ACOUSTIC ESTIMATES OF 0-GROUP FISH ABUNDANCE IN THE BARENTS SEA AND ADJACENT WATERS IN 1992 AND 1993

by

O. Nakken, A. Hylen and E. Ona

Institute of Marine Research
P.O.Box 1870-72, 5024 Bergen, Norway

ABSTRACT

Acoustic and biological data collected during the international 0-group surveys in 1992 and 1993 were used to estimate the abundance of 0-group fish of 4 species; cod, haddock, redfish and polar cod.

The abundances of 0-group cod amounted to $107 \cdot 10^9$ and $84 \cdot 10^9$ specimens in 1992 and 1993 respectively. These estimates are considerably higher than those arrived at by the swept volume/area method when resonable values for trawl catch efficiencies were applied. Instantaneous mortality rates of 8-9 were calculated from the acoustic estimates of 0-group in August and 1-group in February for cod of the 1992 and 1993 year classes.

The acoustic estimates of 0-group haddock abundance amounted to $12 \cdot 10^9$ and $8 \cdot 10^9$ specimens and the ratio between cod and haddock abundances were significantly higher for the acoustic estimates than for the traditional indices of 0-group abundance. For the two year classes under observation instantaneous mortality rates of 4-5 were arrived at from the acoustic estimates of 0- and 1-group haddock.

For 0-group redfish the acoustic estimates of abundance amounted to $38 \cdot 10^9$ and $48 \cdot 10^9$ specimens in 1992 and 1993 respectively.

The estimates arrived at for 0-group polar cod, $100 \cdot 10^9$ and $62 \cdot 10^9$ specimens, were underestimates due to insufficient acoustic coverage of the 0-group polar cod distribution area in both years.

INTRODUCTION

The annual 0-group surveys in August-September in the Barents Sea and adjacent waters provide information on distribution, abundance and biological parameters (length, weight, stomach content e.t.c) of several important species. Indices of abundance are regularly

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computed using two different methods and the time series of both types of indices are presented in the report (Anon 1994).

The area index, AI was introduced by Haug and Nakken (1977). They compared trawl catch rates and acoustic recordings, and for each species they estimated a limit above which catch rates ought to be given 10 times the weight of catch rates below that limit in the calculation of the index of abundance. The index is arrived at simply by adding up areas where the species occur in the catches; areas with catch rates above the estimated limit are multiplied by 10.

The logarithmic index, LI introduced by Randa (1984), is based exclusively on trawlcatches. Catch rates are normalized by using their natural logarithms. Mean values and variances are calculated for geographical areas (strata) as well as proportions of nonzero hauls and the variances of these proportions. The procedure enables both computations of a stratified logaritmic abundance index and confidence limits at the approximate 90-95 percent levels.

Acoustic data have been collected regularly during the annual surveys, but little use has so far been made of these observations when the abundance indices have been computed apart from the estimates of abundance given by Dorchenkov (1993) for a limited area in the Barents Sea in 1992. The only estimates of the total number of 0-group fish (cod) that have been given are those made by Sundby *et al.* (1989). Assuming catching efficiencies (of q=0,1 and 0,25) for the trawl used they arrived at estimates of 0-group cod in the range 0,4-10 billion specimens for the year classes 1979-1988 (Sundby *et al.* 1989).

In order to improve our understanding of energy transfer processes in the ecosystem and our ability to predict recruitment to the fisheries, estimates of absolute abundance at various stages during the prerecruit phase are a neccessity. The present paper is an attemt to estimate the number of 0-group specimens of cod, haddock, redfish and polarcod in 1992 and 1993 based on the acoustic data during the 0-group surveys.

MATERIAL AND METHODS

Field sampling and postprocessing

The material included mean column- or area back scattering coefficients, s_A, sampled with Bergen Echo Integrator, BEI, (Foote *et al.* 1991) and species - and length distributions of the scattering organisms collected with pelagic trawls (Anon, 1992 and 1994). Figures 1 shows the trawl stations and the courselines at which acoustic data were sampled. The geographical distributions of area back scattering coefficients of 0-group fish are presented in Figure2. Trawling and biological sampling of the catches was carried out in accordance with the standards adopted for the 0-group survey (Anon, 1992 and 1994). During the daily postprocessing of acoustic data onboard the vessels (Foote *et al.* 1991) mean values of s_A were partitioned to various groups of scatterers by each 5 nautical miles sailing distance on the basis of

- the appearance of scatterers on the echogram (Figure3)
- the catch composition at the trawlstations
- the frequency distributions of target strength of individual scatterers

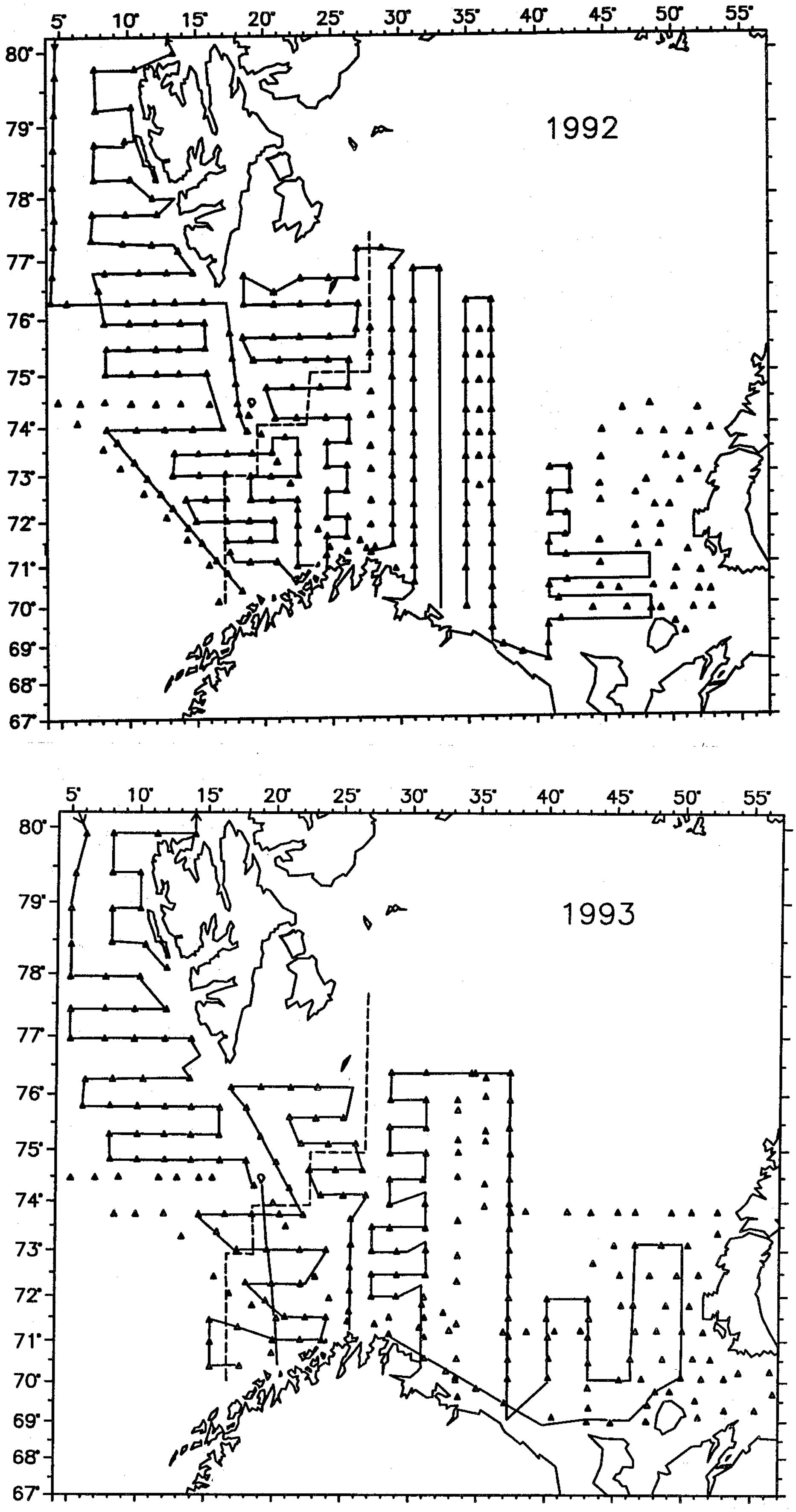

Figure 1. Survey tracks along which acoustic data were available and trawlstations in August-September 1992 and 1993. The thin line is the borderline between the two areas for which estimates of abundance are worked out (Table 1).

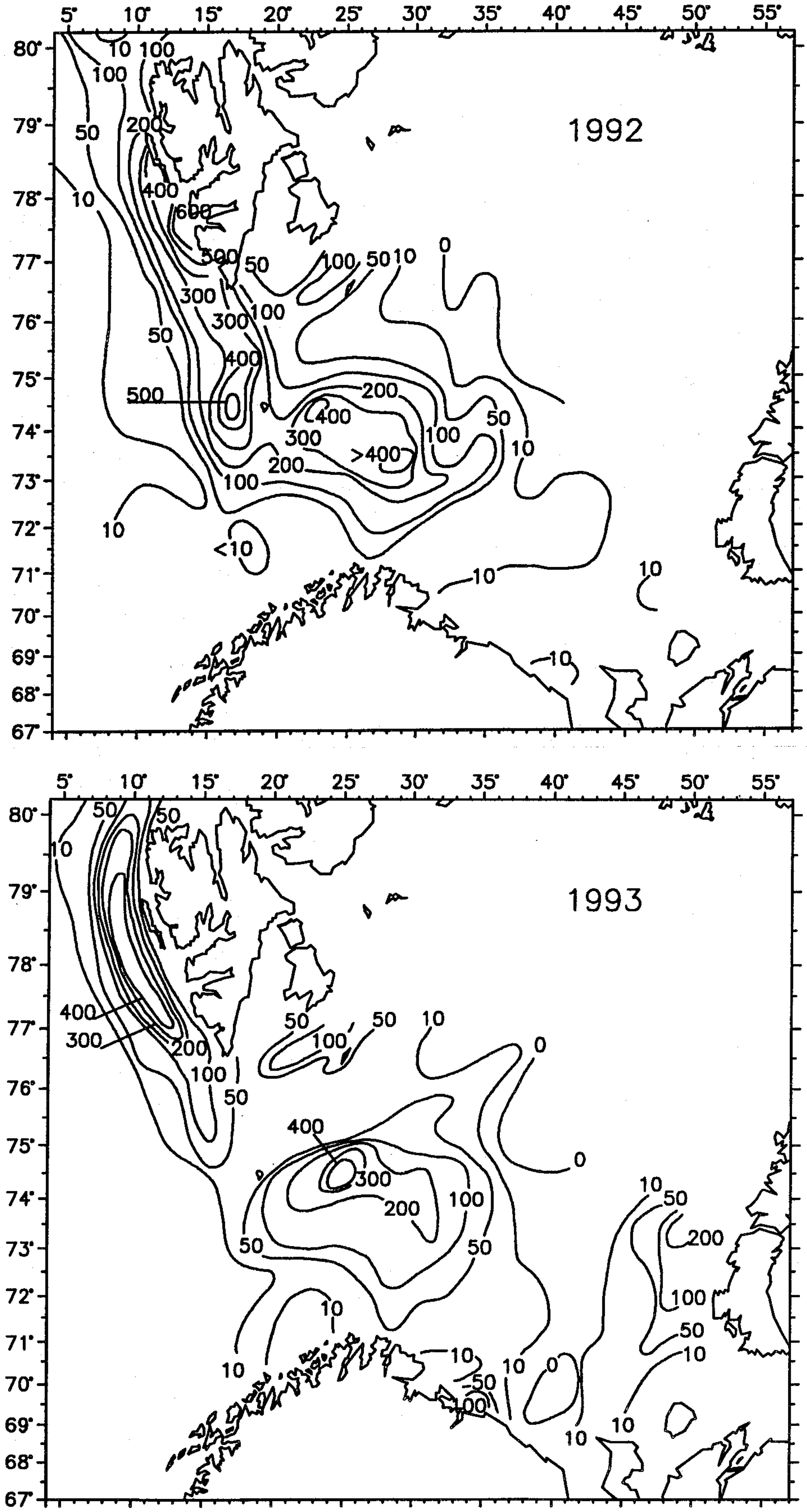

Figure 2. Distribution of the area back scattering coefficient, S_A (m^2/nm^2 of 0-group fish (0-group herring excluded) in August-september 1992 (upper) and 1993 (lower).

s_A-values in the upper 100 m of the water column mainly fell into 3 groups:

- 0-group fish, mainly including cod, haddock, redfish and polarcod. The contribution from other 0-group fish (capelin, long rough dab, Greenland halibut and *Lumpenus spp.*) was insignificant according to the trawl catches (Anon 1992 and 1994).
- 0-group herring; which was frequently observed in dense schools at somewhat shallover depths than the 0-group gadoids and redfish so that its contribution to the total S_A- value could readily be established.
- Plankton; consisting of jellyfish, 0-group squid (*Gonatus fabricii*) and euphausiids, which at times were almost impossible to separate from the 0-group fish layers on the echograms. In these particular areas the separation of plankton back scattering had to be done according to the composition of trawlcatches, and comparison of integrator outputs at different threshold levels on the postprocessing system.

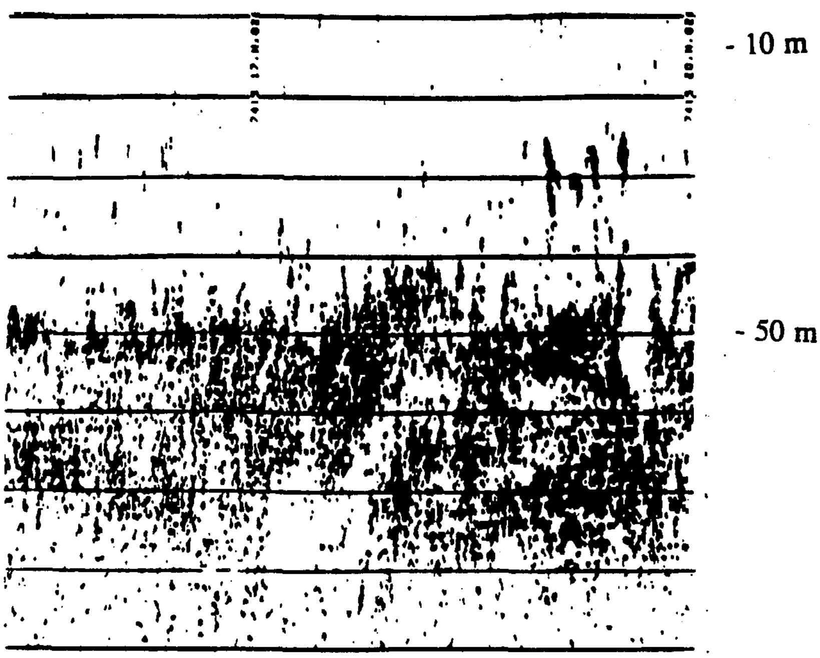

Figure 3. Echogram of 0-group cod in the Barents Sea in August 1992. Horizontal lines mark 10 m depth intervals.

Computations

The mean values of S_A of 0-group fish for each 5 nautical miles sailing distance were plotted in maps and averaged over standard areas of 1 degree latitude by 2 degrees longitude (Figure 4). In each standard area the total catch per unit effort of cod, haddock, redfish and polarcod was assumed to constitute a representative sample of the species- and length composition of the 0-group fish scatterers.

Mean densities of 0-group fish for each standard area were computed in accordance with the usual method (McLennan and Simmonds, 1991) applying the formula

$$\rho_A = \frac{s_A}{<\sigma>} \tag{1}$$

Where ρ_A is fish density (number per nautical mile^2)
s_A is the observed mean area back scattering coefficient of 0-group fish in the

standard area (m^2/nm^2).

$<\sigma>$ is the mean scattering cross-section of one individual 0-group fish (m^2)
$<\sigma>$ was computed using the length frequency distribution of all four target species pooled, and the target strength (TS)-length (L) relationship:

$$TS = 10\log \frac{\sigma}{4\pi} = 20\log L - 68 \qquad (2)$$

which gives

$$< \sigma > = 2.0 \cdot 10^{-6} \cdot \overline{L^2} \qquad (3)$$

Where the fish length L is in cm.

Within each standard area the densities of each target species were assumed to be proportional to the species compositions in the trawl catches. Fish abundances in terms of numbers of specimens were calculated by multiplying the densities with the appropriate area and then accumulated for two separate areas, the Svalbard area and the Barents Sea area (Figure1). The borderline between the two subareas is nearly identical to the one used by Randa (1984).

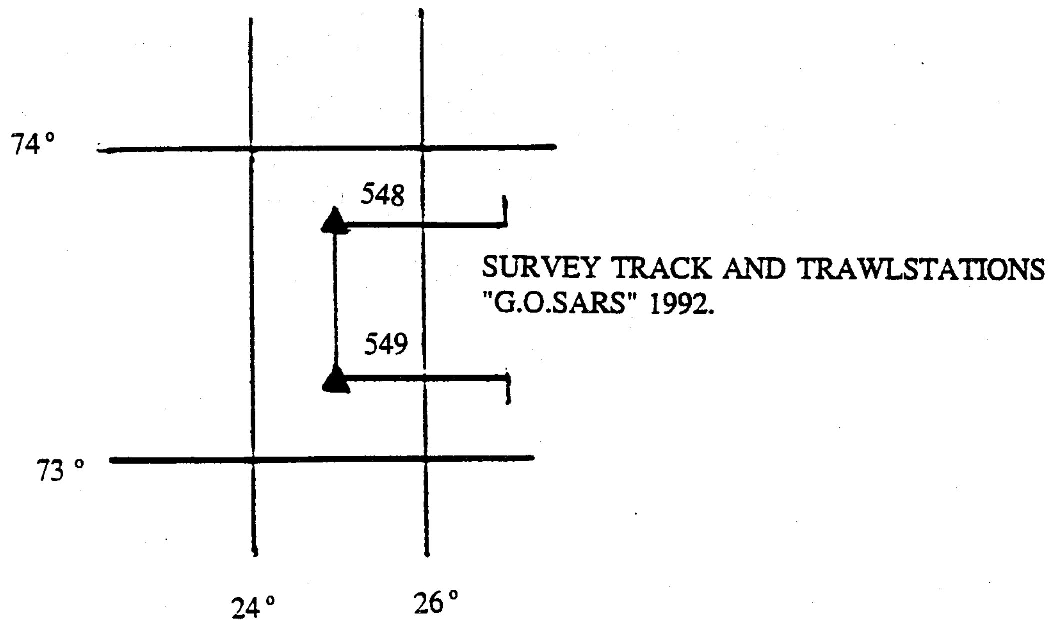

Figure 4. Example of standard area for computation of density (number per unit area) of 0-group fish in 1992 and 1993.

In situ target strength measurements of 0-group cod

Two pure populations of 0-group cod have been measured using the EK-500 split beam echosounder. A comprehensive description of the measuring techniques is given by Ona (1994). The first data set was collected in Parisvatnet, a closed salt water basin used by the Institute of Marine Research for production of cod fry for later release. The transducer was mounted at a fixed raft in the deepest part (7 m) of the basin and TS data were sampled as fish passed the acoustic beam. A total of 566 fish tracks (3396 TS measurements) were analyzed. Length and weight measurements of the fish were obtained from a dipnet catch three days after the acoustic measurements.

The second data set was collected in a fjord in northern Norway (Ullsfjord) with R/V "Michael Sars" in July 1992 where a total of 12 separate trawl hauls were taken of the scatterers along with the acoustic measurements. Ten series containing a total of 8697 target strength measurements were collected in the depth layer 5-45 meters during the trawl hauls. Fish standard lengths were measured to the nearest mm below and the equation.

$$\text{Total length} = \frac{\text{standard length} + 1{,}26}{0{,}941}$$

established during the same survey, was used to obtain comparable length data for the target strength measurement.

RESULTS AND DISCUSSION

The estimates and their reliability

The acoustic estimates of abundance are given in Table 1 for the Svalbard- and Barents Sea area separately. Various sources may have generated errors in these estimates:

Table 1. Acoustic estimates of 0-group abundance in the Svalbard and Barents Sea areas in 1992 and 1993 (Number$\cdot 10^{-9}$)

	1992			1993		
	Svalbard	**Barents S.**	**Total**	**Svalbard**	**Barents S.**	**Total**
Cod	56	51	107	24	50	84
Haddock	4	8	12	2	6	8
Redfish	38	0.1	38	48	0.1	48
Polar cod	100	0.2	100	31	31	62

<u>Insufficient area coverage</u> has particularly affected the estimates of polar cod in both years. It is evident from a comparison of the acoustic coverage (Figs. 1 and 2) with the distribution maps in the annual survey reports (Anon 1992 and 1994) that the distributions of 0-group polar cod were not satisfactionly covered in any of the two years. In 1992 only a fraction of the polar cod distribution area in the south-eastern Barents Sea was sampled by the recording vessels and in 1993 significant areas were left out also to the south-east of Svalbard. For 1992 Dorchenkov (1993) reported acoustic estimates of $170\cdot10^9$ 0-group polar cod and $6\cdot10^9$ 0-group cod in the southeastern area (east of 45° east) based on data from the 0-group survey. The target strength-length relationship he used, (TS=21.8 log L-72.7) generates about twice the density estimates as does equation III for fish lengths 4-10 cm. Dorchenkov's findings indicate therefore that the amount of 0-group polar cod in the southeastern area in 1992 was at the same level as our estimate for the Svalbard area. Hence the estimates of polar cod in Table 1 are much too low in both years.

The acoustic sampling of the distribution areas of cod, haddock and redfish appears adequate in 1992 but in 1993 the lack of acoustic "coverage" in the area between 31°E and 37°E increases the uncertainty of the Barents Sea estimate of cod. In 1993 the values of back scattering used in that area were interpolated from those observed along 31°13'E and 37°20'E.

Species- and length selection in trawlcatches have biased both species- and length distributions; the smaller specimens being less effectively caught than the larger individuals (Hylen *et al.* 1995). Hence the abundances of polar cod and redfish, specimens which had only about half the mean length of cod (and haddock), were underestimated in all standard areas where the two species occurred in mixture with cod (and/or haddock). The abundances of cod in the same standard areas were overestimated accordingly. However, it should be noted that the removal of 1 specimen of cod from the acoustic estimate will generate an increase of 4 specimens in the acoustic estimates of redfish or polar cod because of the differences in mean lengths and target strengths (equation III and I).

The application of the target strength-length relationship commonly accepted for larger fish may not be valid for 0-group. The main results of the *in situ* target strength measurements are shown in Figure5 together with the target strength-length relationship used in the computations (equation II). It appears that the *in situ* experiments resulted in lower values than those estimated from equation II. Although the material is to small to estimate a length dependency, the constant in equation II under the assumed 20 log L dependancy may be estimated at 69.8 rather than 68 as used. This may indicate that the estimates of abundance arrived at (Table 1)for fish of lengths 2-6 cm more likely are underestimates. If so, the estimates of redfish and polar cod (mean lengths of about 4 cm) will be most affected.. However, more results on both the species - as well as the length specific target strength of 0-group fish are needed in order to be conclusive on this point.

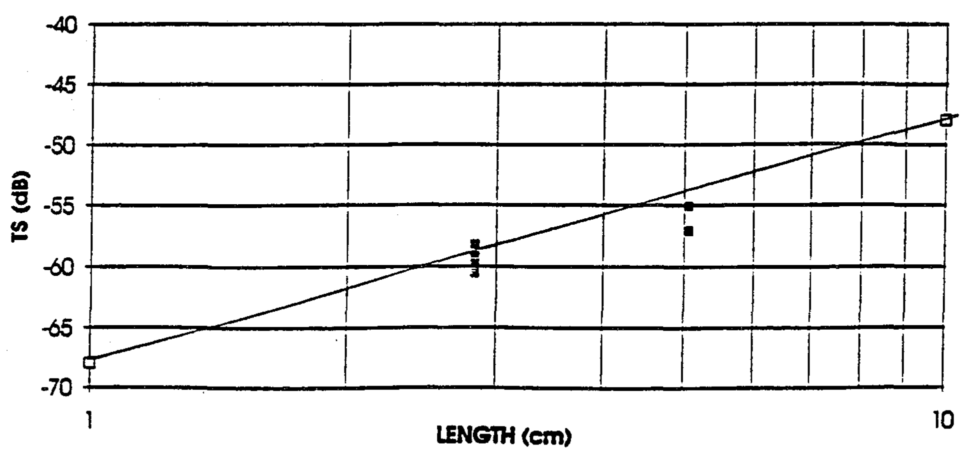

Figure 5. Results of *in situ* target strength measurements of 0-group cod. The line shows the relationship, TS = 20 log L-68 (dB), used in the istimation of abundance of 0-group cod, haddock, redfish and polar cod.

Inaccurate separation of the 0-group fish scattering (s_A-values) from the scattering of other organisms in the upper 100 m layer may have introduced errors to the estimates. As already mentioned it was at times impossible to distinguish between planktonic scatterers and 0-group fish on the echograms and the separation of the total scattering into scattering groups were made rather subjectively on the basis of the composition of the trawl catches. Korsbrekke and

Misund (1993) investigated the subjectivity in the judging of acoustic records by analyzing the homogeneity in allocation of scattering values to various species by different teams of scientists. They found that although the allocation showed variances on a one-to-one value scale a resonable degree of similarity in judgement by the different teams was maintained, and in general the average scattering allocated to a species was rather similar. The analyses was made on data from the winter surveys of young cod and haddock, but it is anticipated that Korsbrekke and Misund's (1993) main conclusions also are valid for the separation of scattering values during the 0-group surveys.

Comparision with the "traditional" abundance indicies

Table 2 shows the acoustic estimates of abundance together with the two types of indices, the logarithmic indies and the area indices as well as the total number of specimens caught during the survey for the two years of observation (Anon, 1992 and 1994). For cod and haddock separately the year to year ratios between the acoustic estimates compare well with the ratios between the two types of abundance indices. However, in both years the acoustic estimates indicate that 0-group cod was 9 to 10 times as abundant as haddock whereas the abundance indices (LI and AI) show a cod/haddock ratio of 3-4. Further, the area indices (AI) indicate abundances of redfish and polar cod of about the same level as for haddock while the acoustic estimates of redfish are 3 and 6 times higher than for haddock and those for polar cod 8 times higher. It thus appears as if the species compositions of the acoustic estimates are more similar to the pattern shown by the total numbers caught (N) than to the indices.

Table 2 Estimates and indices of 0-group abundance. AE = Acoustic estimates (Number$\cdot 10^{-9}$), LI = Logarithmic index (Randa, 1984, Anon, 1993-1994) AI=Area index (Haug and Nakken, 1977) N = Total numbers caught $\cdot 10^{-3}$ (Anon, 1993-1994).

	1992				1993			
	AE	LI	AI	N	AE	LI	AI	N
Cod	107	2.94	1159	179	84	2.09	910	134
Haddock	12	0.87	313	4	8	0.64	240	6
Redfish	38	-	150	80	48	-	162	34
Polar cod	100	-	313	69	62	-	327	326

Sundby *et al.* (1989) used the logaritmic index, LI to compute total numbers of 0-group cod of several yearclasses. They assumed catching efficiencies, q, of the trawl of 0,25 and 0,1 and used the results in their estimation of mortality rates of the year classes both prior to and after the 0-group stage. Assuming similar catching efficiencies and using the same formula as Sundby *et al.* (1989) for the computation of total numbers of 0-group cod in 1992 and 1993, estimates of $19 \cdot 10^9$ and $8 \cdot 10^9$ in 1992, and $8 \cdot 10^9$ and $3 \cdot 10^9$ specimens in 1993 were arrived at. These estimates are considerably below those obtained by the acoustic method.

Apart from the uncertainty of which value of catching efficiency to apply there are reasons to belive that the total numbers were underestimated by the procedure used by Sundby *et al.* (1989). Firstly, the distance towed at each particular depth step, 0,5 nautical mile (10 minutes) should be considered the effort, not the total haul (mainly 1,5 n.m.) which is used now. This would increase the catch rates by a factor 3 and the logarithmic index accordingly.

Secondly, the effect of determining the index as an average of the logarithm of catch rates (Randa, 1984), will, when the antilogarithm of that average is taken, give a total number well below the average of catch rates. Hence it is to be expected that the total numbers estimated by the procedure used by Sundby *et al.* (1989) are underestimates.

Mortality of cod and haddock during the first autumn and winter

The acoustic estimates of 0-group cod and haddock of the 1992 and 1993 year classes and the acoustic estimates of the same yearclasses as 1-group in February 1993 and 1994 (Mehl and Nakken, 1994) were used to calculate mortality rates (Table 3). A substantial reduction in abundance appeared to have taken place during the period August-February and the mortality of cod seems considerably larger than that of haddock for both year classes. Length selection in the trawl used in February have to some extent biased downwards the 1-group figures presented in Table 3 (Dickson 1993, Aglen and Nakken, 1994). Yet, even if the 1-group figures in Table 3 are raised by a factor of 2, the mortalities will come out very high, particularly for cod.

Table 3 Acoustic estimates of abundance of 0- and 1-group cod and haddock of the year-classes 1992 and 1993 (Number$\cdot 10^{-9}$) in the Barents Sea area and the corresponding mortality rate, M (year^{-1}).

Year-class	1992			1993		
	O-GR	I-GR	M	O-GR	I-GR	M
Cod	51	0,9	8,1	60	0,8	8,6
Haddock	8	0,8	4,6	06	0,5	5,0

Assuming that these mortality rates are real, what would have caused them, starvation or predation? Ponomarenko (1984) reported that the abundance of euphausiids, suitable food for 0- and 1-group cod, were of importance for the survival of fingerlings during the first winter. She also pointed out that the winter temperatures in the Barents Sea had an influence on the survival. Regarding predation, the published estimates of the amounts of 0- and 1-group cod removed by cannibalism (Bogstad *et al.* 1993) for several yearclasses in the 1980's will account for only 1-3 percent of the removals from the 1992 and 1993 yearclasses. However, Ponomarenko (1961) reported that significant amounts of 0-group cod were eaten by young cod, 1-3 years of age, during autums in the 1950s. Yet, whatever cause there is for the enormous reduction in numbers during autumn and early winter, acoustic estimates of abundance of 0-group fish might become a tool for the understanding of the energy transfer in the ecosystem. The presence of about 1-2 million tonnes of 0-group fish (plankton feeders) in August in addition to the stocks of capelin and herring may at least in some years add significantly to the food resources for creatures at higher trophic levels.

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