as found during the Icelandic survey in 1987 (Sigurjónsson *et al.*, 1989) of 1.676 (c.v. 0.051).

Sperm whales

Distribution

Sperm whales were exclusively recorded west of the continental slope running from northern Norway to Spitsbergen, separating the Barents and Norwegian Seas (Table 1 and Fig. 9). Especially along and near the slope outside Vesterålen many sperm whales were seen. The majority (85.9%) of the observations were of single animals, while the largest school recorded was one of three animals. The mean school size was 1.12 (c.v. 0.0361).

Abundance estimates

Most of the sightings (90.1%) were made from the barrel and the blow alone was the most frequent sighting cue (78.8%). Several of the observations were made at large radial distances, the largest being estimated at 10,000 meters.

The perpendicular distance distribution for all primary sightings of sperm whales is shown in Fig. 8a. The fitted detection function has the form $g(y) = 1\text{-EXP}[(-y/0.376)^{(1-2.357)}]$. The effective half search-width as calculated from this function is 0.6105 nautical miles (c.v. 0.2150). For the two blocks NØ and LO the separate distributions of perpendicular distances were studied. Although the estimated half search-widths when calculated separately for these distributions differ by some 40%, the distributions were not found to be significantly different at the $\alpha = 0.05$ level by a chi-square test ($X^2 =$

0.76, df=3, 0.5<P<0.9) and therefore the pooled data were used for the estimations presented in Table 6.

The abundance estimates with a total for the survey area of 2,500 (c.v. 0.27) sperm whales, should be considered preliminary, as this is a species with often prolonged dives, where some correction for diving behaviour seems appropriate.

Discussion

Little is known about sperm whales in these waters other than that they are supposed to be mostly solitary males on a summer feeding migration to northern waters. Their solitarity is reflected in the observed mean school size of 1.12 whales/school, which is also comparable to the school size of 1.165 (c.v. 0.030) observed in Icelandic waters (Sigurjónsson et al., 1989).

Sperm whaling from shore stations in Norway was mainly concentrated to hunting grounds off Møre (Southern Norway), off Andenes (north of the Lofoten peninsula), Bear Island and west off Spitsbergen. The survey in 1988 confirmed large concentrations in the eastern parts of the Norwegian Sea (Fig. 9) just as also observed in 1987. In 1987 also a few observations were made farther north, off Bear Island and Spitsbergen (Øritsland et al., 1989).

Nothing is known about the abundance of sperm whales in these waters. Sperm whales have been caught more or less regularly together with fin and sei whales from shore stations in Norway up to 1972. Relatively large numbers of sperm whales taken off North Norway in 1969 (111 whales) and 1970 (51 whales) were ascribed to very high prices for sperm whale oil and not to increasing numbers (Jonsgård, 1974).

In 1988, especially in early summer, unusually high numbers of sperm whales were found dead along the Norwegian coasts, either stranded or drifting (Christensen, 1989). The causes of these deaths or their relationship to abundance in these waters are not known.

Northern bottlenose whale

During the survey, seven sightings with 31 individuals were made of Northern bottlenose whales. These observations were made at Jan Mayen and in the western part of the Norwegian Sea (Table 1 and Fig. 10). The school sizes ranged from two to seven with an average of 4.43 (c.v. 0.1290).

The most frequent sighting cue was given as the body of the animal (5 of 7 cases). The maximum radial distance to a sighting was 1,500 meters. The distribution of the few perpendicular distances recorded is given in Fig. 8d, and sighting rates in Table 7.

Previous catch distributions indicate that the area between Iceland and Jan Mayen has been an important catching ground for bottlenose whales, as have also been the deep waters west of the shelf at Spitsbergen and the slopes outside Lofoten and Møre on the Norwegian coast (Benjaminsen and Christensen, 1979). However, it is also known that the bottlenose whale is a migratory species in these waters, entering the area in early spring with peak abundances in early summer. The majority of bottlenose whales seems to leave the northernmost areas before the end of June, and Icelandic waters by the end of July (Benjaminsen, 1972; Sigurjónsson and Gunnlaugsson, 1989). Since the sightings surveys in 1987 and 1988 were carried out in July, they are not expected to give a representative view of bottlenose whale summer distributions in these waters.

In addition to non-representativeness of distribution, the prolonged dive-times associated with bottlenose whales makes the application of traditional line transect analysis difficult. Benjaminsen and Christensen (1979) give a list of diving times recorded at Iceland and Labrador that range from 14 to 70 minutes, indicating that a correction to line transect estimates would be appropriate.

Killer whales

The killer whale observations were all made in the Norwegian Sea west of the Lofoten area (Fig. 10). Thus data were recorded only in the two blocks NØ and LO. The school sighting rates for these two blocks are given in Table 7. Based on catch statistics and incidental sightings, killer whales are present in the Lofoten area year around and most abundant in the Norwegian Sea during the summer months May-July (Øien, 1988). The observed distribution in the present study compares fairly well to this general pattern.

The mean school size was 14.67 individuals/school (c.v. 0.5337). This high estimate is heavily influenced by an observation of a school of about 100 individuals outside Lofoten. Otherwise the school sizes ranged from 2 to 20, but 90.9% of the schools consisted of 10 or fewer individuals, indicating that the observation of the school of 100 animals may be considered an outlier. If this observation is deleted from the data, the average school size is 7.29 (c.v. 0.138). This estimate is comparable to that observed during the sightings survey in 1987 of 8.9 (c.v. 0.208) (Øien, 1988).

Although 22 schools were sighted, only 7 of them are useful for search width estimation. In all, 12 schools were sighted when in primary searching mode, but it seems to have been problems with estimating radial distances and/or angles to the observations. The perpendicular distances distribution of these sightings is shown in Fig. 8e. The number of school observations are too few to draw any conclusions about search widths based on them only. However, in Fig. 8e is also shown the distribution of perpendicular distances based on whales (n=40), i.e. each whale in a school has been ascribed the school perpendicular distance. Fitting a hazard-rate model to these data results in an effective search half-width of 0.4020 (c.v. 0.183) nautical miles. A crude estimate of pooled abundance in the two blocks is then 3,100 (c.v. 0.63) animals.

From questionnaire surveys, Christensen (1988) estimated 1,507 whales as a maximum occuring on the coast of Norway in mid-winter. No such surveys were made in mid-summer, but as mentioned above, there are indications that killer whales at that time stay offshore (Øien, 1988).

White whales

Only a few observations of white whales were made during the survey (Table 1 and Fig. 10). These were in the southeastern Barents Sea and at the Finnmark and Spitsbergen coasts, which coincide with earlier observations: During the 1987 survey, a few sightings of white whales were made at Spitsbergen (Øritsland _et_ _al_., 1989), and in 1984 white whales, including a large school of more than 100 individuals, were observed in the southeastern Barents Sea (Øien and Christensen, 1985). According to Gurevich (1980), the White Sea including the southeastern Barents Sea, and the waters east and west of Spitsbergen are parts of the summer distribution area of white whales.

Of the five sightings of white whales, one was of a school of 60 whales. Mean school size based on all these observations is 13.40 (c.v. 0.8698). With the large schools excluded, the mean is 1.75 (c.v. 0.274).

Dolphins

Species

The group of animals categorized as 'dolphins' comprises four small odontocetes: The Atlantic white-sided dolphin (Lagenorhynchus acutus), the white-beaked dolphin (L. albirostris), the bottlenosed dolphin (Tursiops truncatus) and the common dolphin (Delphinus delphis). The reason that they are compiled under a common heading is that they have not been dedicated target species of the survey and are generally known by the whalers as 'springere' or 'jumpers'. Only on a few occasions more specific species identifications were made during the cruise.

Distribution

The number of observations by block are given in Table 1 and the distribution of sightings in Fig. 11. As is seen, no observations were made in the western- and easternmost parts of the survey area. The highest sighting rates and densities were found in the Finnmark and Bear Island blocks.

For 51.8% of the sightings, school sizes were reported to be between one and five individuals, and for 31.8% to be between six and ten individuals. The largest school recorded was one of 60 animals, seen at the continental slope west of Bear Island. Mean school sizes calculated by block are not significantly different although large variations are observed. The average school size based on all sightings is 8.31 (c.v. 0.1345).

Abundance estimates

The perpendicular sightings distance distribution for dolphins is shown in Fig. 8b. The detection function fitted to these data, truncated at 1.1 nautical mile,is $g(y) = 1 - EXP[-(y/0.203)^{(1-2.735)}]$, and the corresponding effective half search width is 0.3461 (c.v. 0.2116) nautical miles. The data used for abundance calculations and the results are given in Table 8. The total estimate of dolphins in the survey area was found to be 21,100 (c.v. 0.315).

65.2% of the sightings were made from the barrel; the rest from the wheelhouse roof (5.2%) or the wheelhouse itself (28.8%). Seeing the animals was recorded as the most frequent cue (92.2% of sightings). Although these cetaceans appear to be easy to detect owing to their jumping behaviour and occurence in relatively large schools, estimated (radial) sighting distances in only a very few cases exceeded 1 nautical mile, the greatest distance being 2.70 nautical miles.

Discussion

The abundance estimate presented in Table 8, 21,100 dolphins, should only be considered as a tentative estimate, since no considerations have been taken of among other things, large school size variations, vessel reaction problems (Hammond, 1986), and that the sightings may comprise several species. In fact, rather little is known about the distribution and abundance of dolphins in these waters. Jonsgård (1962) concluded that the four mentioned species of dolphins appear to have been recorded from the waters of Northern Norway, but only the white-beaked dolphin was conclusively identified. He also stated that this probably is the only commonly occuring species in these waters. From the west coast the white-sided dolphin has been positively identified, but its regular northern limit is thought to be at the Trondheim fjord (64°N) (Jonsgård, 1952). Later on, confirmed records of the common dolphin have been reported from Northern Norway, where it is considered to be an occasional visitor (Haug, Gulliksen and Christensen, 1981). The present evidence therefore seems to suggest that the dolphins recorded during this survey mainly were white-beaked dolphins. However, future surveys should address this question and try to identify also dolphin species to reveal these insufficiently known distributional aspects.

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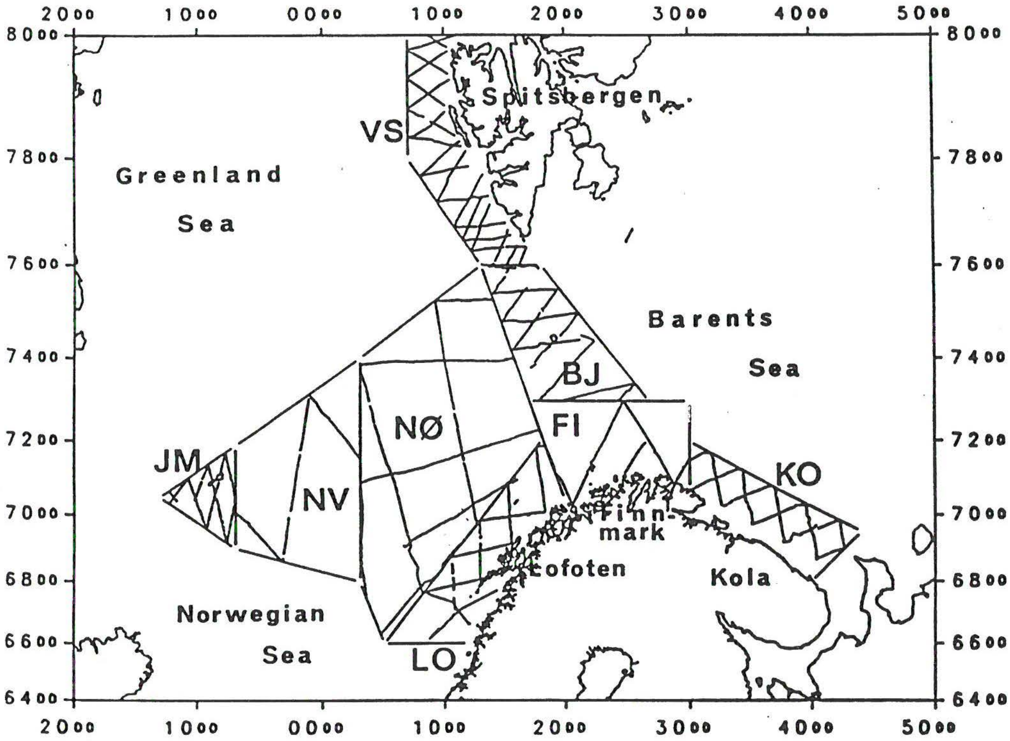

Fig. 1. Boundaries of the eight blocks surveyed by Norwegian vessels in July 1988, and cruise tracks run in primary searching mode.

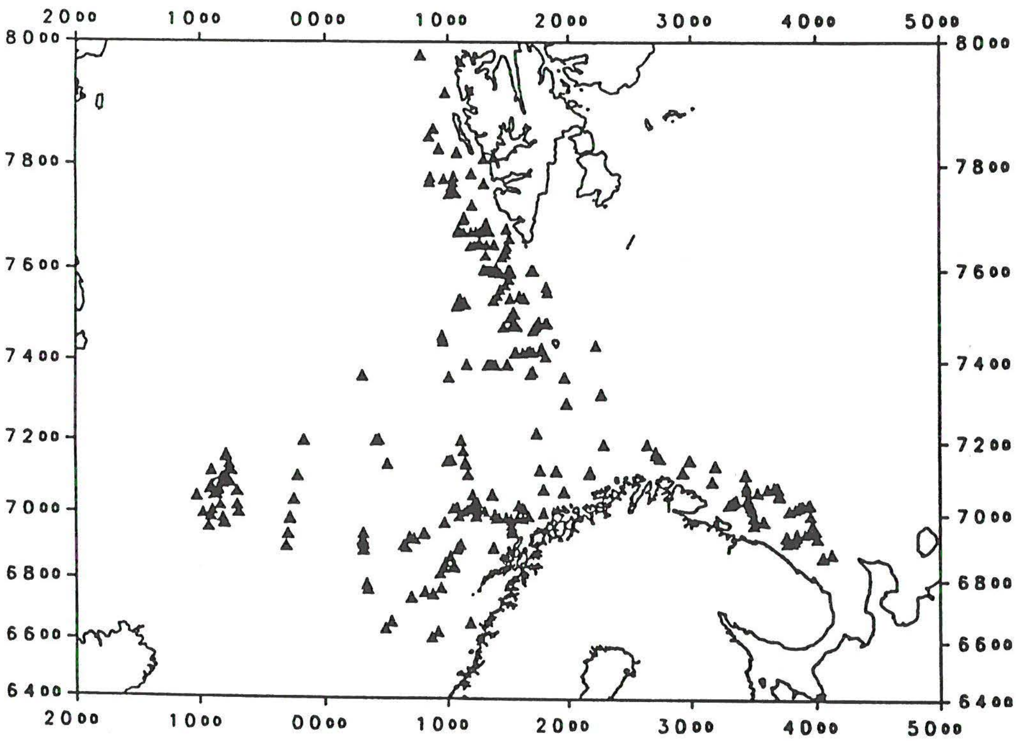

Fig. 2. Sightings (both primary and secondary) of minke whales as recorded during the shipboard survey in July 1988.

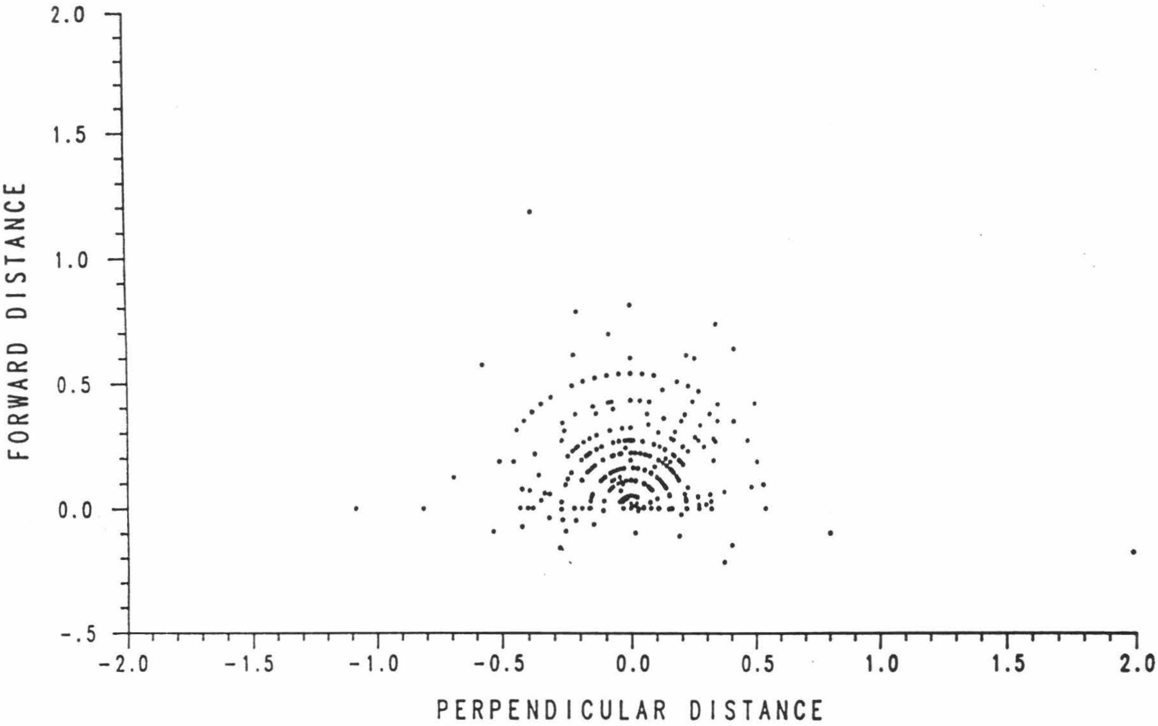

Fig. 3. Scatter plot of primary minke whale sightings relative to the observation platform. Scale on both axises is nautical miles.

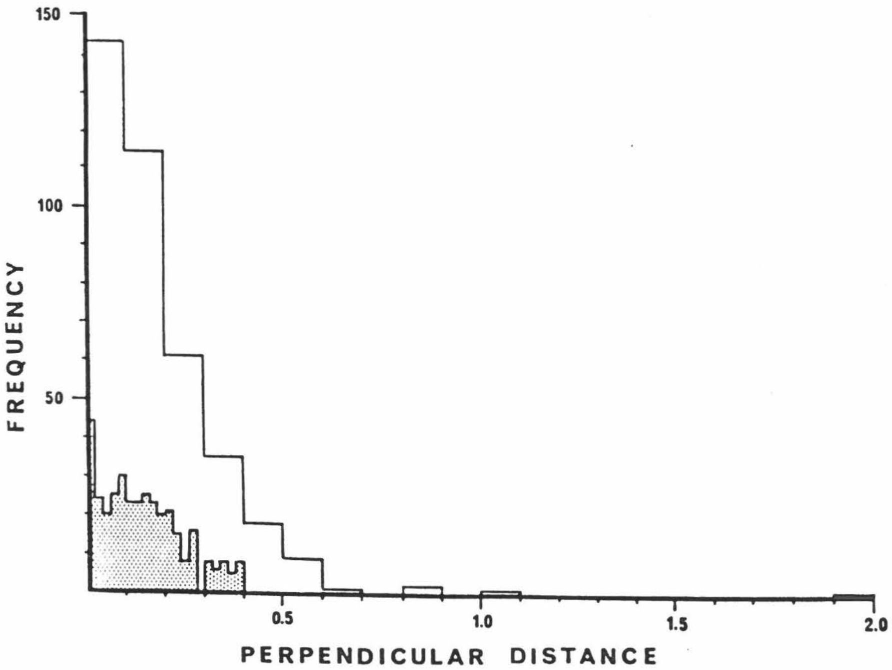

Fig. 4. Frequency distribution of perpendicular distances to primary minke whale sightings pooled over all blocks. In addition to frequencies grouped by 0.1 nautical mile intervals, frequencies by 0.02 nautical mile intervals are also shown out to 0.4 nautical miles (hatched bars).

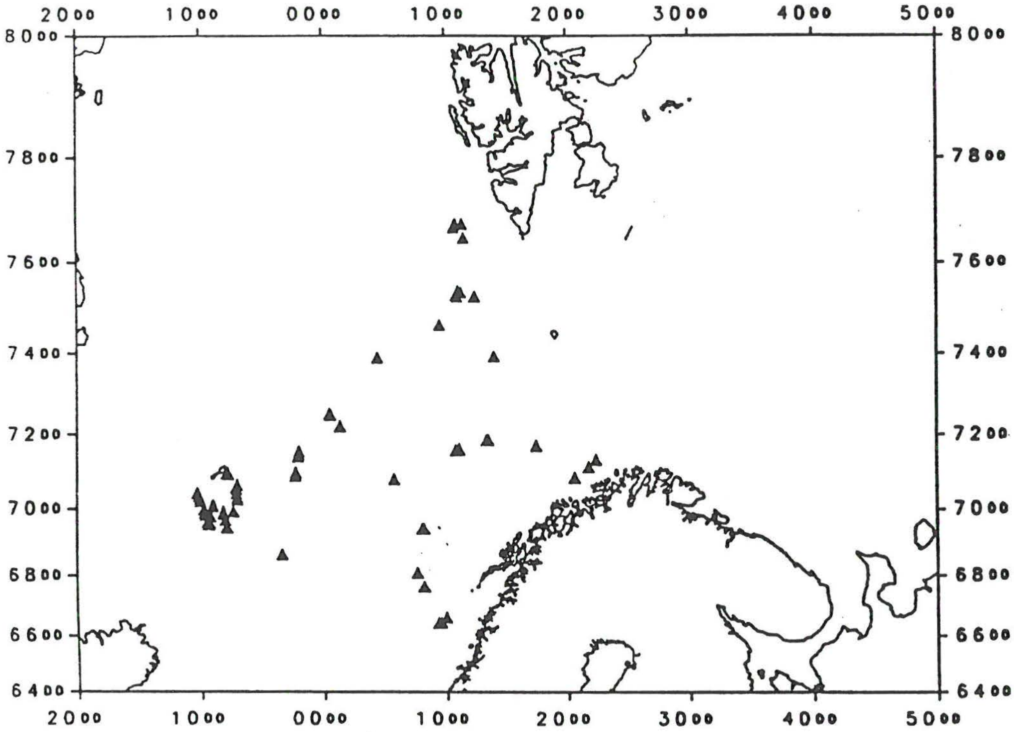

Fig. 5. Fin whale sightings during the July 1988 survey.

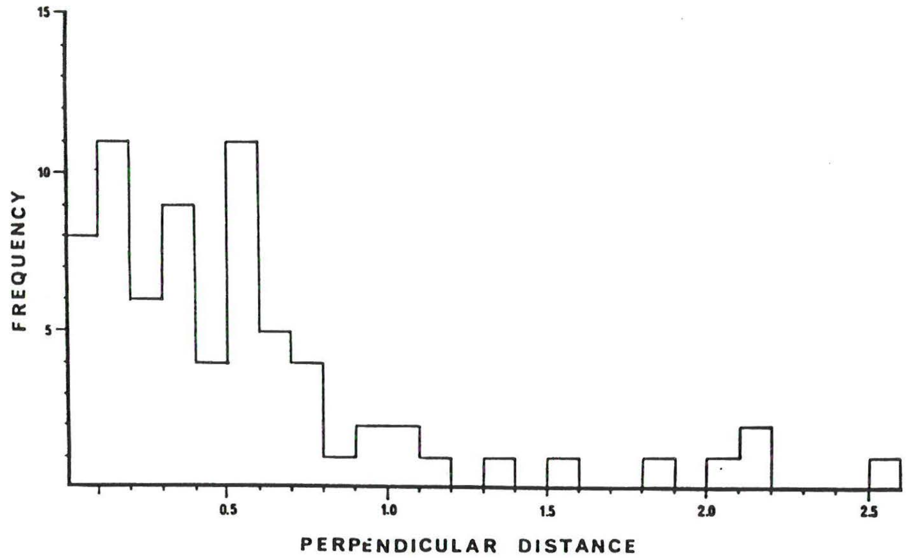

Fig. 6. Frequency distribution of perpendicular distances to primary fin whale sightings pooled over all blocks.

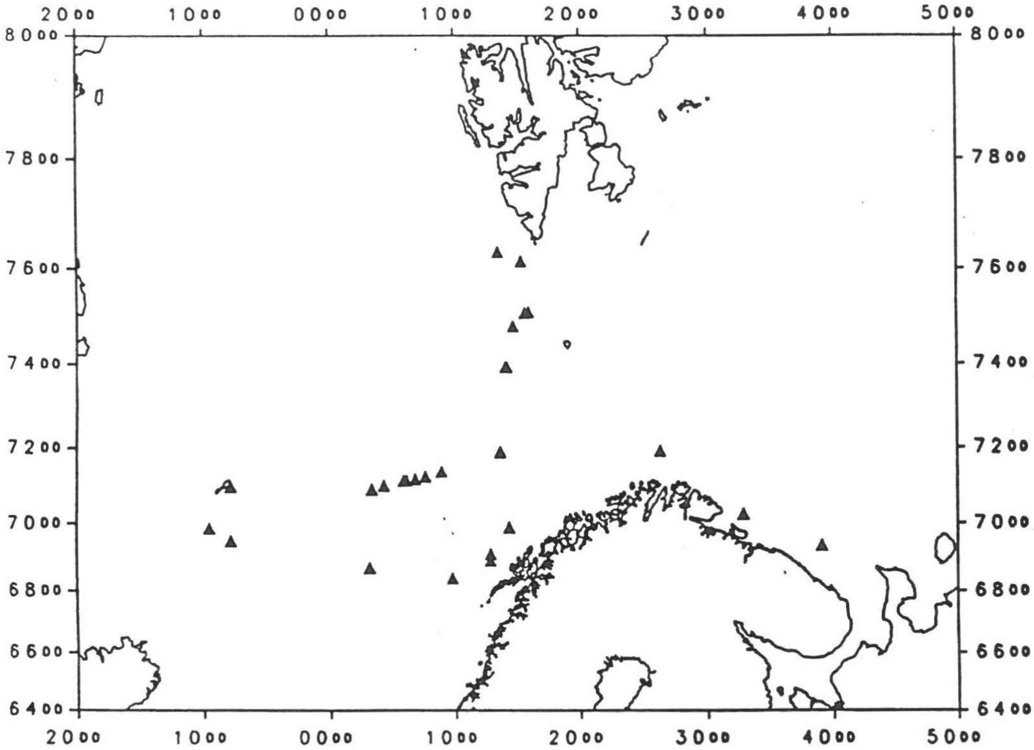

Fig. 7. Sightings of humpback whales during the July 1988 survey.

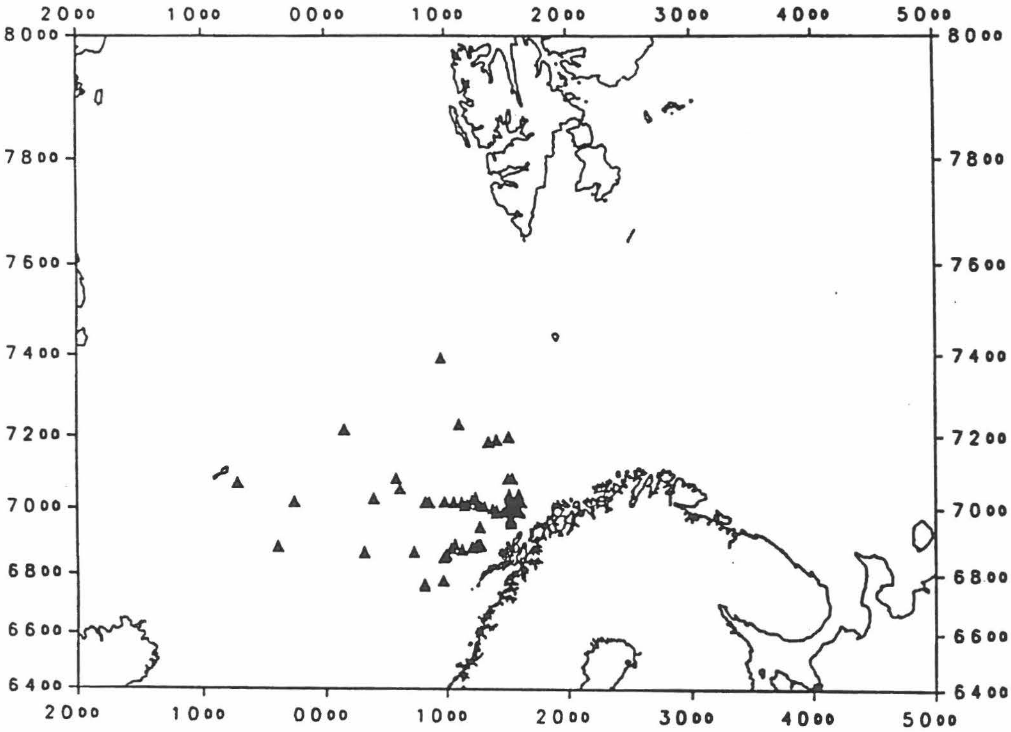

Fig. 9. Sightings of sperm whales during the July 1988 survey.

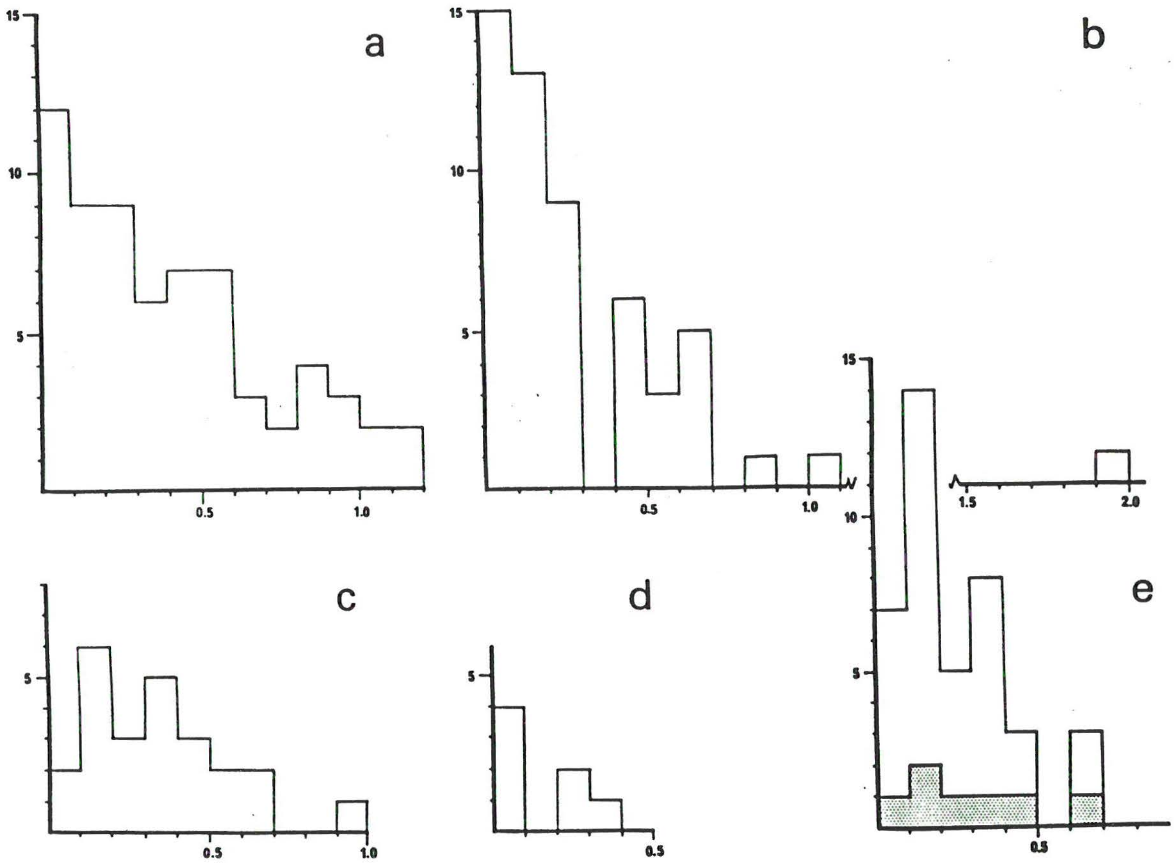

Fig. 8. Frequency distributions of perpendicular distances to primary sightings of (a) sperm whales, (b) dolphins (Delphinidae), (c) humpback whales, (d) North Atlantic bottlenosed whales and (e) killer whales. Killer whale distribution is given both for pods (hatched bars) and for individual whales (unhatched bars). Horizontal axises show perpendicular distances grouped by 0.1 nautical mile intervals.

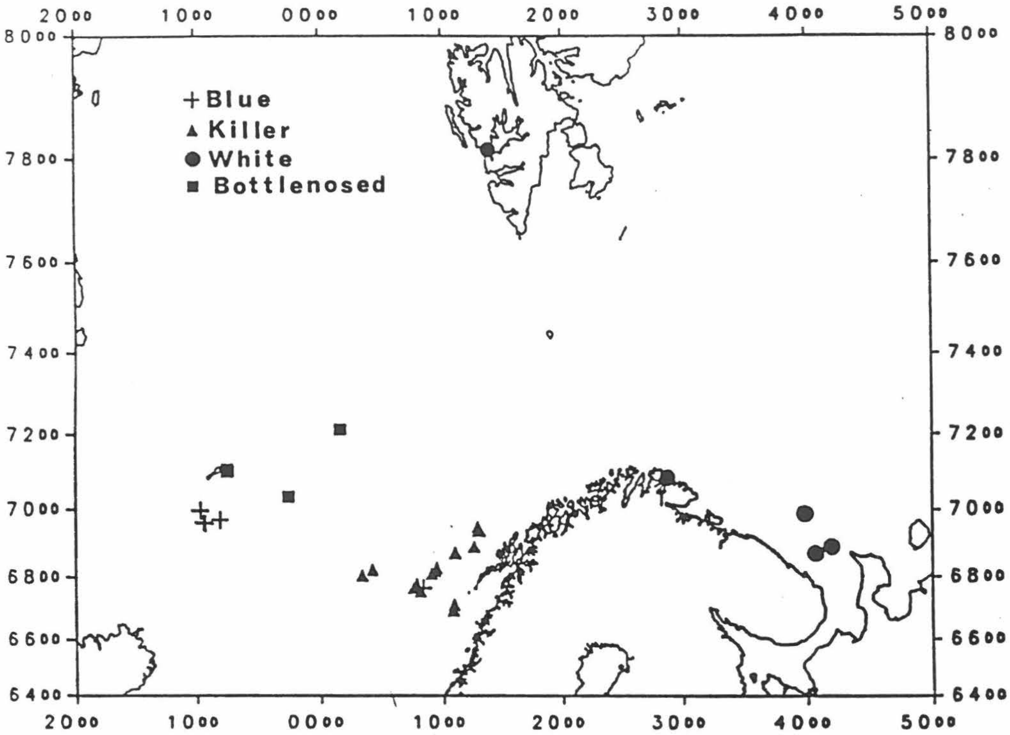

Fig. 10. Sightings of blue, killer, white and North Atlantic bottlenosed whales during the July 1988 survey.

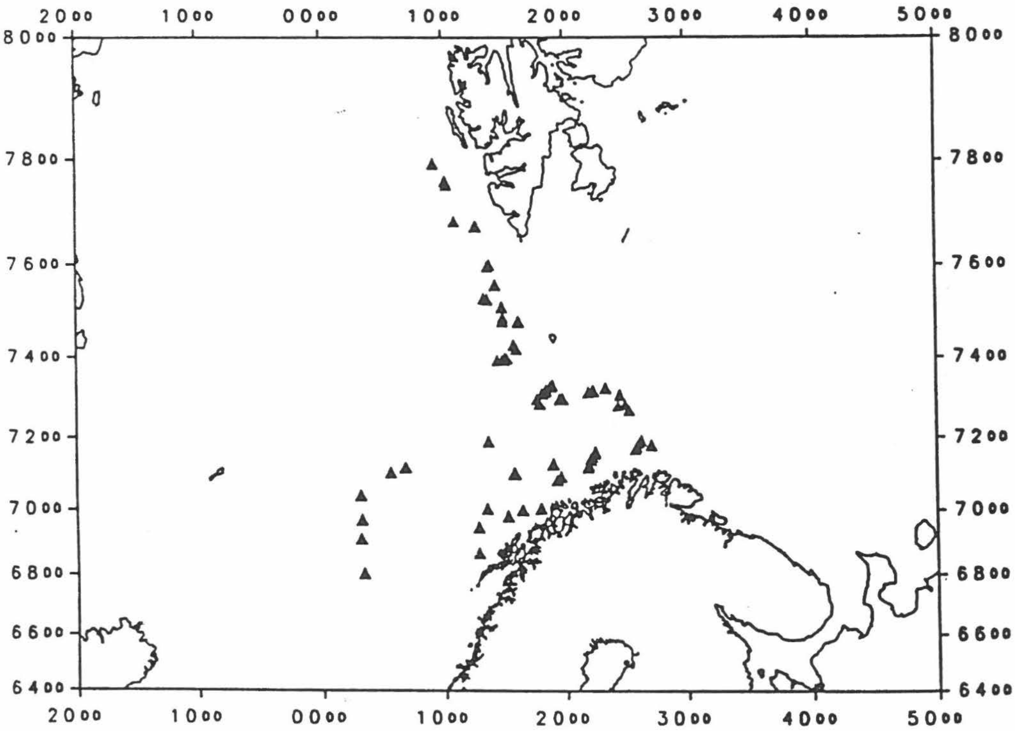

Fig. 11. Sightings of dolphins (Delphinidae) during the July 1988 survey.

Table 1. Sightings of whales recorded during line transect surveys in July 1988 by species and block. P = primary sightings with perpendicular distribution information; T = total number of sightings. To the left of the slash is given number of schools, to the right number of individuals. Also given is primary search effort (nautical miles), areas of blocks (square nautical miles) and mean school sizes by species, pooled over all blocks. 'Dolphins' comprise small Delphinidae, usually whitebeaked dolphins (see text).

Species		Block: JM	NV	NØ	LO	FI	KO	BJ	VS	TOTAL	Mean school size
Search effort,L,naut.m.		601.3	487.7	2010.9	1089.3	548.5	904.0	908.0	1084.0	7633.7	
Area,A,sq. naut.m.		10,718	52,719	101,339	37,944	28,129	28,315	21,503	14,461	295,128	
Minke whale	P	21/ 21	8/ 8	75/ 79	20/ 22	16/ 19	131/160	55/ 56	59/ 67	385/432	1.15
	T	37/ 44	19/ 24	86/ 92	29/ 31	16/ 19	132/161	85/ 96	67/ 76	471/543	(0.0286)
Fin whale	P	36/ 73	10/ 10	15/ 25	3/ 6	1/ 2	.	.	5/ 10	70/126	1.83
	T	56/117	13/ 16	19/ 32	8/ 12	1/ 2	.	.	6/ 11	103/190	(0.0738)
Blue whale	P	2/ 4	.	.	.	.	.	.	.	2/ 4	2.00
	T	5/ 10	.	.	1/ 1	.	.	.	.	6/ 11	(0.0)
Humpback whale	P	2/ 4	.	13/ 17	3/ 3	1/ 1	2/ 7	1/ 1	2/ 3	24/ 36	1.48
	T	3/ 6	.	14/ 18	3/ 3	1/ 1	2/ 7	3/ 8	2/ 3	28/ 46	(0.1112)
Harbour porpoise	P	.	5/ 22	2/ 3	10/ 19	2/ 3	3/ 5	.	.	22/ 52	2.15
	T	.	5/ 22	3/ 5	17/ 31	5/ 7	7/ 12	1/ 2	.	38/ 79	(0.1888)
Killer whale	P	.	.	6/ 33	1/ 7	.	.	.	.	7/ 40	14.67
	T	.	.	9/ 62	13/191	.	.	.	.	22/253	(0.5337)
Whitebeaked dolphin	P	.	.	.	.	5/ 39	.	.	.	5/ 39	7.80
	T	.	.	.	.	5/ 39	.	.	.	5/ 39	(0.2935)
'Dolphins'	P	.	.	15/ 54	5/ 40	9/ 73	.	16/107	4/ 27	49/301	8.34
	T	.	1/ 5	18/ 63	8/ 47	21/160	.	27/355	6/127	81/757	(0.1428)
Northern bottlenose whale	P	5/ 23	2/ 8	.	.	.	.	.	.	7/ 31	4.43
	T	5/ 23	2/ 8	.	.	.	.	.	.	7/ 31	(0.1290)
White whale	P	.	.	.	.	1/ 1	3/ 65	.	.	4/ 66	13.40
	T	.	.	.	.	1/ 1	3/ 65	.	1/ 1	5/ 67	(0.8698)
Sperm whale	P	1/ 2	3/ 3	21/ 22	41/ 47	.	.	.	.	66/ 74	1.12
	T	1/ 2	20/ 26	22/ 24	56/ 62	.	.	.	.	99/114	(0.0361)
Unidentified 'large whales'	P	9/ 18	4/ 5	17/ 20	8/ 8	.	3/ 3	2/ 2	3/ 3	46/ 59	
	T	11/ 20	4/ 5	22/ 25	12/ 12	.	3/ 3	2/ 2	3/ 3	57/ 70	
Unidentified 'whales'	P	1/ 1	.	.	1/ 1	.	.	.	1/ +	3/ 2+	
	T	2/ 2	.	.	1/ 1	.	.	.	1/ +	4/ 3+	

Table 2. Uncorrected abundance estimates of minke whales based on results from sightings survey in July 1988, by blocks and also as contributions to the Central and Northeastern stocks of minke whales. Effective half search width is estimated from perpendicular distances pooled over blocks and truncated at 0.7 nautical miles. Numbers in brackets are coefficients of variation.

Stock:	Central		Northeastern					
Block:	JM	NV	NØ	LO	FI	KO	BJ	VS
No. of schools, n	21	8	75	20	14	131	53	59
Sighting rate, n/L	0.0349	0.0164	0.0373	0.0184	0.0255	0.1499	0.0584	0.0544
	(0.2779)	(0.3468)	(0.2286)	(0.2755)	(0.2069)	(0.3258)	(0.2954)	(0.2748)
Effective search half width, w, naut.m.	0.2792 (0.0554)							
Mean school size, s	1.00	1.00	1.08	1.09	1.19	1.22	1.16	1.14
	(0)	(0)	(0.0289)	(0.0833)	(0.1145)	(0.0485)	(0.1255)	(0.0555)
Whale density, ind./sq.naut.m.	0.0625	0.0294	0.0721	0.0359	0.0543	0.3166	0.1213	0.1111
	(0.2834)	(0.3512)	(0.2370)	(0.2931)	(0.2429)	(0.3340)	(0.3257)	(0.2858)
Uncorrected abundance	670	1,548	7,311	1,363	1,529	8,964	2,609	1,606
	(0.2834)	(0.3512)	(0.2370)	(0.2931)	(0.2429)	(0.3340)	(0.3257)	(0.2858)
- contributions to stocks:	2,218 (0.2596)		23,381 (0.1554)					
Uncorrected abundance, all blocks:	25,599 (0.1437)							

Table 3. Frequencies of perpendicular distances to primary minke whale sightings given by block. Frequencies grouped in 0.1 n.mile bins for distances less than or equal to 0.7 nautical miles.

	Upper limit of class interval						
Block	0.1	0.2	0.3	0.4	0.5	0.6	0.7
JM	7	7	5	1	1	0	0
NV	4	3	0	0	1	0	0
NØ	31	21	13	6	2	2	0
LO	6	8	3	1	1	1	0
FI	1	10	2	1	0	0	0
KO	54	36	21	13	3	4	0
BJ	19	12	7	7	5	2	1
VS	21	17	10	6	5	0	0
Total	143	114	61	35	18	9	1

Table 4. Uncorrected abundance estimates of fin whales based on results from sightings survey in July 1988, by blocks and also as contributions to the East Greenland and North Norway stocks of fin whales. Effective half search width is estimated from perpendicular distances pooled over blocks and truncated at 1.4 nautical miles. Numbers in brackets are coefficients of variation.

Stock:	East Greenland-Iceland		North Norway			
Block:	JM	NV	NØ	LO	FI	VS
No. of schools, n	34	7	15	3	1	5
Sighting rate, n/L	0.0565	0.0144	0.0075	0.0028	0.0018	0.0046
	(0.6502)	(0.5038)	(0.4908)	(0.7289)	(0.7784)	(0.8855)
Effective search half width, w, naut.m.	0.8030 (0.0952)					
Mean school size, s	2.10	1.00	1.67	1.75	2.00	1.83
	(0.1045)	(0)	(0.1394)	(0.1429)	(0)	(0.2603)
Whale density, ind./sq.naut.m.	0.0739	0.0090	0.0078	0.0031	0.0022	0.0052
	(0.6654)	(0.5127)	(0.5190)	(0.7489)	(0.7842)	(0.9279)
Uncorrected abundance	792	473	790	161	63	76
	(0.6654)	(0.5127)	(0.5190)	(0.7489)	(0.7842)	(0.9279)
- contributions to stocks:	1,265 (0.4586)		1,045 (0.4096)			
Uncorrected abundance, all blocks:	2,309 (0.3121)					

Table 5. Uncorrected abundance estimates of humpback whales based on results from sightings survey in July 1988, by blocks and total. Effective half search width is estimated from perpendicular distances pooled over blocks. Numbers in brackets are coefficients of variation.

Block:	JM	NØ	LO	FI	KO	BJ	VS
No. of schools, n	2	13	3	1	2	1	2
Sighting rate, n/L	0.0033	0.0065	0.0028	0.0018	0.0022	0.0011	0.0018
	(0.6876)	(0.4086)	(0.7840)	(1.4307)	(0.4949)	(0.6222)	(0.5206)
Effective search half width, w, naut.m.				0.6032 (0.1633)			
Mean school size, s	2.00	1.29	1.00	1.00	3.50	1.00	1.50
	(0.5000)	(0.0975)	(0)	(0)	(0.1429)	(0)	(0.3333)
Whale density, ind./sq.naut.m.	0.0055	0.0070	0.0023	0.0015	0.0064	0.0009	0.0022
	(0.8657)	(0.4507)	(0.8008)	(1.4400)	(0.5404)	(0.6433)	(0.6394)
Uncorrected abundance	59	704	88	42	181	20	32
	(0.8657)	(0.4507)	(0.8008)	(1.4400)	(0.5404)	(0.6433)	(0.6394)
Uncorrected abundance, all blocks:				1,126 (0.3104)			

Table 6. Uncorrected abundance estimates of sperm whales based on results from sightings survey in July 1988, by blocks and total. Effective half search width is estimated from perpendicular distances pooled over blocks. Numbers in brackets are coefficients of variation.

Block:	JM	NV	NØ	LO
No. of schools, n	1	3	21	41
Sighting rate, n/L	0.0017	0.0062	0.0104	0.0376
	(0.9474)	(0.3367)	(0.3294)	(0.3693)
Effective search half width, w, naut.m.		0.6105 (0.2150)		
Mean school size, s	2.00	1.00	1.05	1.15
	(0)	(0)	(0.0455)	(0.0488)
Whale density, ind./sq.naut.m.	0.0028	0.0051	0.0089	0.0354
	(0.9715)	(0.3995)	(0.3960)	(0.4301)
Uncorrected abundance	30	268	906	1,344
	(0.9715)	(0.3995)	(0.3960)	(0.4301)
Uncorrected abundance, all blocks:	2,548 (0.2706)			

Table 7. Primary sightings, sighting rate and mean school size by blocks for whale species for which no effective search widths have been calculated. Numbers in brackets are coefficients of variation.

Block:	JM	NV	NØ	LO	FI	KO
Blue whale						
No. of schools, n	2	.	.	.	.	.
Sighting rate, n/L	0.0033	.	.	.	.	.
	(0.6876)					
Mean school size, s	2.00	.	.	.	.	.
	(0)					
Northern bottlenose whale						
No. of schools, n	5	2	.	.	.	.
Sighting rate, n/L	0.0083	0.0041	.	.	.	.
	(0.9474)	(0.5770)				
Mean school size, s	4.60	4.00	.	.	.	.
	(0.1766)	(0)				
Killer whale						
No. of schools, n	.	.	6	1	.	.
Sighting rate, n/L	.	.	0.0030	0.0009	.	.
			(0.6410)	(1.2827)		
Mean school size, s	.	.	6.86	25.60	.	.
			(0.2453)	(0.7279)		
White whale						
No. of schools, n	.	.	.	.	1	3
Sighting rate, n/L	.	.	.	.	0.0018	0.0033
					(0.5417)	(0.5049)
Mean school size, s	.	.	.	.	1.00	21.67
					(0)	(0.8847)

Table 8. Uncorrected abundance estimates of 'dolphins' (see text) based on results from sightings survey in July 1988, by block and total. Effective half search width is estimated from perpendicular distances pooled over blocks and truncated at 1.1 nautical miles. Numbers in breckets are coefficients of variation.

Block:	NØ	LO	FI	BJ	VS
No. of schools, n	15	5	13	16	4
Sighting rate, n/L	0.0075	0.0046	0.0237	0.0176	0.0037
	(0.3982)	(0.3956)	(0.5728)	(0.4937)	(0.5245)
Effective search half width, w, naut.m.			0.3461 (0.2116)		
Mean school size, s	4.29	7.00	7.96	11.74	6.75
	(0.1901)	(0.1881)	(0.1598)	(0.2589)	(0.2796)
Whale density, ind./sq.naut.m.	0.0465	0.0465	0.2725	0.2985	0.0361
	(0.4894)	(0.4865)	(0.6312)	(0.5963)	(0.6309)
Uncorrected abundance	4,710	1,765	7,666	6,419	522
	(0.4894)	(0.4865)	(0.6312)	(0.5963)	(0.6309)
Uncorrected abundance, all blocks:			21,082 (0.3154)		

ESTIMATES OF g(0) FOR MINKE WHALES

BASED ON AN INDEPENDENT OBSERVER EXPERIMENT

DURING THE NORWEGIAN SIGHTINGS SURVEYS IN JULY 1988

ABSTRACT

An independent observer experiment was conducted in a high density area of minke whales at the continental shelf west off Spitsbergen. The wheelhouse roof was used as the independent observer platform, although not ideal as it had an obstructed forward view. All g(0) estimates, including the estimates combining the two platforms, were significantly less than 1. The appropriate estimate of g(0) for the barrel sightings would be the one taking the forward obstruction into consideration, i.e. $g_A(0) = 0.56$ (s.e.=0.07).

INTRODUCTION

Several line transect surveys have been conducted by Norwegian vessels in recent years in the Northeast Atlantic. Sightings estimates of minke whale abundance based upon these surveys (Øien and Christensen, 1986; Øien, 1989a;1989b) have not been corrected for any possible deviations from the assumption in line transect theory that no whales are missed on the trackline, formulated in terms of the detection function as g(0)= 1 (Burnham, Anderson and Laake, 1980). From variable speed, parallel ship and independent observer experiments made during the IWC/IDCR Antarctic Assessment Cruises there are some indications that this probability is less than unity (Butterworth, Best and Basson, 1982; Butterworth, Best and Hembree, 1984; Butterworth and Borchers, 1988).

The majority of minke whale sightings in the Northeast Atlantic have been made by detecting the animal itself, in contrast to the more conspicuous blows usually seen in the Southern Hemisphere. This has raised the question whether the g(0)= 1 assumption for minke whales seen during the Norwegian surveys has been severely violated.

METHODS

The independent observer experiment was conducted during the July 1988 Norwegian sightings survey onboard the vessel Willassen Senior in the block VS off Spitsbergen (Øien, 1989b). The second half of the cruise was devoted to this experiment. In addition to the barrel, a platform was also established on the wheelhouse roof with separate communication lines to the wheelhouse where observations were recorded and the decision made by the senior scientist whether sightings were definite (D), possible (P) or remote possible (R) duplicates or non-duplicates (N). Weighting of duplicates has been performed following the suggestions by Butterworth and Borchers (1988). Accordingly, the point estimates of g(0) have been based on number of duplicates weighted as $n_{AB} = (D + {}^{2}/_{3}\ P + {}^{1}/_{3}\ R)$, and ranges have been indicated by using definite duplicates (D) only and all possible duplicates (D+P+R) as lower and upper end points, respectively.

Although the barrel and the wheelhouse roof were audially separated, it might have been possible for the spotters on the wheelhouse roof to see the topmen in the barrel, which in turn would mean that their observations could be affected to a certain degree by the searching behaviour of the topmen. An additional problem was caused by the foremast obstructing the view from the wheelhouse roof in a sector straight ahead. In searching mode during the independent observer experiment there were two primary observers both in the barrel and on the wheelhouse roof, and the searching speed was ten knots.

The sightings surveys conducted by Norway in 1987 and 1988 were run with an intended constant searching effort from the barrel by two spotters, while additional effort from other positions has been more or less incidental. Accordingly, most of the sightings during these surveys have been made from the barrel (Øien, 1989a;1989b), and g(0) for the barrel observers is therefore of main interest.

Approaches that have been suggested for analyzing data collected during independent observer experiments include the g(y) product integral (Butterworth, Best and Basson, 1982; Hiby and Hammond, 1987; Butterworth and Borchers, 1988) which utilizes the proportion of the sightings which are duplicates, and the direct procedure (Butterworth and Borchers, 1988) which takes into account the distribution of these duplicates as well as the proportion above. The analyses presented here have been based on the g(y) product integral method, for which g(0) can be estimated by (Butterworth and Borchers, 1988):

$$\hat{g}_A(0) = \frac{n_{AB}}{n_B} \cdot \frac{\int_0^\infty \tilde{g}_B(y)\,dy}{\int_0^\infty \tilde{g}_A(y)\cdot\tilde{g}_B(y)\,dy} = \frac{n_{AB}}{n_B} \cdot \frac{w_B}{G}$$

where

$$g(y) = g(0)\cdot\tilde{g}(y) \text{ with } \tilde{g}(0) = 1,$$

and $\tilde{g}(y)$ is chosen as the hazard-rate form

$$\tilde{g}(y) = 1 - \exp[-(y/a)^{(1-b)}],$$

$g_A(y)$ and $g_B(y)$ refer to the detection functions for the barrel (A) and the wheelhouse roof (B), n_{AB} is the number of schools sighted from both the barrel and the wheelhouse roof, n_B is the number of schools sighted from the wheelhouse roof, and w_B is the effective search half-width from the wheelhouse roof (if $g_B(0) = 1$).

An equivalent estimate for $g_B(0)$ is:

$$\hat{g}_B(0) = \frac{n_{AB}}{n_A} \cdot \frac{\int_0^\infty \tilde{g}_A(y)dy}{\int_0^\infty \tilde{g}_A(y) \cdot \tilde{g}_B(y)dy} = \frac{n_{AB}}{n_A} \cdot \frac{w_A}{G}$$

A combined estimate of g(0) for the two platforms is given by

$$\hat{g}_{AB}(0) = \hat{g}_A(0) + \hat{g}_B(0) - [\hat{g}_A(0) \cdot \hat{g}_B(0)] \ .$$

If the detection functions for the two observer platforms are asymmetrical about the transect line, a weighted combination of the functions above modeled separately for port (P) and starboard (S) observations can be used (Hiby and Hammond, 1987):

$$G = \frac{(n_A(P) \cdot n_B(P) \cdot G(P) + n_A(S) \cdot n_B(S) \cdot G(S))}{(n_A(P) \cdot n_B(P) + n_A(S) \cdot n_B(S))}$$

$$w_B = \frac{(n_B(P) w_B(P) + n_B(S) w_B(S))}{(n_B(P) + n_B(S))}$$

In cases where the observer B platform has an obstructed view in the forward direction, an estimator for $g_A(0)$ that has been suggested is:

$$\hat{g}_A(0) = n_{AB} \Big/ \sum_{i=1}^{n_B} \tilde{g}_A(y_{iB})$$

where y_{iB} is the perpendicular distance of the i-th sighting by B (Hiby and Hammond, 1987).

Standard errors of the g(0) estimates as calculated above have been tentatively estimated as the standard errors of the corresponding jack-knife estimates based on individual legs of the transects surveyed with two observer sets (Fig. 1); there were nine such legs.

RESULTS AND DISCUSSION

The transects were conducted in the independent observer mode, totalling 447.8 nautical miles in length, and are shown in Fig. 1. The experiment started on 18 July and concluded on 26 July, with some survey effort carried out on all but one day. The sighting rate during the experiment was 0.0916 (c.v= 0.2906) schools of minke whales per nautical mile surveyed. This is approximately twice the sighting rate recorded during the total survey of the block VS off Spitsbergen, and generally in the upper range of sighting rates obtained during the Norwegian surveys (Øien, 1989a; 1989b).

The number of schools observed from the barrel during the experiment was 32 (n_A= 32) and from the wheelhouse roof 19 (n_B= 19). As seen from Fig. 2, truncation of the data at 0.6 nautical miles reduces number of barrel sightings to 31 while the wheelhouse roof sightings remain unaffected. There were 10 duplicates, of which seven were classified as 'definite' (D= 7) and three as 'possible' (P= 3). Thus the point estimates of g(0) have been calculated with n_{AB}= 9, and the lower and upper end points of ranges with n_{AB}= 7 and n_{AB}= 10, respectively.

The distributions of barrel and wheelhouse roof perpendicular sighting distances are shown in Fig. 2. As the independent observer platform on the wheelhouse roof had an obstructed forward view, irregularities in the distribution for this platform near the trackline were expected. Angular distributions of the barrel and wheelhouse roof sightings are shown in Fig. 3, and their positions relative to the vessel plotted in Fig. 4. The perpendicular sightings distributions when the data from the port and starboard sides are presented separately, are shown in Fig. 5. From these figures, the wheelhouse roof sightings seem to have been hampered by the foremast. In addition, asymmetry in the wheelhouse distribution seems to be involved. A chi-square test applied to the wheelhouse data pooled into near-trackline (out to 0.2 nautical mile perpendicular distance) and far-from-trackline (remaining) sightings, reveals a significant difference between port and starboard sides from this platform (X^2=4.54 (Yates' correction applied; it should also be noted that not all expected cell frequencies in this test were at least 5, as commonly recommended), $0.025 < P < 0.05$). We are not aware of other obstructions of view than the foremast. Other explanations of asymmetries could be that glare conditions were prevailing on one side of the vessel. Glare problems were recorded in connection with 18 of the 32 barrel sightings and in 10 of the 19 wheelhouse roof sightings. While sightings recorded from the barrel were equally shared between starboard and port sides both with and without glare problems (8/10 and 7/7 respectively), this was not the case for the wheelhouse roof sightings when glare problems were present (7 observations on the port, 3 on the starboard); without glare the ratio here was 5 starboard to 4 port sightings. Furthermore, of 7 sightings made from the wheelhouse roof when glare was a problem on the starboard, 5 were made on the port side. These observations suggest that glare may explain the asymmetries of the wheelhouse roof sightings. It is, however, strange that the barrel sightings do not seem to be influenced in the same way by the glare problems. In fact, there may be some evidence to the contrary as 7 of the 10 barrel sightings made when glare was a problem to the port, also were made on the port side. Unfortunately, the data are too few to arrive at firm conclusions. These irregularities, whatever their causes are, provide the rationale for attempting alternate ways of estimating g(0).

It is interesting to note here that the ratio of sightings from the independent observer platform (i.e. the wheelhouse roof) to sightings from the barrel is 0.6:1 which is similar to values obtained from the Antarctic assessment cruises (Butterworth and Borchers, 1988). The proportion of barrel sightings seen by the independent observer is 31% in our experiment, which is also similar to values obtained from these cruises for vessels without an obstructed forward view. For one vessel/year combination in the Antarctic surveys with such an obstruction, the proportion was considerably lower, 8% (the K27 in 1985/86, Butterworth and Borchers, 1988). One obvious reason for the higher proportion in our experiment could be that the Antarctic cruises were conducted with one observer in the independent observer platform, while we had two observers there. Nevertheless, the difference is large and other explanations for the higher proportion may be likely. For example, there may be some indication from Figs 2-5 that also the barrel observers had a reduced forward searching effort. This pattern could arise if the two barrel observers involuntary concentrated their searching effort on 'their' side of the vessel with inefficient searching straight ahead of the vessel. Further, a higher proportion of duplicates would be expected if there is dependence between the platforms. Of the 10 definite or possible duplicates, 3 were observed simultaneously, and for the others approximately 1 to 4 minutes elapsed between sightings from either platform. However, sample size is too small to evaluate these effects in more detail.

The perpendicular sightings distance data were grouped into 0.1 nautical mile intervals and truncated at 0.6 nautical miles, but not smeared prior to fitting the hazard-rate function. The effect of smearing was investigated by applying method 2 of Buckland and Anganuzzi (1988) with a multiplier of 2 prior to fitting the hazard-rate. Smearing factors for the barrel were found to be $\Delta\theta/2= 3.59^0$ for angles and $\delta/2= 0.125$ for radial distances and for the wheelhouse roof $\Delta\theta/2= 7.93^0$ and $\delta/2= 0.5$, respectively. Smearing increased the estimates of w_A and w_B with approximately 2% and were therefore considered to be of minor concern in the analyses.

Estimates of g(0) for the barrel, wheelhouse roof and both combined are shown in Table 1. The point estimates are apparently not influenced by the method of analysis. Ranges of estimates illustrate the influence of duplicate classification, especially here where low numbers are involved. A more rigid procedure, based on classification during the analysis, as suggested for example by Hiby and Hammond

(1987), would perhaps be more satisfactory from an analytical point of view.

95% confidence intervals have been estimated by $t_{0.05}(8) \cdot$ s.e. where $t_{0.05}(8)$ is the critical *t*-value at probability 0.05 with 8 degrees of freedom (9 transects were used in the calculations) and s.e. is the jack-knife standard error estimate. These standard error estimates are remarkably low which may be a small sample accident, but perhaps also a result of the perpendicular distance distributions being essentially flat (Fig. 2) with little parameter variation in the fitted g(y)s. On the basis of confidence intervals, all the g(0) estimates are significantly less than 1.0. Provided the jack-knife standard error estimates are reliable, it can safely be concluded that a correction factor should be applied to the minke whale abundance estimates deduced from surveys in the Northeast Atlantic (Øien 1989a;1989b).

Since the $g_A(0)$'s estimated for the barrel are similar regardless of the underlying formulae used, it is not necessary to choose between them on other than grounds of principle. As obstruction and asymmetry seem to be involved in the wheelhouse sightings, either case (ii) or case (iii) for the barrel sightings in Table 1 should be considered as point estimate candidates.

Another approach to estimate g(0) is the 'direct procedure' (Butterworth and Borchers, 1988) which utilizes duplicate proportion data and their distribution. The data from the experiment presented here are too scarce to satisfy the demands of a more sophisticated analysis by this method. However, the distributions shown in Fig. 2

are virtually flat out to 0.3 nautical miles and approximate estimates of g(0)s can then be calculated if we ignore the data beyond this point, which seem to be an acceptable approximation at least for the wheelhouse roof sightings (Fig. 2b) which are relevant for the estimation of $g_A(0)$ for the barrel. Modelling of $g_A(y)$ and $g_B(y)$ by flat functions out to 0.3 nautical miles then gives the simple results

$$\hat{g}_A(0) = \frac{n_{AB}}{n_B} = \frac{9}{16} = 0.56 \quad \text{(Fig. 2b)}$$

$$\hat{g}_B(0) = \frac{n_{AB}}{n_A} = \frac{7}{24} = 0.29 \quad \text{(Fig. 2a)}$$

Assuming independence, standard errors of these estimates follow from the binomial distribution:

$$\text{s.e.}\ (g_A(0)) = \sqrt{(9/16)(7/16)/16} = 0.12$$

$$\text{s.e.}\ (g_B(0)) = \sqrt{(7/24)(17/24)/24} = 0.09$$

These estimates, at least for the barrel, are not very different from those obtained by the more complicated procedures.

If a physical dependence exist between the two platforms of an independent observer experiment, a positive bias of g(0) estimates is likely. Recently, also the theoretical basis for estimating g(0) from such experiments has been questioned. Schweder (1989) has shown that independence conditioned on the whale surfacing process does not imply unconditional independence. The failure of the independence assumption may result in an upward bias in the estimates of g(0), but he also holds that the relatively cheap independent observer experiment may be calibrated by more reliable methods.

Another question is related to whether the g(0) corrections presented by this analysis can be taken as general correction factors in the Norwegian vessel surveys, which in the case of the 1987 and 1988 surveys have been conducted in a standardized way. g(0) may be vessel dependent but also stratum dependent. The experiment discussed here was conducted in a high density area, one reason being the higher expectation of whale encounters. The whale densities in most of the other blocks surveyed were considerably lower (Øien, 1989a;1989b). If for example the whale spotters (previous whalers) are more effective in high density areas as the occurence of more sightings is likely to be an incentive for looking harder, the g(0) estimates presented here could be positively biased also in respect of application to those blocks. Future cruises should consider this possibility of g(0) varying with vessel and stratum.

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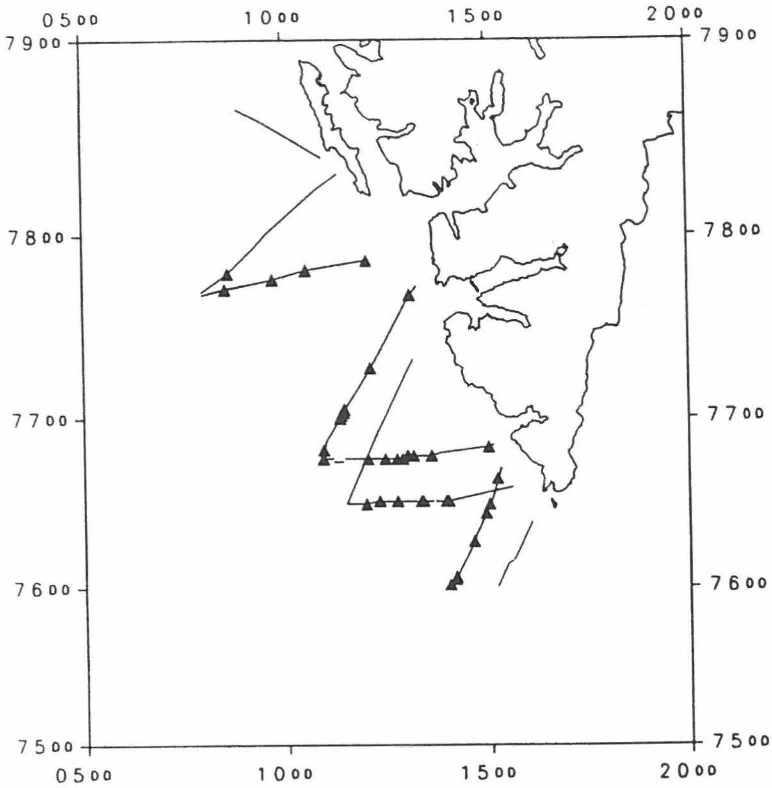

Fig. 1. Transects ran in independent observer mode at the west coast of Spitsbergen July 1988. Triangles indicate primary sightings of minke whales.

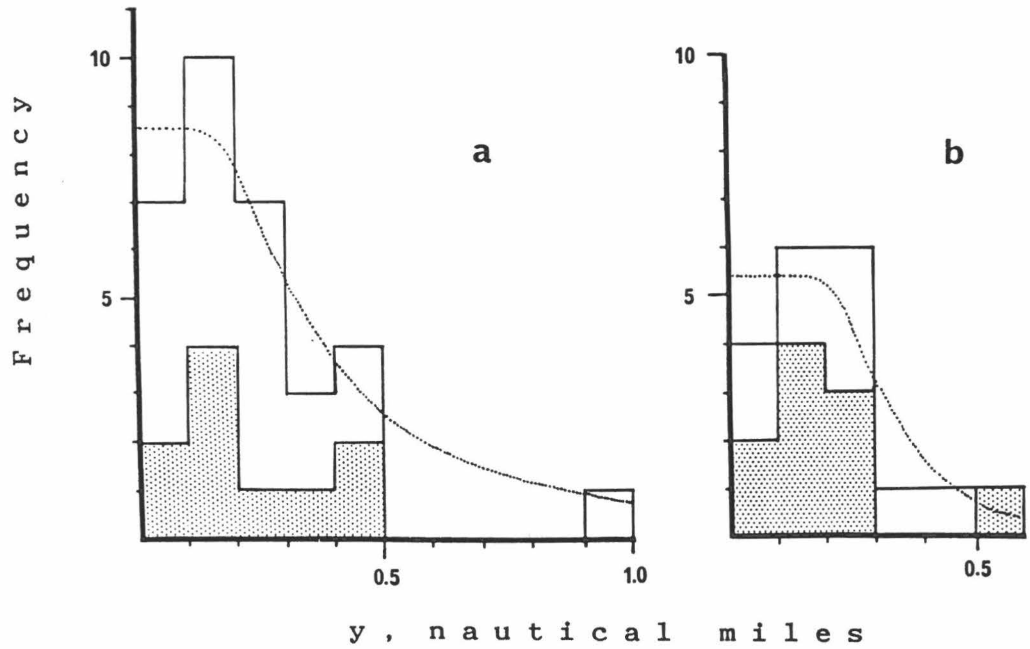

Fig. 2. Distributions of perpendicular distances to primary sightings and hazard-rate model fits for the barrel (a) and the wheelhouse roof (b). The parameter estimates of the hazard-rate model $g(y) = 1 - \exp[-(y/a)^{(1-b)}]$ are a= 0.304, b= 2.993 and a= 0.291, b= 4.500 for the barrel and the wheelhouse roof, respectively. Hatched histograms are distributions of duplicates.

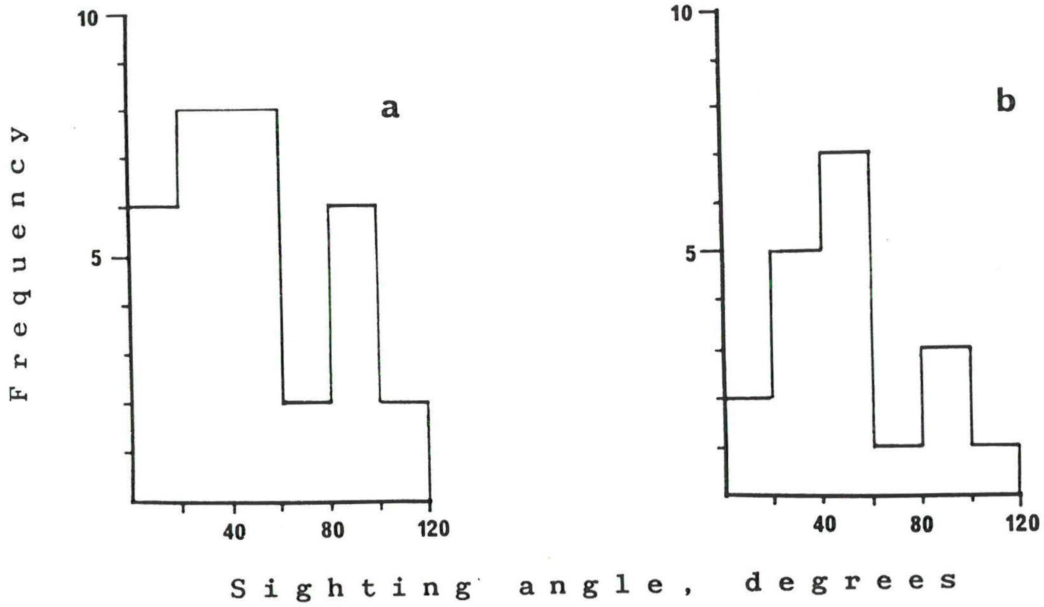

Fig. 3. Angular distributions of barrel (a) and wheelhouse roof (b) sightings. Sighting angles have been grouped in 20^0 bins.

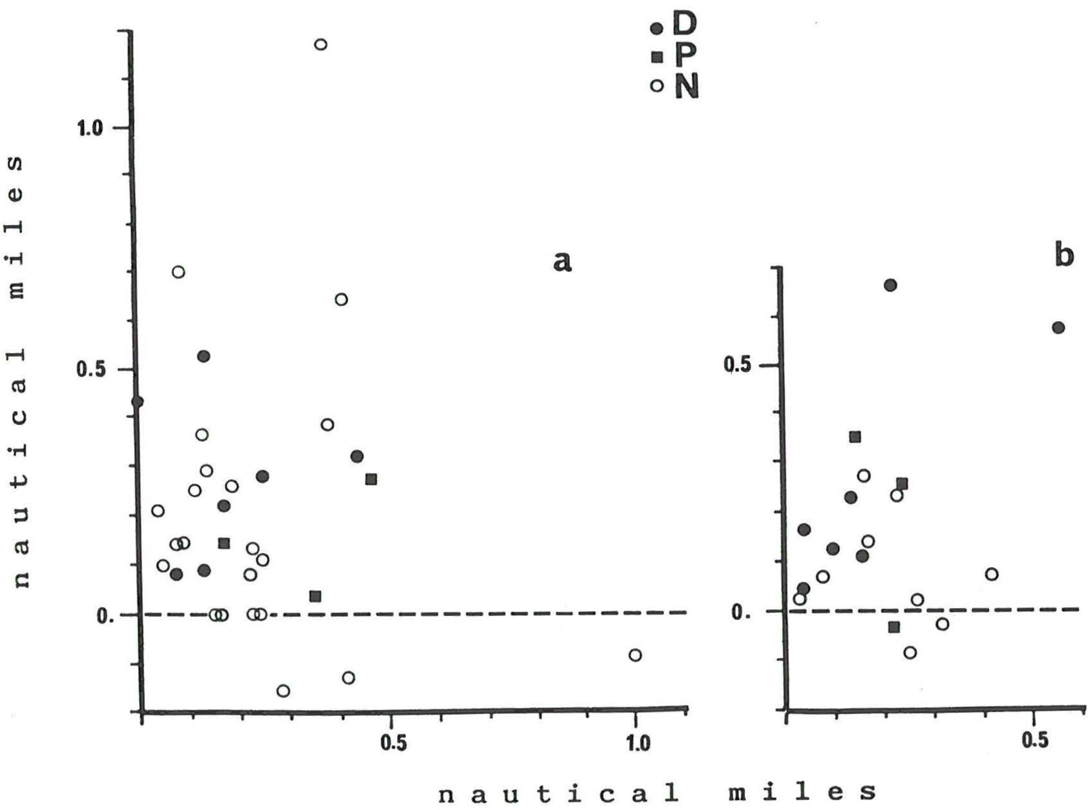

Fig. 4. Positions relative to the vessel of primary sightings made from the barrel (a) and the wheelhouse roof (b). Port and starboard sightings have been combined. Vertical axis is forward distance (trackline), and horizontal axis is perpendicular distance. Sightings marked as duplicates (D), possible duplicates (P) and non-duplicates (N).

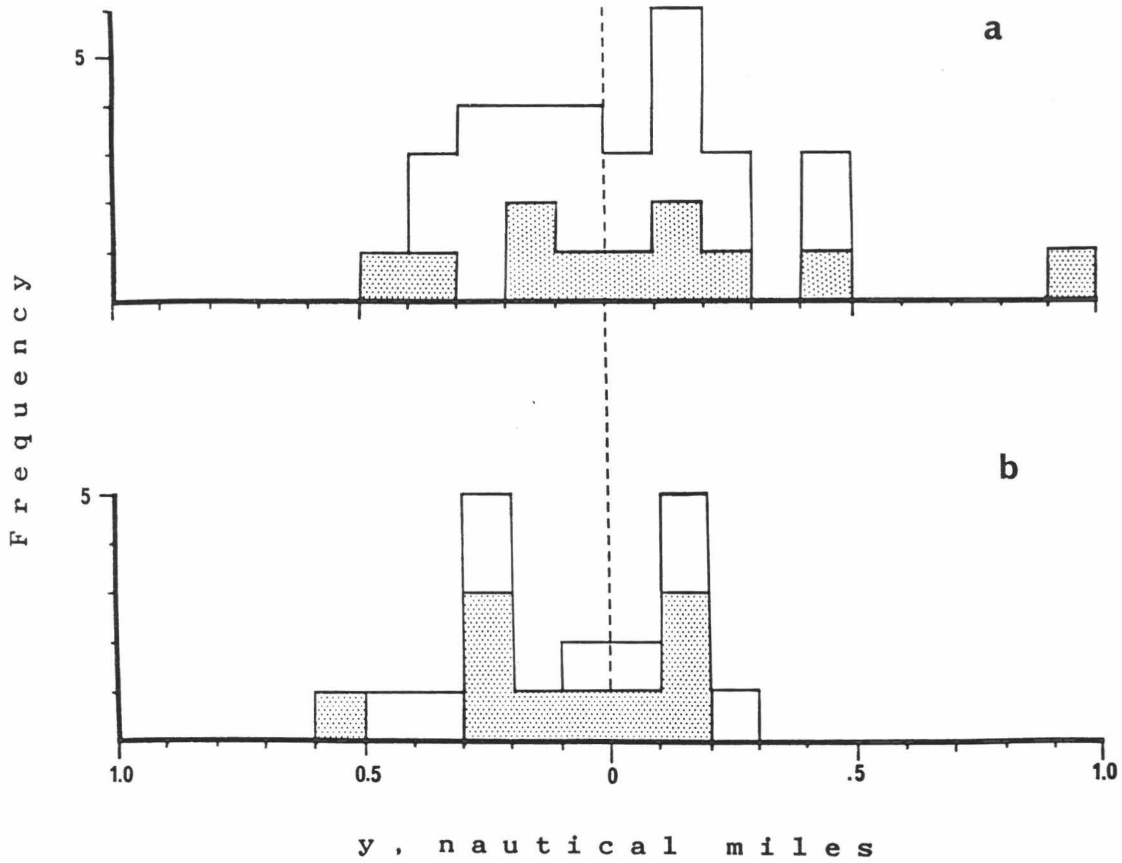

Fig. 5. Perpendicular distances to primary sightings made from the barrel (a) and wheelhouse roof (b) shown for the port and starboard sides of the vessel. Hatched histograms are distributions of duplicates.

Table 1. Estimates of proportion of minke whale schools seen on the trackline by the barrel ($g_A(0)$), the wheelhouse roof ($g_B(0)$) and combined ($g_{AB}(0)$). Standard errors are given in brackets. Case (i) is the standard product integral with data truncated at 0.6 nautical miles; in case (ii) additional weighting is included to account for asymmetries in distributions; and in case (iii) only the barrel detection function has been used. The estimation procedures for g(0) and standard errors are explained in the text.

Platform and case	Estimate	Range	95% conf. interval
Barrel $g_A(0)$			
(i)	0.58 (0.08)	0.45-0.64	0.42-0.74
(ii)	0.55 (0.08)	0.43-0.61	0.37-0.73
(iii)	0.56 (0.07)	0.43-0.62	0.41-0.72
Wheelhouse roof $g_B(0)$			
(i)	0.41 (0.12)	0.32-0.45	0.13-0.69
(ii)	0.37 (0.06)	0.29-0.41	0.23-0.51
Combined estimate $g_{AB}(0)$			
(i)	0.75 (0.08)	0.62-0.80	0.57-0.93
(ii)	0.72 (0.04)	0.59-0.77	0.63-0.81