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NORWEGIAN COMBINED ACOUSTIC AND BOTTOM TRAWL SURVEYS FOR DEMERSAL FISH IN THE BARENTS SEA DURING WINTER

by

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ABSTRACT

A combined acoustic and bottom trawl survey for demersal fish in the Barents Sea has been conducted annually since 1981. The main aim is to map the spatial distribution and obtain indices of abundance (numbers at age) of cod, haddock, redfish and Greenland halibut. In addition other biological information and CTD-data are collected. The survey covers an area of about 150,000 square nautical miles, and is carried out with 3 vessels and about 25 scientific staff for a period of 25-30 days. The abundance indices and weight at age data are used directly in the stock assessments in ICES. Stomach data of cod are together with other information used to estimate the Northeast Arctic cod stock's consumption of important prey species, e.g. capelin, cod and haddock. This information is further used in the assessment of these species. The tuning diagnostics indicate that the indices from the survey are the most reliable among the tuning data, and the assessments of Northeast Arctic cod and haddock are thus heavily dependent on the results of the survey. Since the management relies heavily on the assessments, the surveys can have a direct effect on the TAC's. Several changes in survey methodology aiming at increased reliability of the results have been introduced. Some of these changes had large effects on the index level. The time series have therefore been adjusted in order to maintain and improve comparability. However, it is suggested that also in the adjusted series, most recent years index/stock ratios for cod are higher than those from the first 10 years period; a matter that should be taken into account in the stock assessments.

1. CURRENT OBJECTIVES

A combined acoustic and bottom trawl survey for demersal fish in the Barents Sea is conducted annually in January - March by the Institute of Marine Research, Bergen (IMR). The main aim of the survey is to map the spatial distribution and obtain indices of abundance (numbers at age) for the most important commercially exploited dermersal fish species in the Barents Sea. The target species are cod (*Gadus morhua*), haddock (*Melanogrammus aeglefinus*), golden redfish (*Sebastes marinus*), deep-sea redfish (*S. mentella*) and Greenland halibut (*Reinhardtius hippoglossoides*).

The main objectives are:

- to obtain indices of abundance of the target species by length and age groups
- to estimate mean length and weight at age for cod and haddock
- to collect stomach samples of cod for studies of growth processes in cod and cod predation on important prey species, itself included (cannibalism)

Data and results are used in the stock assessments in ICES and in several projects at IMR, especially multispecies research and development of survey methodology.

2. HISTORY

In 1970 IMR initiated a project to find the most suitable time of the year to estimate the abundance of prerecruits of cod and haddock in the Barents Sea by an acoustic survey (Hylen and Smedstad, 1972). It was found that the period January to the middle of March was most favourable for applying acoustic methods, based on the following requirements (Dalen and Smedstad,1979, 1983):

- the species concerned have the most advantageous spatial location or spread within their area of distribution
- most of the fish have to stay off the bottom to be detected acoustically
- a minimum of migrating movements of the fish within the surveyed area to minimise certain biases in the estimates
- not too strong interference of other species among those being assessed

From 1974 increasing effort was gradually put into assessing abundance of recruits of Northeast Arctic cod and haddock and since 1976 the survey has followed a detailed and well-defined schedule and working plan (Dalen and Smedstad, 1979). In 1981 a stratified random bottom trawl survey was started in the same area at the same time of the year (Dalen *et al.* 1982). The bottom trawl survey was originally regarded as a supplement to the acoustic survey, as one expected so low future stock levels that the acoustic method might become insufficient. Gradually, however, the bottom trawl survey has become at least as important as the acoustic survey. Since 1993 the survey area has been extended to the north and east to obtain a more complete coverage of the younger age groups of cod. The target species were originally cod and haddock, but since the mid-1980s abundance indices have also been estimated for the redfish species and Greenland halibut.

3. TECHNICAL DESCRIPTION

Acoustic indices of abundance have been obtained each year since 1976 and swept area indices since 1981. In 1980 there was a malfunction of the acoustic system (Dalen and Smedstad 1983), and the results from that year have been excluded from the time series. Hence, for 1981 and onwards annual indices of abundance of cod and haddock exist for both types of observations.

3.1 The acoustic survey

The acoustic methodology is described by Dalen and Smedstad (1979, 1983), Dalen and Nakken (1983) and MacClennan and Simmonds (1991). Dalen and Smedstad (*op. cit.*) introduced the expression "extended acoustic method", which includes the following processes:

- observing and recording integrated echo intensities by means of calibrated echo sounders and echo integrators
- identifying and distributing (interpreting, scrutinising) recordings on species or species group by means of biological trawl samples, echograms, integrator readings and target strength observations
- determining the size and age distribution of recorded fish by means of biological samples (trawling)
- applying mathematical models to estimate fish density, amounts of fish and distribution of length, weight and age

The performance of the acoustic measurement system has been more or less continuously improved since the survey started and several generations of echo sounders and echo integrators have been in use. In later years, 1992-1997, all IMR research vessels have been fitted with retractable instrument keels offering the opportunity to lower the acoustic transducer 2.5-3.5 m below the hull in order to reduce or avoid the transmission loss due to airbubbles in the near surface layer in bad weather. Prior to 1992 when hull mounted transducers were used the acoustic observations were corrected for air bubble transmission loss as described by Dalen and Løvik (1981). In some instances towed transducers were also applied, towing at depths well below the bubble layer. However, the use of towed transducers in rough sea constituted a considerable operational problem and caused substantial delay when trawling had to be carried out frequently.

At present recordings are made by SIMRAD EK500 scientific echo sounder (Bodholt *et al.*, 1988) and Bergen Echo Integrator (BEI) system (Knudsen, 1990). Raw data are displayed and interpreted on a graphics workstation. Recordings of echo density, s_A, are stored in BEI with high resolution, and species allocated values are stored as 10 meter channel values for the pelagic layer and as 10 channels á 1 metre in the bottom zone for each nautical mile (n.m.). Species allocation is normally done on a 5 n.m. basis.

The survey area is divided into rectangles of half a degree (30 n.m.) in the north-south direction and one degree in the east-west direction (Fig. 1). For each species (or species group, e.g. redfish) and rectangle the arithmetic mean of echo density $\bar{s}_A$ is calculated for the layer from the surface and down to 10 m above the bottom (pelagic echo density) and for the 10 m layer nearest the bottom (bottom echo density). Until 1992 the whole water column was treated as one layer in this procedure and cod and haddock were taken as one species group.

Echo densities are converted into fish density by:

$$\overline{\rho}_A = \frac{\overline{s}_A}{\overline{\sigma}_A} \tag{1}$$

$\overline{\rho}_A$ mean fish density (number / n.m.^{2}) in rectangle
$\overline{s}_A$ mean echo density (m^2 / n.m.^{2}) in rectangle
$\overline{\sigma}_A$ mean backscattering cross section for single fish (m^2) in rectangles

For cod, haddock and redfish the backscattering cross section (σ), target strength (TS) and fish length (L in cm) are related as (Foote, 1987):

$$\mathrm{TS} = 10 \cdot \log\left(\frac{\sigma}{4\pi}\right) = 20 \cdot \log(L) - 68 \tag{2}$$

Until 1992 the target strength $\mathrm{TS} = 21.8 \cdot \log(L) - 74.9$ was applied for cod and haddock. The 1981-1992 part of the time series has later been corrected using the target strength/length relationship in the equation above (Aglen and Nakken, 1997).

The backscattering cross section/length relationship allows the equation above to be written on a more appropriate form for practical use:

$$\overline{\rho}_A = 5.021 \cdot 10^5 \cdot \overline{s}_A \,/\, \overline{L^2} \tag{3}$$

$\overline{L^2}$ being the mean of "squared lengths" (bottom and pelagic by rectangle).

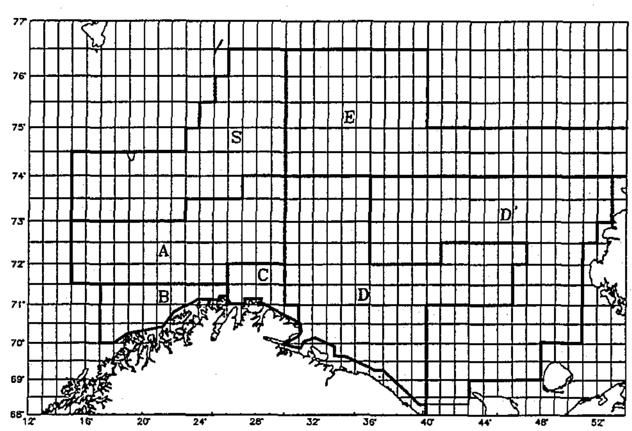

Figure 1. The Barents Sea with rectangles and subareas used in the calculation of acoustic abundance indices.

Mean square fish lengths, $\overline{L^2}$, are estimated in the following way:
For each rectangle two sets of trawl catches are selected, one representing pelagic echo density and one representing bottom echo density. This is a subjective process and also trawl catches outside the rectangle are used. Only bottom trawl catches are applied for the bottom layer, while both pelagic and bottom trawl catches are used for the pelagic layer. Length distribution for each species, rectangle and layer is found by calculating the number in each 5 cm length group per unit towed distance for each station's catch, corrected for size dependent capture efficiency in the bottom trawl (Aglen and Nakken *op. cit.*, see below). Let f_i denote the sum of catches per n.m. in length group i and let L_i be the length in cm in the centre of

length group i :

$$\overline{L^2} = \frac{\sum_{i=i_{\min}}^{i_{\max}} f_i \cdot L_i^2}{\sum_{i=i_{\min}}^{i_{\max}} f_i} \tag{4}$$

After the mean density of a species $\overline{\rho}_A$ in a rectangle and layer is calculated , this density is split into 5 cm length groups according to the length distribution in the rectangle, and the number of fish in each 5 cm length group is found by multiplying by the area in n.m.^{2}. Numbers in rectangles are summed up to each of the subareas A, B, C, D, D', E and S. For cod and haddock the number of fish in each age group in each subarea is found by applying the same age-length keys as estimated in the bottom trawl survey (see below).

3.2 The bottom trawl survey

The survey methodology is described in Dalen *et al.* (1982) and in Hylen *et al.* (1986b). The sampling trawl is a Campelen 1800 shrimp trawl with 80 mm mesh size in the front. Until 1993 a codend with 35-40 mm stretched mesh size was used. Since this mesh size can give a considerable selection of 1 year old cod, the mesh size was changed to 22 mm in 1994. The survey indices have not been corrected for this change. Until 1988 the trawl was equipped with rubber bobbins but in 1989 a rockhopper ground gear was introduced. This improved the capture efficiency of the trawl, particularly for small fish (Engås and Godø, 1989). The survey indices (both acoustic and bottom trawl indices) for cod and haddock from 1981-1988 have later been corrected for this change (Godø and Sunnanå, 1992; Aglen and Nakken, 1997). The length of the sweep wires are 40 m. Both bottom trawl doors (Steinshamn V- and W-doors, 7.1 m^2, 1500 and 2050 kg) and doors for pelagic/bottom trawling (Vaco combi doors, 6 m^2, 1500 kg) have been applied.

Since 1993 a constraint technique on the spread of bottom trawl doors (Engås and Ona, 1993) has been used on about every second trawl haul. 150 m from the doors the distance between the sweep wires is "locked" with a 10 m long rope, giving an almost constant spread (48-50 m), independent of wire length / trawl depth. Without the constraint technique the distance between the doors is 50-60 m, increasing with increasing depth and depending on the ratio between the wire length and depth. With the constraint technique the variation in door spread within a tow is reduced. Analysis of the data 1993-1996 has shown no significant effect on the overall catch rates. One would expect the catch rates to be reduced, at least for some size groups. The reduction in catch rates might, however, be countered due to an increase in catch rates for the tows where the trawldoors otherwise would have been overspread.

The standard tow duration was 60 min. until 1985 when it was reduced to 30 min. Godø *et al.* (1990) found no significant difference in catch rates between these two tow durations. The towing speed is 3 knots, and the distance towed is measured with a doppler log or preferably with GPS. Today the SCANMAR system is used on all trawl hauls. The equipment measures door spread, mouth opening and bottom contact, and provides "on-line" information on trawling performance.

The positions of the bottom trawl stations are determined prior to the survey. When the investigations started in 1981 the survey area was divided into 4 subareas with 35 strata (Fig. 2) based on the horizontal fish distribution from acoustic surveys in the period 1977-1980 and the knowledge of important fishing grounds (Dalen *et al.,* 1982). The stations were distributed according to the formula:

$$n_i = N \cdot V_i \cdot \frac{a_i}{A} \tag{5}$$

n_i number of stations in stratum i

N total number of stations

a_i area of stratum i

A total survey area

V_i subjective weighting factor of "importance" (0.25, 1.0, 2.0 or 3.0)

The subjective weighting factor was based on the distribution of cod and haddock as observed during the surveys in 1977-1980. Each stratum was divided into rectangles, 15' longitude and 7.5' latitude, and rectangles to be trawled in were chosen at random. For large strata containing few stations, the stations were placed at random within main parts of the strata to ensure good coverage. Within a chosen rectangle the trawl station could be taken anywhere. Fig. 2 shows the stations taken in 1987.

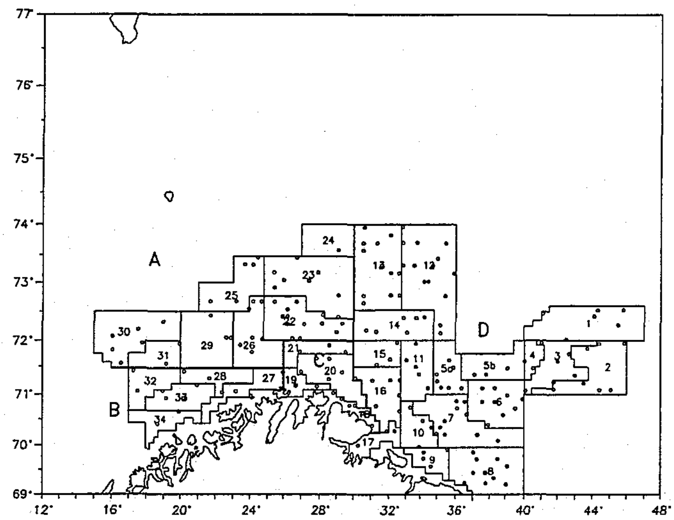

Figure 2. The survey area with subareas (A,B,C,D) and strata used in the bottom trawl survey 1981-1992. Stations taken in 1987 are also shown (random positions).

Since 1990 the stations have been more evenly distributed over the whole survey area, with fixed predetermined positions at 1-3 densities (20 n.m. in 1990-92 and 1997, 20/30/40 n.m. in 1993-95, 16/24/32 n.m. in 1996). In order to obtain a more complete coverage of the younger age groups of an increasing cod stock 3 new subareas with 18 strata were included in the survey in 1993 (Fig. 3). This extension to north and east also included the southern part of the Svalbard area. Parts of 10 different strata from the Svalbard strata system (Fig. 4) were applied.

The survey area now consisted of 63 strata altogether, and with a total of about 330 stations several strata got relatively few stations allocated. In order to get better estimates of fish densities and minimise the variance within each stratum, a new strata system for the whole area was introduced in 1996. It consisted of 7 subareas with 23 strata and the stations were spaced at regular grids with 3 densities (Fig. 5), based on the distribution of cod in the bottom trawl surveys in 1990-1995.

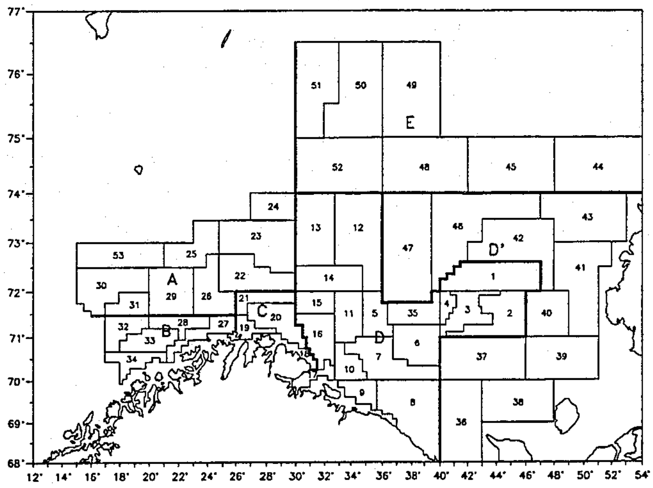

Figure 3. The survey area with subareas (A,B,C,D,D',E,S) and strata used in the bottom trawl survey 1993-95.

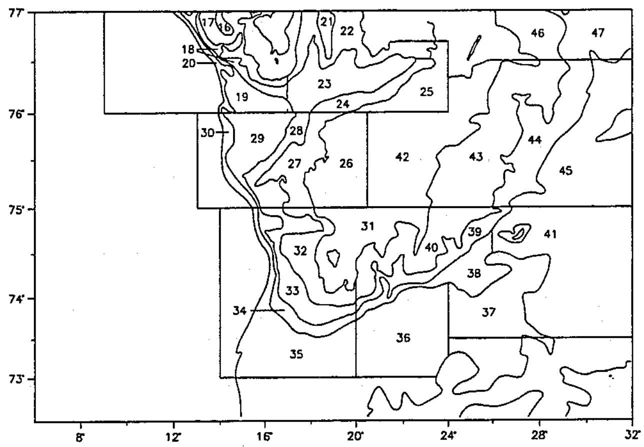

Figure 4. Southern part of the Svalbard area and strata used (32-41) in the bottom trawl survey 1993-1995.

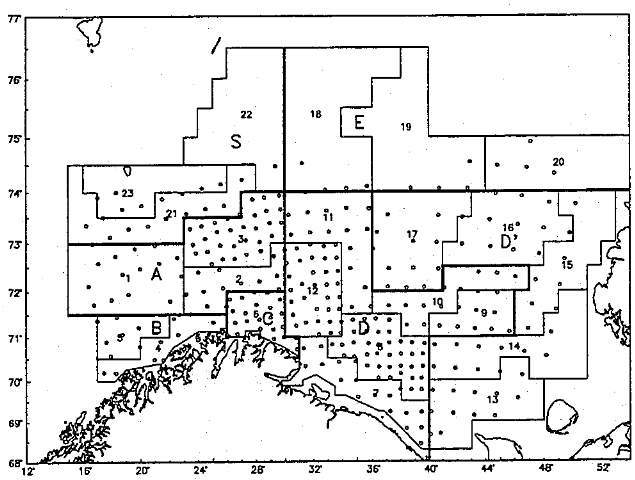

Figure 5. The survey area with subareas (A,B,C,D,D',E,S) and strata used in the bottom trawl survey since 1996. Stations taken winter 1996 are also shown; fixed positions, distance = 16/24/32 nautical miles.

Length based abundance indices by area are estimated in the following way: For each trawl station and length a point observation of fish density is calculated:

$$\rho_{s,i} = \frac{f_{s,i}}{a_{s,i}} \tag{6}$$

$\rho_{s,i}$ numbers of fish/n.m.^{2} observed at station s (length i)

$f_{s,i}$ raised length frequency

$a_{s,i}$ swept area:

$$a_{s,i} = \frac{d_s \cdot EW_i}{1852} \tag{7}$$

d_s towed distance (n.m.)

EW_i length dependent effective fishing width:

$$EW_i = \alpha \cdot i^{\beta} \tag{8}$$

$$EW_i = EW_{i_{\min}} \text{ for } i \le i_{\min}$$

$$EW_i = EW_{i_{\max}} \text{ for } i \ge i_{\max}$$

The parameters used are given in the following table:

Species	α	β	$i_{\min}$	$i_{\max}$
Cod	5.91	0.43	15 cm	62 cm
Haddock	2.08	0.75	15 cm	48 cm

Based on the results of Dickson (1993a,b) a length dependent effective fishing width of the trawl was introduced in the calculations in 1995 (Korsbrekke et al., 1995) and the indices back to 1989 has been recalculated. Aglen and Nakken (*op. cit.*) have corrected the time series prior to 1989 applying a correction based on mean length at age.

Point observations of density at length are summed up to 5 cm length groups $\rho_{s,l}$ where l denotes length group. Stratified indices of abundance by length groups and strata:

$$L_{p,l} = \frac{A_p}{S_p} \cdot \sum_{s \text{ in stratum } p} \rho_{s,l} \tag{9}$$

$L_{p,l}$ abundance index, stratum *p*, length group *l*

A_p area (in n.m.^{2}) of stratum *p* (or the part covered by the survey)

S_p number of stations in stratum *p*

The degree of coverage of the northern and easternmost strata are changing from year to year. Area covered is calculated from the total area of the stratum multiplied with proportion of stations taken.

These indices are estimated for each of the strata within the subareas A, B, C, D, D', E and S. Total indices by length are obtained from summation over subareas.

3.3 Biological sampling and age-length keys

Each trawl catch is sorted and further measurements are taken according to standard procedures. All fish species are weighed and the total number is calculated. The whole catch or a representative subsample of important species is measured for length (1 cm scale for demersal species and ½ cm scale for pelagic species). Individual information, i.e. length, weight, age (otoliths), sex and maturity) is collected from a certain number of cod and haddock. In the first couple of years a representative subsample of 100 fish was analysed per station, 2 stations per strata. From 1984 this sampling was done stratified, with samples of 5 fish per 5 cm length group on each station. In the same year a stomach sampling programme for cod started (Mehl and Yaragina, 1992). Stomachs were collected on most stations with other biological sampling, 5 fish per 5 cm length group. Based on the work of Pennington and Vølstad (1994) and Bogstad *et al.*, (1995) the number of fish sampled per 5 cm length group was reduced from 5 to 2 in 1993, while the number of stations sampled per stratum was increased from 2 to 4. Since 1996 1 fish is sampled per 5 cm length group on all predetermined bottom trawl stations with more than 10 specimens of cod or haddock in the catch. In addition, similar samples are taken from all pelagic trawl hauls.

From 1986 individual samples have also been taken of redfish (*S. marinus* and *S. mentella*) and Greenland halibut. In general 5 fish per 5 cm length group from 2 stations per stratum are sampled. In the two last years additional samples have been taken of redfish from large bottom trawl catches (> 50 specimens of *S. marinus* and > 100 specimens of *S. mentella)* and from all pelagic catches. In the same period Greenland halibut have been sampled on all stations with catch, all specimens in 1996 and 5 of each sex per 5 cm length group in 1997.

Until 1992 different age-length keys (ALKs) were used in calculation of the two indices. For the acoustic index an unweighted ALK based on all samples in each main area was applied, while for the bottom trawl (swept area) index each 5 cm length group on stations with age samples was weighted by the total catch of the actual species on that station when the ALK for each main area was made. From 1993 the same ALK is used for both indices. All age samples in the area are used. The traditional estimation of age-length keys has been changed to estimate keys that for each 5 cm length group give weighted proportions of the observed age groups. Such keys are estimated for each of the main areas. All age samples from the same stratum and length group are given equal weight:

$$w_{p,l} = \frac{L_{p,l}}{n_{p,l}} \tag{10}$$

$n_{p,l}$ number of age samples in stratum p and length group l

Proportions are estimated as:

$$P_a^{(l)} = \frac{\sum_p n_{p,a,l} \cdot w_{p,l}}{\sum_p n_{p,l} \cdot w_{p,l}} \tag{11}$$

$p_a^{(l)}$ weighted proportion of age a in length group l and stratum p

$n_{p,a,l}$ number of age samples age a in length group l and stratum p

Note that the weighting factors can be summed up to total swept area estimates. The weighting factors describe each age sample's "share" of the total swept area estimate. A small bias is introduced because age samples from the same 5 cm length group are given equal weight although we have assumed a length dependent capture efficiency. This bias is largest for the smaller fish. Numbers at age are calculated as:

$$N_a = \sum_p \sum_l L_{p,l} \cdot P_a^{(l)} \tag{12}$$

Mean length and weight is calculated as (only weight is shown):

$$W_a = \frac{\sum_p \sum_l \sum_j W_{a,p,l,j} \cdot w_{p,l}}{\sum_p \sum_l \sum_j w_{p,l}} \tag{13}$$

$W_{a,p,l,j}$ being the weight of sample *j* in length group *l*, stratum *p* and age *a*

3.4 Further on survey design and effort

The division of the survey area into rectangles in the acoustic investigation and the stratification used in the bottom trawl investigation have to a large extent determined the survey design. In the first years when an acoustic survey was carried out by one research vessel for 5-6 weeks, the survey pattern and distribution of trawl stations were designed on the basis of (Dalen and Smedstad, 1983):

- the expected extension area of young cod and haddock
- the probable distribution of the species in the area
- the probable size distribution of the species
- the large-scale behaviour of the species

The survey pattern was mainly equidistant parallel lines, more close in higher fish concentrations, with some zigzag paths. Biological sampling took place when the patterns of the echo recordings of demersal species changed or when biological data were needed in response to distribution and coverage.

When the survey in 1981 was extended to also include a bottom trawl investigation, two commercial trawlers were hired to carry out the survey together with the research vessel. The hired trawlers took the major part of the trawl stations included in the bottom trawl survey, working from the east to the west and with a survey pattern minimising the sailed distance. A few of the fixed bottom trawl stations (in the eastern part of the survey area) were taken by the research vessel. The research vessel still followed mainly parallel course tracks 20 n.m. distant in most of the area (Fig. 6), with a somewhat more open pattern in the east and north (30-40 n.m. distance). Most of the course lines followed a south-north direction.

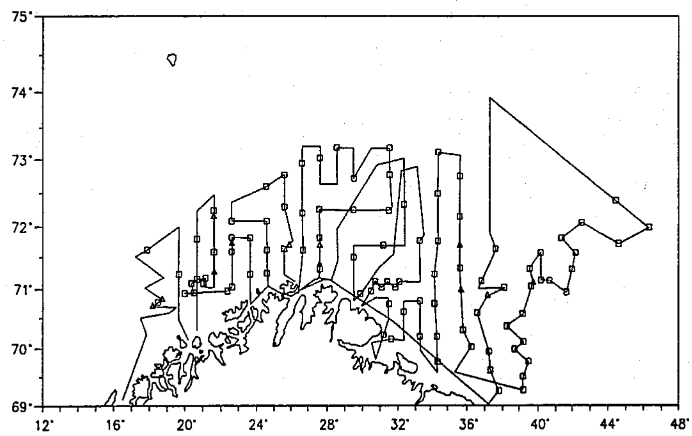

Figure 6. Survey tracks and trawl stations taken by R/V "G.O. Sars" winter 1984.

In the mid-1980s there was a strong improvement in the recruitment of both cod and haddock, and in the acoustic investigation the proportion of the biomass found pelagically increased substantially. From 1986 the survey therefore was carried out by two research vessels and one commercial trawler. This increased the capability for both acoustic coverage and pelagic sampling. Although the research vessels took an increasing part of the bottom trawl stations in the bottom trawl survey, the number of stations had to be reduced by about 1/3 (to the minimum required for keeping the precision at an acceptable level). The course tracks and survey pattern were mainly as in the previous years.

In 1990-1992 a fixed station grid was applied in the bottom trawl survey, and the survey pattern became even more regular than before. When the survey area was extended to the east and north in 1993 also the survey period and effort of the research vessels were increased, following the same survey patterns as earlier. From 1995 the survey has been carried out by three research vessels. This together with the new strata system introduced in 1996 (Fig. 5) gave a higher degree of flexibility in the survey design. In the past the research vessels often covered separate parts of the survey area, but from now on they to a large extent followed adjacent course tracks (Fig. 7). Also the total survey effort could be reduced a little. Table 1 summarises the survey effort for the years 1981-1997, and in Table 2 all the changes in survey design, methods, gear etc. are listed.

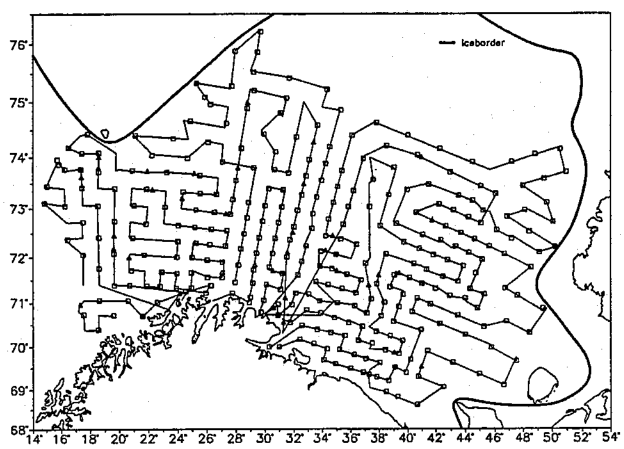

Figure 7. Survey tracks and trawl stations taken by R/Vs "G.O.Sars", "Johan Hjort and "Jan Mayen" winter 1995.

Table 1. Time period, area covered, number and type of vessels, vessel days, person days at sea, number and type of trawl stations in the Norwegian demersal fish survey in the Barents Sea winter 1981-1997.

Year	Period	Area ($n.m.^2$)	Vessels Res/Com	Vessel days	Person days	Trawl st. bottom/pel	Trawl st. swept area
1981	20.1-27.2	88835	1R/2C	114	456	?	273
1982	26.1-5.3	88835	1R/2C	111	432	324/0	262
1983	26.1-5.3	88835	1R/2C	100	428	350/7	279
1984	28.1-9.3	88835	1R/2C	113	472	340/12	271
1985	25.1-8.3	88835	1R/2C	102	456	364/25	300
1986	23.1-3.3	88835	2R/1C	112	666	280/76	193
1987	26.1-3.2	88835	2R/1C	94	554	263/21	209
1988	10.1-8.3	88835	2R/1C	112	732	299/27	192
1989	27.1-26.2	88835	2R/1C	85	475	291/33	203
1990	29.1-3.3	88835	2R/1C	74	414	283/8	231
1991	30.1-6.3	88835	2R/1C	77	488	320/23	302
1992	28.1-7.3	88835	2R/1C	78	450	298/38	218
1993	10.1-25.2	137642	2R/1C	107	789	321/114	243
1994	21.1-10.3	143840	2R/1C	103	652	359/69	289
1995	27.1-2.3	186554	3R	85	610	399/36	300
1996	5.2-5.3	165281	3R	79	636	362/31	329
1997[1]	3.2-3.3	87549	3R	62	510	286/13	178

[1)] Norwegian zone only

Table 2. Changes in survey design, methods, gear etc. in the Norwegian dermersal fish survey in the Barents Sea winter 1981-1997.

Year	Change from	To
1984	Representative age sample, 100 per station	Stratified age sample, 5 per 5-cm length group
1986	1 research vessel, 2 commercial trawlers	2 research vessels, 1 commercial trawler
1987	60 min. tow duration	30 min. tow duration
1989	Bobbins gear	Rock-hopper gear (time series corrected)
1990	Random stratified bottom trawl stations Simrad EK400 echo sounder	Fixed station grid, 20 n.m. distance Simrad EK500 echo sounder and BEI postprocessing
1992-97	Hullmounted transducers	Keel mounted transducers
1993	TS = 21.8 log L - 74.9 for cod and haddock	TS = 20 log L - 68 for all demersal species (time series corrected)
	Fixed survey area (A,B,C,D), 1 strata system, 35 strata Fixed station grid, 20 n.m. distance No constraint technique on bottom trawl doors 5 age samples per 5-cm group, 2 per stratum	Extended, variable survey area (A,B,C,D,D',E,S) 2 strata systems, 53 + 10 strata Fixed station grid, 3 densities Constraint technique on bottom trawl doors 2 age samples per 5-cm group, 4 per stratum (cod and haddock)
	Weighting of age-length keys by total catch	Weighting of ALK by swept area estimate
1994	35-40 mm mesh size in codend	22 mm mesh size in codend
1995	Constant effective fishing width of the trawl	Fish size dependent effective fishing width (time series corrected)
	2 research vessels, 1 commercial trawler	3 research vessels
1996	2 strata systems and 63 strata 2 age samples per 5-cm group, 4 per stratum	1 strata system and 23 strata 1 age sample per 5-cm group, all stations with > 10 specimens (cod and haddock)

3.5 Other information collected, data storage and standard analysis

In addition to the biological and acoustic sampling of the target species (see above), hydrographic data (temperature and salinity) are collected on every fixed bottom trawl station by a CTD-probe. Routinely also three standard hydrographic transects with CTD-stations from surface to bottom are taken during the survey. Mean values of temperature and salinity are computed for selected parts in each of the three transects. The survey is also used for methodological studies, e.g. extra trawling for increasing the knowledge on gear performance, selectivity and capture efficiency.

The biological information (data from trawl stations) is written on standard forms and computerised onboard on ASCII files. There is not sufficient manpower to read and computerise all the age material onboard, and most of the cod stomachs are analysed after the survey. However, in later years an increasing part of the age and stomach material has been finalised onboard.

The acoustic registrations are interpreted daily onboard the vessels, and both raw and interpreted data are stored in an Ingres database. Also ASCII files for calculation of mean echo density (s_A) by target species, layer and rectangle are produced (see above). The averaging was earlier done manually, but is now done automatically by an SAS-routine. The FORTRAN program for calculating the acoustic abundance indices requires the files with average s_A-values, files telling which biological information (trawl stations) is to be applied for splitting groups on species and species on length groups in each layer, and files with age-length keys for each species.

During the survey ASCII files with trawl, temperature and course data are transferred to the main vessel (telex via satellite). On the main vessel preliminary swept area estimates on length are calculated by an SAS-routine. Maps showing course tracks and distribution of temperature and target species in the bottom trawl investigation are prepared and plotted by other SAS-routines.

Most of the analysis and presentation of survey results are, however, still done ashore. Files with average s_A-values and allocated trawl stations from the different vessels are combined and the biological information is completed and checked for errors before it is included in annual ASCII files and SAS datasets. Then acoustic abundance indices and final swept area estimates are made for the target species, distribution maps are prepared and mean length and weight at age for cod and haddock are estimated (weighted the same way as the ALK, see above), before the survey is reported (Dalen *et al.*, 1982, 1983, 1984; Hylen *et al.*, 1985, 1986a, 1988, 1992; Godø *et al.*, 1987, 1992; Jakobsen *et al.*, 1989, 1990; Korsbrekke *et al.*, 1993, 1995; Mehl, 1997; Mehl and Nakken, 1994, 1996).

The routine analyses and reporting after the survey take about one month and 100 person days.

4. USE OF SURVEY INFORMATION

4.1 Vertical distribution and availability

The vertical distribution of the fish affects the availability to the bottom trawl and the acoustic equipment in different ways. Concentrations of fish close to the bottom are effectively sampled by the bottom trawl but underestimated by the acoustics since much of the fish will be situated in the acoustic dead zone of 1-2 m up from the bottom. Pelagic concentrations which are clearly off the bottom are, on the other hand, effectively sampled by the echo sounder but less available to the bottom trawl; the availability depending on the distance between fish and bottom as well as the size of the fish (Aglen, 1996). A table which summarises the recorded echo density as a function of distance from bottom for each 50 m bottom depth interval has therefore been presented in the annual cruise reports in the most recent years both for cod and haddock (Korsbrekke *et al.*, 1995, Mehl and Nakken, 1996). This information is very useful in order to judge and qualify the year to year comparability in either of the two index series and may also become the main basis for a quantitative estimate of annual availability in future.

4.2 Assessment calibration

The main demersal stocks in the Barents Sea have since 1993 been assessed using XSA for tuning the VPA. For Northeast Arctic cod and haddock the indices from the survey (trawl and acoustic) have in most of the assessments shown the best performance, challenged by the trawl/acoustic indices from the Russian survey. Bottom trawl indices from the survey have also been included in the tuning of the Greenland halibut VPA and performs as well as the other surveys involved, though there clearly are problems with the assessment due to the lack of directed surveys for this species. Abundance indices from bottom trawl have been calculated for the redfish species *Sebastes marinus* and *S. mentella since 1986,* but only for length groups. This information is used to evaluate the abundance of recruiting year classes, but is not used directly in the calculations. However, for both species there is work in progress to establish abundance indices on age from 1992 onwards.

The text table below shows the most recent (Anon., 1997) survivors estimates (millions) for the dominant year classes of cod for the four main sets of survey indices used in the assessment:

	Norway		Russia		Final
Year class	**Trawl**	**Acoustic**	**Trawl/Ac.**	**Acoustic**	**Assessment**
1989	168	184	195	143	178
1990	534	517	452	286	467
1991	503	418	379	283	427

The Russian acoustic estimates clearly deviate from the others. However, they have been unstable and are automatically downweighted in the tuning. The other three surveys have been more consistent and have reflected the same main trends in the stock, but there are nevertheless differences which to some extent is caused by sampling noise, but also by survey design and methodology. The survivors estimates from these three surveys are, however, all within 20% from the final assessment.

4.3 Recruitment estimates

In the stock assessment of cod and haddock the number at age of the recruiting year classes (age 3) in the most recent years is normally taken from the VPA or XSA. Predicting recruitment one or two years ahead may be based on indices of younger age groups, applying information on natural mortality in the last year(s) or running a special program for estimating the recruitment (RCT3). For medium-term forecasts the long-term average recruitment is normally used (Anon., 1997).

The recruitment program requires, in addition to survey indices and VPA numbers for previous year classes at the age of recruitment or earlier, survey indices for the year classes to be estimated. In the last assessment (Anon., 1997), 1-group survey indices from the acoustic and bottom trawl investigations were applied together with 0-group indices and Russian 1-group survey indices. In the regression between age 3 VPA numbers and survey indices for cod the indices from the Norwegian winter survey got the highest weights, while in the regression between age 1 VPA numbers and survey indices for haddock the 0-group indices got the highest weights.

4.4 Consumption, predation mortality and growth estimates

Methods and some results of the joint Norwegian-Russian stomach sampling programme on cod in the Barents Sea are given in Mehl and Yaragina (1992). The most important use of the data so far has been to calculate the Northeast Arctic cod stock's consumption of commercially important prey species (Mehl, 1989; Bogstad and Mehl, 1992, 1997; Bogstad and Gjøsæter, 1994). In addition to stomach content data, a model for gastric evacuation, temperature data, VPA numbers, survey indices, maturity ogives and weight at age data are used in the calculations. The consumption estimates are further used in the assessment and management of capelin, cod and haddock.

The Barents Sea capelin stock has been managed by a target spawning stock strategy. The assessment procedure is based on an acoustic estimate in the autumn, a maturation model, individual growth of the maturing capelin from autumn till spawning, natural mortality on maturing capelin in the autumn after the survey, consumption by cod from January till spawning (1 April) (Anon., 1993). Bogstad and Gjøsæter (*op. cit.*) describe a method for calculating the amount of capelin that can be consumed by cod during the spawning migration of capelin. This method was used in the assessment of capelin in 1990-1992, but is only applicable in periods with high capelin abundance.

The calculated consumption of cod by cod has been included in the VPA (XSA) as an additional catch (Anon., 1996, 1997). This has been done by converting the calculated consumption in tonnes of each length group by each predator age group, to number of each prey age group consumed by each predator age group, using age-length keys and length-weight relationships from survey data. An initial value for the number at age of cod is needed. The XSA is then run with this additional catch included, and a new number of cod at age is calculated. This is then fed into the consumption calculations, and the process is continued until convergence. Including cannibalism in this way improved the fit between the survey data and the XSA.

The calculated consumption of haddock by cod is included in the XSA for haddock (Anon., 1997). The calculations require input from the most recent cod assessment.

Growth in Northeast Arctic cod appears to be dependent on capelin availability (Ajiad *et al.*, 1992; Mehl and Sunnanå, 1991). Based on the stomach content data together with other sources (gastric evacuation model, temperatures and various parameters) a bioenergetic model for Northeast Arctic cod has been developed (Ajiad *et al.*, 1994; Ajiad 1996). The model describes the growth of Northeast Arctic cod fairly well, and it has been used to make short-term predictions of individual growth.

4.5 Environmental monitoring

The hydrographic observations taken during the survey give an indication of the year to year variability of the ocean winter climate in the area. The main target species, cod, shows large variations in distribution area which are related to temperature conditions (see Ottersen *et al.*, 1986 and Michalsen *et al.*, 1996 for references) and the environmental data has thus become a useful tool in explaining the displacements and growth of cod (Nakken and Raknes, 1987, Loeng, 1989). Together with the monthly observations of temperature along the Kola meridian (~34 degrees eastern longitude) made by PINRO, Murmansk, and the maps of surface temperatures and ice coverage from The Norwegian Meteorological Institute, the hydrographic data are also used for survey effort planning purposes prior to each survey. Effort is designated to parts of the area on the basis of the development in sea temperature prior to the survey and the expectations of the horizontal distribution of the fish. A system which enables routine computation of the ambient temperature of each species and age group, based on the work by Ottersen *et al.* (1996), is being developed. The considerable range in temperature, spatial and temporal, in the habitat of each age group of a species makes such a system a necessity if more reliable estimates of consumption and growth are wanted.

4.6 Other research (improving gear, methods etc.)

Engås (1994) and Godø (1994) have summarised the effects of trawl performance and fish behaviour on the capture efficiency of demersal sampling trawls and other factors affecting the reliability of abundance estimates from bottom trawl surveys. Below a couple of studies partially done in connection with the winter survey are briefly mentioned.

It was soon evident that the bottom trawl catches did not reflect the age structure of cod in the survey area accurately, with fish less than four years old being progressively underrepresented in the catches (Engås and Godø, 1986). In 1984 a research programme was initiated to improve the reliability of survey results. Many of the experiments were carried out during routine surveys, either incorporated in the survey or conducted at the end of the survey. One of the major findings was a length-dependent escape of cod and haddock under the standard sampling trawl; small fish were thus severely underrepresented in the catches (Engås and Godø, 1989a). If growth changes over time, length- and age-based population models using such survey data will produce population estimates by age with varying accuracy from year to year (Godø and Walsh, 1992). The escape was also found to have a considerable effect on the species composition; cod, more than haddock, tended to dive under the fishing line. To improve the efficiency of the sampling trawl, the bobbins gear was replaced with a heavier rockhopper groundgear. Based on parallel trawling experiments, conversion factors for comparing catches from the two sampling gears were calculated (Godø *et al.*, 1989). These factors have been used to adjust data and indices from 1981 to 1988 to make them consistent with those from 1989 onwards (Godø and Sunnanå, 1992; Dickson, 1993a, b; Aglen and Nakken, 1997).

Based on other parallel trawling experiments Engås and Godø (1989b) showed that the total catch increased with increasing sweep length, while small fish were relatively underestimated by the trawl with the longer sweeps. They concluded that combining survey results without compensating for the effect of using different sweep lengths will bias the estimates.

5. DISCUSSION

5.1 Sources of error

Acoustic estimates

Hylen *et al.* (1986b) discussed the most important types of errors which have occurred:

- acoustic sampling errors (near bottom detection, transmission loss due to air bubbles during bad weather, fish migration)
- errors in the manual pre-processing of data
- trawl sampling errors

In his review on errors in acoustic abundance estimation of fish, Aglen (1994) indicated that most commonly the average fish density will be negatively biased by 5-45 per cent mainly due to unrecorded fish near the bottom (dead zone) and/or because of horizontal avoidance. In the Barents Sea winter surveys horizontal avoidance is considered of minor importance since all fish of the target species are situated at depths greater than 100 m, mostly between 150 and 300 m. The problem with unrecorded fish at and near the bottom has always been recognised (Hylen and Nakken, 1983; Hylen *et al.*, 1986b) and it still remains a major source of negative bias in the acoustic estimates. This is clearly illustrated in areas where the echo densities computed from the bottom trawl catches largely exceed those measured by the acoustic instruments. Hylen and Nakken (*op. cit.*) estimated the dead zone abundance from a comparison of bottom trawl catches and acoustic observations. The method they used required, however, knowledge of the effective sampling height of the bottom trawl; knowledge which became available only quite recently (Aglen, 1996).

The transmission loss due to air bubbles in the water during bad weather has become much less after the introduction of keel mounted transducers on the research vessels (see above). Also the uncertainty of fish migration within the survey area during the survey is reduced due to a more synoptic coverage. Another problem not mentioned by Hylen *et al.* (*op. cit.*) is year to year variations in single fish target strength because of variations in stomach content, liver condition and size of gonads. We have no information on how such variations have effected the estimates.

The introduction of BEI reduced the subjective element in the allocation of echo values to the different species. Korsbrekke and Misund (1993) found a reasonable degree of similarity in the allocated values by two independent teams during four surveys.

The trawl sampling errors are related to the problem of getting representative length distributions of the acoustically recorded fish. The length distributions are used to convert echo density to numbers. Pelagic concentrations are often difficult to catch by pelagic trawl and there is no exact knowledge on the effective fishing height of the bottom trawl, but studies indicate that large fish recorded up to 50 m or more above the bottom are caught (Aglen, 1996). Also due to other circumstances the bottom trawl is not sampling the different sizes with the same efficiency. Bias towards lower length will increase the numbers estimated but reduce the biomass. The problem with unrepresentative sampling is considered to be a major source of error in the acoustic estimates.

Swept-area estimates

Bias in swept area estimates are related to changes in the capture efficiency of the sampling trawl. Since the trawl is not sampling different sizes with the same efficiency, this introduces a bias and varying growth makes the bias vary between years. This size dependent capture efficiency is also changing with temperature, time of the day and possibly also depth. There are also signs that fish are caught easier when they occur together than when they are caught as single fish not being affected by other fish in the vicinity (Godø, 1994). A higher capture efficiency at higher densities will introduce an overestimate of abundant year classes while poor year classes are underestimated. On the other hand high densities of fish will lead to accumulation in the front of the trawl and fish arriving later on may overflow and escape (Godø *et al.* 1990). At high densities the fish may also become more vertically distributed and less available to the bottom trawl (Godø and Wespestad, 1993).

5.2 Consequences of changes

Obviously, the main aims of the changes in survey methodology (Table 2) have been to reduce and/or remove biases and increase the precision in the estimates. Some of these changes had large effects on the index level and although the time series have been adjusted in order to maintain and improve comparability, potential users of the corrected series should be aware of the following:

The within age group comparability of the abundance indices is strongly dependant on size/age in both series (swept area and acoustics). It is poor for age 1 both for cod and haddock but increases with size/age up to age 3 (haddock) and 5 (cod). There are several factors contributing to this. The large codend mesh size (35-40 mm) used prior to 1994 allowed fish less than 12-13 cm in length to escape in great numbers. Hence, for 1981-1993, the indices of abundance as well as estimated mean lengths and weights at age 1 (and partly age 2) are based on samples which introduced a downward bias in annual abundance and an upward bias in mean length and weight. These biases cannot be corrected and variable annual growth of the smaller fish may thus have introduced an additional year to year variability in the estimated indices of abundance as well as in mean lengths and weights in these years. Also, it is questionable to which extent the age 1 indices from these years are comparable with those obtained in 1994 and later.

The extension of the survey area towards north and east in 1993 included important parts of the distribution area of 1-4 years old cod, particularly in warm climatic periods. In the years 1993-1996 the proportion of young cod in the "old" survey area (subareas A,B,C and D) showed pronounced year to year variations for ages 1 and 2 with a mean value of less than 0.5. For age groups 3 and older fish the year to year variability was less and the mean values of the "old" survey area proportions of total numbers were 0.68 (age 3), 0.80 (age 4) and 0.85 (age 5 and older). Hence the extension of the survey area in 1993 introduced an increase in estimated abundance at age of about 15 (age 5 and older), 20 (age 4) and 30 (age 3) per cent that ought to be considered when comparisons are made or the indices are being used in the VPA tuning. A final point to be noted regarding the uncertainties in the abundance indices of age 1 (and 2) is the large correction factors (multipliers) which were used for small sized fish when adjusting for the change of groundgear in 1989 (Godø and Sunnanå, 1992).

In the years 1994-1996 the restraining rope technique for controlling the door spread was applied at 50 per cent of the trawl stations. There was no overall significant difference in catch rates by size class between restrained and unrestrained hauls. Eventual effects could be masked by other sources of variability including diurnal variation.

In addition to these changes the instrumentation measuring and monitoring the geometry and performance of the trawl has been improved throughout the time series. Stations at which problems with door spread, bottom contact etc. are observed are not used in the estimation.

The ability to detect such problems has been improved considerably and there is reason to believe that this has led to relatively higher mean catch rates.

The main consequence of the improvements in the acoustic system is an increased reliability of the measurements. There are, however, reasons to believe that these improvements also have resulted in a general but unknown increase in the level of the s_A-values of the target species and thereby also in the abundance estimates. The daily interpretation of the acoustic data includes some cases of subjective judgements and decisions. Examples of such cases are the discrimination of fish echoes from the bottom echo at variable bottom depths and the value of bubble correction factor to be applied for bad weather recordings during the years when only hull mounted transducers were in use. Most likely a more cautious approach was taken in such judgements and decisions in the early years of the survey than in more recent years when the quality of the data was largely increased, resulting in an increased index level in the 1990s compared with previous years.

5.3 Effort, precision and reliability

The effort in the acoustic survey is sailed distance (in nautical miles) and in the bottom trawl survey the number of trawl stations. In both surveys average fish densities are estimated by subareas and are then multiplied by the size of the areas to give the number of fish. The reliability - or error - of the average values is dependent on the number of observations and the variation of these. The higher the variation, the higher number of observations are needed to give a desired precision.

Normally the fish have a patchy distribution, with smaller areas of high density and between these larger area of lower density. The probability of hitting the high densities is much lower than hitting the low densities, and when planning the survey design (stratification system and density of course tracks and stations in different areas) this is to some degree taken into account, based on the relationship between fish distribution and oceanographic conditions in previous years .

As a measure of precision the coefficient of variance (CV = mean value divided by the standard error of mean) is often used; the lower the coefficient the better the precision of the mean value. Nakken (1996) found that for cod a precision of 20 % or better (CV . 0.15-0.20) in both surveys requires 6000-8000 nautical miles sailed distance and about 300 bottom trawl stations. This is approximately the effort used and precision obtained in 1995-1996, and an increase in effort would only improve the precision marginally. A further improvement in the allocation of trawl stations to strata based on expected fish distribution and variance would, however, probably increase the precision somewhat, as found by Smith and Gavaris (1993) for cod on the Scotian Shelf. For haddock > 30-40 cm the CVs in the swept area estimates are much higher. This is partly due to a survey design based on the expected cod distribution. To improve the precision of the haddock estimate the density of the trawl stations should be increased, either by redistributing the stations or preferably by increasing the total number of trawl stations.

5.4 The relationship between stock numbers and abundance indices; the catchability coefficient

For VPA tuning purposes the catchability coefficient, q, is usually defined by the equation

$$I = q \cdot N \qquad \text{or} \qquad N = \frac{I}{q} \tag{1}$$

N stock numbers at age
I abundance index

Equation (1) expresses a proportionality between the two variables; a straight line through the origin in an *I-N* diagram. Using pooled data for 3-5 years old cod in various regression models (linear through origin, linear with intercept and log linear), Godø (1995) found that the log linear model gave the best fit. This means that a relationship of type

$$N = c \cdot I^d \tag{2}$$

where c and d are constants ($d < 1$) ought to be preferred for VPA tuning purposes. Godø (*op. cit.*) suggested that reduced catchability at low abundances is the main cause for the deviations from linearity. Aglen and Nakken (1997) carried out regressions for each age group 1-7 for haddock and 1-5 for cod assuming relationships of the types

$$N = a_1 \cdot I + b \tag{3}$$

$$N = a_2 \cdot I \qquad \text{(NB! equivalent to (1))} \tag{4}$$

using the converged part of the VPA series. For haddock >2 years old the intercepts were insignificantly different from zero and the slopes almost equal ($a_1 \approx a_2$) meaning that equation (1) is a reasonable approximation of the relationship between stock numbers and survey indices.

For cod, on the other hand, the intercepts had quite large values and a_2 was substantially larger than a_1 for all age groups. These results indicate that equations (4) and /or (1) are not appropriate relationships and that relationships of types (2) and (3) should be considered for VPA tuning purposes for the cod stock. Fig. 8 shows a plot of the three relationships.

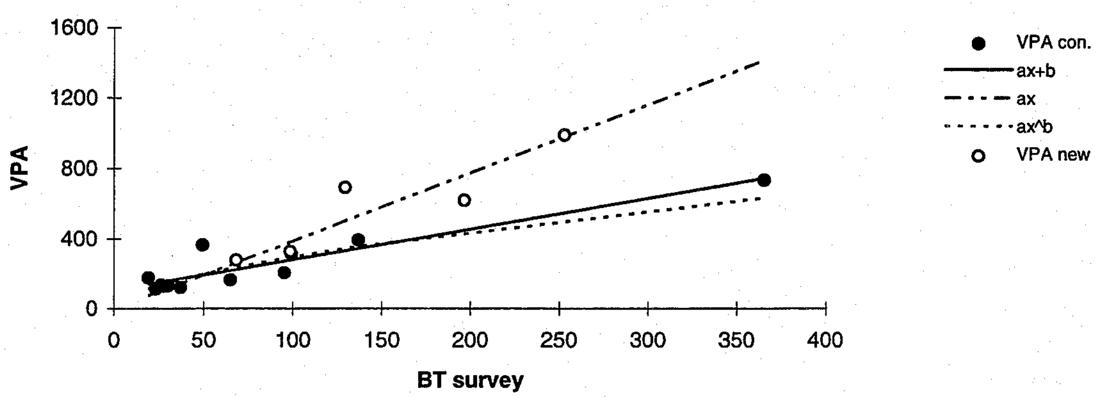

Figure 8. Relationship between stock numbers (VPA) and bottom trawl indices for age 4 cod 1981-1997.

5.5 Possibilities for improvement and future use

Future improvements should focus both on reducing sampling errors as well as on increasing the comparability of recent years' indices with those obtained in the period 1981-1992.

At present the largest source of error (bias) in the acoustic estimates is most likely associated with the quantities of unrecorded fish in the near bottom zone (Aglen *et al.*, 1997). This problem might be reduced by towing a high resolution transducer at a relatively short distance above the bottom. Hence, the solution introduces operational difficulties which have to be overcome. A solution based on an extrapolation procedure as suggested by Ona and Mitson (1996) may also reduce the bias, but it will fail completely in cases when all fish is situated in the dead zone as has been frequently observed. The acoustic estimates will also be effected by the ability to obtain representative samples of the recorded fish since catch numbers at length are used in the estimation procedure. Improved sampling capability of both the pelagic and demersal trawl would reduce errors in the estimates. Realising that it is impossible to have trawls which sample all cod (or any fish species) in the length range 10-100 cm with the same efficiency, studies on fish behaviour during sampling and how the results can be used to reduce the sampling errors with the existing trawls ought to be continued.

A major source of error in the swept area estimates is the fish size dependent vertical capture efficiency of the bottom trawl (Aglen, 1996). For a given vertical distribution profile of fish density, the fraction that is caught will depend on fish size; the bigger the fish the larger is the effective fishing height of the bottom trawl. Hitherto this effect has not been taken into account quantitatively when densities have been estimated. The approach outlined by Dickson (1993a,b) and Godø (1994) combined with model results based on studies as described by Aglen (1996) offers some promising possibilities for quantification of the effect; the vertical density profile is measured acoustically and a fish size dependent capture efficiency model is used to estimate the fraction that is caught. Since the vertical density profiles tend to be compressed towards bottom during trawling (Godø, 1994) such profiles should be observed both below the vessel and above the trawl.

For both surveys it is in future necessary to get quantitative estimates of diurnal and annual availability of the various length groups of the target species.

The north- and eastward extension of the distribution area of young cod is positively related to cod abundance and sea temperature (Ottersen *et al.*, 1996; Michalsen *et al.*, 1996). There is thus a possibility that a relationship can be established between cod proportions north and east of subareas ABCD and abundance and temperatures so that proportions can be estimated for the years 1981-1992 when observations from those areas were lacking. Such a correction would improve the comparability of the abundance indices within the whole time series 1981-1996 and it would also reduce the between year variability for the period 1981-1992 when observations were made in subareas ABCD only. In order to establish and test such a relationship more years with complete coverage of the entire cod distribution area are needed.

5.6 The importance of the surveys for the fishery management

Surveys for demersal fish in the Barents Sea were introduced to obtain fishery-independent information about the stock and more up-to-date information about the abundance of the recruiting year classes. The Northeast Arctic cod with historical catch levels of about 800 000 tonnes has been the main stock both for the surveys and for the management. Although the survey results are used also for other species, it is the importance for the management of the cod which is relevant to discuss.

Assessments prior to 1984 relied on commercial data, mainly cpue from the trawl fleets. However, the reliability of the assessments was not satisfactory, in some cases probably due to changes in the fishing pattern of the trawlers in response to quota restrictions.

The use of the survey indices as basis for the assessments has not been unproblematic, partly because of changes in the survey design, partly because of changes in the VPA tuning, and partly for reasons not yet clear, but in general the precision of the assessments has improved. Especially the information on the recruiting year classes obtained by the survey has been valuable. Besides, the large TAC restrictions in the early 1990s clearly destroyed the continuity in the commercial trawl data and assessments during this period would have been extremely difficult without the survey data. It cannot be ruled out that commercial cpue data can prove useful in future assessments, but since they may be influenced by management decisions and possibly other uncontrollable factors, it is not advisable to base the assessment only on such data.

The management of the Northeast Arctic cod has in recent years relied heavily on the advice given by ACFM. Thus, the precision of the survey indices used in the assessment can have a direct effect on the TAC. Introduction of the «precautionary approach» in the management advice will increase the importance of the surveys. The stock is shared equally between Norway and Russia and it is therefore reasonable that the two countries should share the cost of the surveys used in the assessment. At present a joint survey is not conceivable due to differences in gear and methodology and the current situation with two separate national surveys is likely to continue in the future.

6. CONCLUSIONS

- Within the 16 years history of the surveys the quality of data and results have increased considerably due to changes in survey methodology which were generated by increased knowledge of fish behaviour as well as developments in instrumentation. Biases in the estimates of abundance have been reduced and the precision increased partly also due to increased effort.
- Some of the changes had large effects on the index level and although the time series have been adjusted to maintain comparability it is likely that recent years index/stock ratios are somewhat higher than those from the first 12 years (1981-1992).
- For haddock the relationships between stock numbers at age from the converged VPA and corresponding survey index values can be approximated by a straight line through the origin. For cod the best fit to the data points is obtained by a linear relationship including a rather large intercept or by a power function; a matter that should be noted when results are used in VPA-tuning and stock assessment.
- Further reductions of errors in the abundance indices as well as in results from the use of these indices depend on increased quantified knowledge of fish behaviour in general and during sampling, and particularly how fish behaviour and distribution are related to environmental conditions.

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