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RECRUITMENT INDICES FOR THE ARCTO-NORWEGIAN COD FOR THE PERIOD 1965-1979 BASED ON THE INTERNATIONAL 0-GROUP FISH SURVEYS

by

Kjell Randa
Institute of Marine Research
Postbox 1870
5011 Bergen, Norway

ABSTRACT

The trawl data from the International 0-group fish surveys in the Barents Sea are analysed. The fishing powers of the participating vessels are estimated and corrected for. Relative indices of yearclass strength are computed on a linear and a logarithmic scale. The strongest yearclasses are found to be, in order, 1970, 1975 and 1973. Medium year classes are 1971, 1977, 1972 and 1974, the rest, for the period 1965-1979, is poor. These indices, when excluding the 1969 yearclass, give a correlation of 0.93 for the linear index and 0.96 for the logarithmic index for the period 1965-1975, with VPA estimates of 3-years old cod. Linear regression are used to predict the absolute size of the recruitment 1976-1979 yearclasses, and indicates an average recruitment of about 300 mill. 3-years old fish.

INTRODUCTION

The knowledge of the size of the recruiting yearclasses is one of the basic needs for a successful stock assessment. The International 0-group fish surveys in the Barents Sea have been conducted since 1965, and the results from these surveys have been utilized in particular inthe assessment of the Arcto-Norwegian cod stock (ANON 1980). This paper reanalyses the basic data and gives recruitment indices, that are compared with yearclass strength derived from VPA. The results are utilized to predict the absolute size of the yearclasses 1976-1979 at age 3. The method for computing the old 0-group indices is given in HAUG and NAKKEN (1977) and results are given in ANON 1981.

MATERIAL

Each year since 1965 joint international (Norway, USSR and up until 1976 UK) 0-group fish surveys have been carried out in the Barents Sea in the period August-September. The aim of these surveys is to measure the level of recruitment of the most important fish species in the area. This include species like Arcto-Norwegian cod, Arcto-Norwegian haddock, capelin, herring, redfish, polarcod, Greenland halibut and long rough dab.

The survey is a trawl survey carried out by three to five research vessels. Trawl stations are taken at every 30 nautical mile (Fig. 1) or when echorecordings change, using a small meshed pelagic trawl. The trawl depth is decided from the echograms and the trawl is towed in the depth of the recordings, mostly less than 50 m. If no recordings are present the trawl is towed at the surface using 6 big floats on the headrope. The trawl is towed for 1 nautical mile at about 3 knots.

In 1981 a new standard trawl procedure was chosen (ANON 1981). The recorded data from each of the trawlhauls constitute the basic material for this analysis.

METHODS

Relative fishing power of the vessels

Altogether 11 different vessels have participated in the survey in the period since 1965. Both the trawls and the vessels have increased in size and there has been a change from side to stern trawlers.

Parameters for the most common used gears are given in Table 1. The Norwegian "Harstadtrawl" has been used by the Norwegian and UK vessels since 1972. The Russian pelagic trawl has been used by USSR vessels during the whole period. The Boothbay trawl was used by UK vessels on a few stations during the period 1969-1972. The Engel trawl was also used by the UK vessels until 1971. Before 1972 the Norwegian vessels used a trawl similar to the Engel trawl but details are not available.

In order to assess the difference between vessels and gears, the relativ fishing power for different vessels and gears have been estimated using the methods of ROBSON (1966).

The method may be outlined as follows using the notation and formula from FOX (1971):

$$C_{ij} = q_i \cdot f_{ij} \cdot P_j \cdot E_{ij}$$

where
- C_{ij} = catch of vessel i in area j
- q_i = fishing power of vessel i
- f_{ij} = fishing effort of vessel i in area j
- P_j = mean population size in area j
- E_{ij} = log-normal distributed variable

Dividing by the effort and taking natural logarithm we get:

$$\ln(C_{ij}/f_{ij}) = \ln(q_i) + \ln(P_j) + \ln(E_{ij})$$

or

$$Y_{ij} = \alpha_i + \beta_j + e_{ij} \qquad (1)$$

This is a linear two-way analysis of variance model without interaction. Since we are not able to estimate the parameters of (1) we re-parameterize the model using relative fishing power and relative population size:

$$Y_{ij} = \alpha_s + \beta_s + (\alpha_i - \alpha_s) + (\beta_i - \beta_s) + e_{ij}$$

or

$$Y_{ij} = \mu + \alpha_i' + \beta_j' + e_{ij} \qquad (2)$$

The parameters of this model (2) are estimatable and may be obtained by regression.

Relative fishing power and relative population size are defined as follows:

$$r_i = \frac{q_i}{q_s}$$

$$D_i = \frac{P_i}{P_s}$$

The subscript s denotes standard and the fishing power of the standard vessel is set to 1.0.

The relative fishing powers are estimated as

$$r_i = e^{\hat{\alpha}_i'} (1\text{-Var } (\hat{\alpha}_i')/2)$$

and approximate 95% confidence limits are estimated as

$$CI_i = e^{(\hat{\alpha}_i' \pm 1.96 \sqrt{\text{Var } (\hat{\alpha}_i')})}$$

Statistical distribution

Few if any fish species are distributed at random in the sea. This is reflected in great variance between trawl hauls. This implies that a great number of trawl hauls are needed to estimate the abundance with any precision. This has been observed for various kinds of fish PENNINGTON and GROSSLEIN (1978), DAAN, HISLOP, HOLDEN and LAHN-JOHANNESSEN (1975), BECKER and CORTON (1974), JONES 1956 and TAYLOR 1953. These investigations indicate that a negative binomial distribution may fit the observed distribution of trawl catches. For a discussion of the properties of the negative binomial distribution see ANSCOMBE (1950). The negative binomial distribution is a two parameter distribution with parameters m (the mean) and k.

The variance is given by:

$$\sigma^2 = m + m^2/k$$

The parameter k may be estimated using a maximum likelihood estimator (BLISS and FISHER 1953).

$$Z = \sum_{i=0}^{\infty} \left(\frac{A_i}{k + i}\right) - N \ln (1 + \bar{x}/k)$$

where

A_i = accumulated frequency of all hauls containing more than i fish

N = number of hauls

$\bar{x}$ = arithmetic mean of the hauls

This equation may be solved by iteration for Z = 0 using trial values of k. The variance of the estimated k is given by:

$$\mathrm{Var}\ (k) = (k_1 - k_2)/(Z_2 - Z_1)$$

where k_1 is the final estimate of k and k_2 is the previous, and Z_1 and Z_2 are corresponding values of Z.

To test the goodness of fit of the negative binomial distribution a Kolmogorov-Smirnov test was used (NUROSIS 1979).

The parameter k may be interpreted as a measure of the aggregation in the fish distribution. The degree of aggregation increases as the value of k decreases. A stable value of k for varying values of $\bar{x}$ indicates that the distributional properties of the fish are rather independent of stock size.

Transformations to normalize data

In order to be able to calculate confidence limits and perform statistical tests (T-tests, analysis of variance) the catch data need to be transformed. The purpose of a transformation is to normalize the data and make mean and variance independent.

The variance of the negative binomial distribution may be written:

$$\sigma^2 = m^2 \left(\frac{1}{m} + \frac{1}{k} \right)$$

This gives:

$$\sigma = m\sqrt{\frac{1}{m} + \frac{1}{k}} \qquad (3)$$

For constant k and k much less than m this gives a proportional relationship between mean and standard deviation. This relationship implies a logarithmic transformation (JONES 1956).

The most commonly used transformation y=ln(x+1) involves a certain danger when there is a large number of zero observations (ULLTANG 1978, PENNINGTON and GROSSLEIN 1978), because the data may still be unnormalized after the transformation.

Another approach is suggested by PENNINGTON and GROSSLEIN (1978) using the transformation $y=\ln(x)$, $x\neq 0$ and a distribution named the delta distribution. The assumptions underlying this distribution are that a fixed proportion p of the observations are zero and the positive nonzero observations follow a log-normal distribution. Estimators for the mean (L) and the variance (r^2) in this distribution is given by AITCHINSON and BROWN (1957) as:

$$L = \begin{cases} \frac{N_1}{N} e^{\bar{Y}} \psi(\tfrac{1}{2}S_y^2, N) & N_1 > 1 \\ \frac{x_1}{N} & N_1 = 1 \\ 0 & N_1 = 0 \end{cases}$$

$$r^2 = \begin{cases} \frac{N_1}{N} e^{2\bar{Y}} \left(\psi(2S_y^2, N_1) - \frac{N_1-1}{N-1} \psi\left(\frac{N_1-2}{N_1-1} S_y^2, N_1\right)\right) & N_1 > 1 \\ \frac{x_1^2}{N} & N_1 = 1 \\ 0 & N_1 = 0 \end{cases}$$

where N is the total number of trawl stations and N_1 is the number of nonzero stations and $\bar{Y}$, S^2 and ψ is defined as follows:

$$\bar{Y} = \frac{1}{N_1} \sum_{i=1}^{N_1} \ln(x_i)$$

$$S_y^2 = \frac{1}{N_1-1} \sum_{i=1}^{N_1} (\ln(x_i) - \bar{Y})^2$$

and $\psi(T,N)$ is an adjustment function for retransformation of the lognormal distribution given as

$$\psi(T,N) = \sum_{i=1}^{\infty} \frac{(N-1)^{2i-1}\, T^{i}}{i!\, N^{i} \prod_{\substack{j=2 \\ j \geq i}}^{i} (N-3+2j)} + 1$$

Indices of yearclass abundance

Two sets of abundance indices are calculated. One on logarithmic scale and the other on the untransformed scale. As an untransformed index the stratified mean of the means L of the delta distribution is used and the logarithmic index being calculated as the stratified mean of $\bar{Y}$ multiplied by the proportion p of nonzero hauls.

Stratification

The surveyed area was divided into 17 strata (Fig. 2). Strata 1-11 form an eastern Barents Sea area and strata 12-17 form a western Spitsbergen/Bear Island area. The strata should be considered as geographical areas and not strata in the proper statistical meaning of the word. This because the strata is constructed after the surveys and allocation of trawlstations to the different strata on statistical considerations are not possible. This means that variance may not be reduced to any significant extent by the strata chosen. Stratified mean and variance of the mean for both indicies are calculated as

$$\bar{Y}_{ST} = \frac{1}{A} \sum_{i=1}^{k} a_i \cdot \bar{Y}_i \qquad (4)$$

$$s^2_{\bar{Y}_{ST}} = \frac{1}{A^2} \sum_{i=1}^{k} \frac{a_i^2 \cdot s_i^2}{n_i}$$

where a_i = the area of stratum i
A = the total area
$\bar{Y}_i$ = transformed mean in stratum i
S_i^2 = transformed variance in stratum i
n_i = numbers of trawlstations in stratum i
k = number of strata.

Confidence limits

1. Logarithmic index

The confidence limits are calculated as the product of the confidence limits of the stratified transformed mean and the proportion of nonzero hauls (PENNINGTON and GROSSLEIN 1978).

First calculate confidence limits for $\bar{Y}_{ST}$ based on normal theory.

$$\bar{Y}_{ST} - S_{\bar{Y}_{ST}} \cdot t < \bar{Y}_{ST} < \bar{Y}_{ST} + S_{\bar{Y}_{ST}} \cdot t$$

or

$Y' < \bar{Y} < Y''$ where t is a t-distributed variable with probability 0.95 and N-k degrees of freedom. Then calculate confidence limits for p (p having a binomial distribution).

$$\frac{1}{1+t^2/N} \left(p + \frac{t^2}{2N} \pm t((p(1-p)/N+t^2/4N^2))^{\frac{1}{2}}\right) \quad \text{(LINDGREN 1968)}$$

where t=1.96 or written $p' < p < p''$.

We then construct final confidence limits for the logarithmic index as follows:

$$p' \cdot Y' < p \cdot \bar{Y} < p'' \cdot Y''$$

2. Retransformed index

These confidence limits were calculated using the formula of JONES (1956). The stratified retransformed mean (L_{ST}) was calculated using the same formula (4) as for the transformed mean just using L_i instead of $\bar{Y}_i$ in the formula (4). The confidence limits are calculated as:

$$L_{ST}\, e^{-S_{\bar{Y}_{ST}} \cdot t} < L_{ST} < L_{ST}\, e^{S_{\bar{Y}_{ST}} \cdot t}$$

The size of these confidence limits are 95% only if the logarithm of L_{ST} is normally distributed. This is probably not true of all the years included in this investigation.

RESULTS AND DISCUSSION

Analysis of fishing power

The areas used in the model described is shown in Fig. 3. This is the central area of the Barents Sea were all of the vessels have trawl hauls. The areas were chosen rather large to ensure all vessels stations in most of the areas. The mean catch of each vessel in each area each year was estimated and used as input to the model.

Since the model (2) assumes no interaction between vessel and area, a two-way analyses of variance was performed in order to test for interaction. Before running the analysis all catch data were transformed using the formula $y=\ln(x)$. The results are shown in Table 2 and indicates that there is no significant interaction.

As a standard vessel "G.O. Sars" 1971-1979 was chosen. The estimated relative fishing powers are shown in Table 3. Although most of the estimated relative fishing powers do not differ significant, the differences are of such magnitude that they indicate real differences.

The wide confidence limits reflect the large variance in the catch data and that the areas chosen may be too large, thereby generating a large within area variance. However, the reason for choosing the rather large areas were that all of the vessels should have stations in most of the areas.

Two vessels "Havdrøn" (Norway) and "Jastreb" (USSR) have only participated one year each and are not included in the analysis. Their relative fishing powers are assumed to be 1.0.

All catches of a vessel were divided by the vessels relative fishing power and these catch data are used for the rest of this analysis.

Fitting of the negative binomial distribution

The parameters of the negative binomial distribution were estimated using the maximum likelihood estimator and the results are given in Table 4.

The maximum difference between the observed and theoretical negative binomial (with estimated parameters) cumulative distributions, the Kolmogorov-Smirnov test statistic and its probability is also shown in Table 4. This shows that for all years the data is rather well fitted by a negative binomial distribution. Since there is an approximate linear relationship between the mean and standard deviation in a negative binomial distribution (3) a logarithmic transformation should be appropriate (JONES 1956).

The correlation between the estimated k-value and the mean is only 0.099 indicating that they are independant. This indicates that the distributional properties of the 0-group cod is independant of yearclass strength.

There seems to be no trends in the estimated k-values with time. The autocorrelation with one year time-lag is 0.106 which is not significant.

Estimated indices

To test the normalizing effect of the two different transformation the transformed distributions are tested against normal distributions using a Kolmogorov-Smirnov test. The results are given in Table 5. The transformation y=ln(x+1) does not normalize the distribution for any year while the transformation y=ln(x) normalize the data for all years except 1969, 1973 and 1974 at a 5% significance level.

Indices of yearclass abundance was estimated for the western and eastern areas seperately and for the total area. The results are given in Table 6, and indicates that the yearclasses 1970, 1973 and 1975 are the most abundant at the 0-group stage. The 1970 yearclass is abundant in both the Spitsbergen/Bear Island area and in the Barents Sea, while the 1973 and 1975 yearclasses are poor in the Spitsbergen/Bear Island area. Of the other yearclasses the most numerous are the 1971, 1977, 1972 and 1974. These may be considered average in strength, and the rest of the year classes, poor.

From Table 6 we see that the Barents Sea component of the yearclass is the most important. This is also reasonable as the eastern area is about 71% of the total areawhere 0-group of Arcto-Norwegian cod is found. The exceptions are the 1978 and 1979 yearclasses where the western components are the most important. This may be due to the cooling of the eastern Barents Sea during the latest years (ANON 1981).

Correlation with recruitment indices from VPA.

The VPA estimates of the absolute numbers of 3-years old cod are taken from ANON (1980). Assuming the yearclasses 1965 to 1975 are well predicted by the VPA the correlation between VPA estimates and the retransformed index (RI) is 0.83 and between VPA and the logarithmic index (LI) it is 0.88 for the period 1965-1975. The regression lines are as follows: VPA=3.54·RI+399 and YPA=576.76·LI+267. From these two regression lines the number of 3-years old fish may be predicted. These predicted values with their confidence limits are shown in Table 7. The confidence limits of the predicted values are calculated as described in ZAR (1974, Ch.16). This table indicates that the VPA estimates of 3 years old fish are within the confidence limits of the predicted number of 3 years old cod from the regression lines, except for the 1966, 1969, 1972, 1973 yearclasses as calculated from the retransformed index and the 1969 and 1973 yearclasses calculated from the logarithmic index. Both indices fail to predict the 1969 yearclass. This may be due to lower efficiency of the survey in the first years or that the VPA overestimates the 1969 yearclass. USSR young fish investigations also indicates that the 1969 yearclass is rather poor (TRAMBACHEV and BARANOVA 1978). Due to this a new regression is computed without the 1969 yearclass. The resulting regression lines are VPA=3.86·RI+313 (R=0.93) and VPA=613.68·LI+184 (R=0.96) (Fig. 4). Both these regressions are also highly significant. The estimated number of three years old fish from these regression lines are given in Table 8.

These two last regression lines may be used to give estimates of the absolute recruitment to the Arcto-Norwegian cod for the period 1976 to 1979. The results are given in Table 8. This indicates that the recruitment for this period equals about 300 millions 3 years old fish. This is well above the recruitment assumed by ANON (1980). This is mainly due to the large positive intercept of the regression lines. A recruitment index of zero would give an estimate of 313 mill. and 184 mill. 3 years old fish from the retransformed and logarithmic indices respectively.

Also an increased natural mortality on agegroups 1-3 due to the cooling of the Barents Sea the latest years may explain some of these differences. This has been shown by PONOMARENKO 1973, who states that warm winters favours survival, especially the first winter at the bottom.

Table 8 also shows the old 0-group indices (from ANON 1981) and these gives a correlation with the VPA estimates of 0.70. If the 1969 yearclass is removed the correlation increases to 0.77

giving the regression line Y=1.56•OGR+279. The old 0-group index for the 1969 yearclass is 93, giving an absolute estimate of 3 years old recruits of 424 mill. which shows that the 1969 yearclass is also badly underestimate by this index, relative to the VPA estimates. Table 8 also gives the predicted values from the old 0-group indices. It shows that also the 1970 yearclass is severely underestimated and the 1973 yearclass is badly overestimated. This indicates that the new indices (RI and LI) should be used instead of the old 0-group indices for assessment purposes.

The results of this investigation indicates that the yearclass strength may be predicted from these 0-group investigations. Further precision in prediction may be obtained by introducing other factors affecting the mortality of the young cod from 0-group to 3 years of age into the analysis. This may include factors like temperature, salinity, abundance of food and predation.

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Table 1. Trawls used during the 0-group surveys.

GEAR	SIZE	CODEND MESHSIZE
"Harstadtrål"	18.3 m x 15.3 m	8 mm
USSR pelagic trawl	10 m x 6 m	8 mm
Boothbay trawl	3 m x 2 m	Unknown
Engel trawl	Unknown	Unknown

Table 2. Analysis of variance. Test for interraction between vessels and areas.

YEAR	F-VALUE	DF	PROB.
1967	3.08	5, 5	0.121
1969	1.05	15,35	0.434
1970	1.11	8,37	0.379
1971	0.59	17,59	0.889
1972	0.13	3,15	0.943
1973	1.41	17,55	0.167
1974	1.36	6,32	0.261
1975	0.84	9,54	0.587
1976	0.45	11,23	0.913
1977	1.18	8,53	0.328
1978	2.24	8,40	0.045
1979	0.66	6,26	0.684

Table 3. Estimated fishing powers with confidence limits relative to G.O. Sars (1971-1979).

VESSEL	RELATIVE FISHING POWER	CONFIDENCE LIMITS
G.O. Sars (1971-1979)	1.000	
G.O. Sars (1970)	0.221	0.060-1.706
G.O. Sars (1965-1969)	0.493	0.148-2.931
J. Hjort (1965-1973)	1.936	0.856-5.481
J. Hjort (1975-1979)	1.536	0.697-4.172
E. Holt (Pelagic trawl)	0.518	0.106-9.601
E. Holt (Boothbay trawl)	0.574	0.175-3.291
Cirolana (Pelagic trawl)	0.551	0.253-1.464
Cirolana (Boothbay trawl)	0.040	0.012-0.220
A. Knipovich	0.563	0.241-1.678
F. Nansen	0.734	0.350-1.844
Poisk	0.537	0.280-1.178
Odissey	0.723	0.305-2.216

Table 4. Parameters of the negative binomial distributions and the goodness of fit.

YEAR	NO. OF HAULS	MEAN	K-VALUE	STANDARD ERROR	MAX. DIFF.	KOLM.SMIR. TEST STAT.	1-TAIL PROB.
1965	73	0.2	0.0032	0.0037	0.8	0.09	0.50
1966	121	0.2	0.0949	0.0457	4.7	0.43	0.49
1967	141	0.5	0.1183	0.0360	3.8	0.32	0.50
1968	146	0.2	0.0607	0.0247	4.2	0.35	0.50
1969	222	4.0	0.1507	0.0197	11.9	0.80	0.27
1970	148	383.6	0.1592	0.0166	15.3	1.25	0.04
1971	242	31.8	0.1186	0.0124	10.6	0.68	0.37
1972	147	8.3	0.1502	0.0220	4.8	0.40	0.49
1973	257	76.4	0.1080	0.0103	17.9	1.12	0.08
1974	201	4.1	0.0960	0.0147	7.0	0.49	0.48
1975	253	105.5	0.0834	0.0085	13.8	0.87	0.22
1976	200	1.4	0.1254	0.0221	5.4	0.38	0.50
1977	255	13.4	0.0929	0.0109	11.1	0.70	0.36
1978	244	5.7	0.1020	0.0129	12.5	0.80	0.28
1979	220	4.1	0.1328	0.0178	8.4	0.56	0.45

Table 5. Kolmogorov-Smirnov test for normality of the distributions resulting from the transformations y=ln (x+1) and y=ln(x).

	Y=ln(x+1)		y=ln(x)	
YEAR	KOLM.SMIR. TEST.STAT.	1-TAILED PROB.	KOLM.SMIR. TEST.STAT.	1-TAILED PROB.
1965	4.58	0.00	Not estimatable	
1966	5.79	0.00	1.11	0.09
1967	5.87	0.00	1.10	0.09
1968	6.38	0.00	0.94	0.17
1969	5.10	0.00	1.58	0.01
1970	1.56	0.01	0.90	0.19
1971	4.55	0.00	0.78	0.28
1972	3.78	0.00	0.90	0.20
1973	4.00	0.00	1.60	0.01
1974	5.76	0.00	1.31	0.03
1975	4.68	0.00	1.06	0.11
1976	6.01	0.00	1.03	0.11
1977	5.61	0.00	0.93	0.17
1978	5.65	0.00	1.14	0.07
1979	5.27	0.00	1.02	0.12

Table 6. Estimated retransformed and logarithmic indices with confidence limits of yearclass strength.

A-Western area.

YEAR	RETRANSFORMED INDEX	CONFIDENCE LIMITS(95%)		LOGARITMIC INDEX	CONFIDENCE LIMITS(95%)	
1965	0.00					
1966	0.04			0.01		
1967	0.00					
1968	0.03			0.01		
1969	0.99	0.77	1.29	0.21	0.10	0.40
1970	166.08	94.17	292.90	2.10	1.37	2.86
1971	5.78	3.16	10.57	0.42	0.17	0.81
1972	0.64	0.59	0.69	0.14	0.07	0.26
1973	0.93	0.66	1.31	0.10	0.03	0.25
1974	0.05	0.05	0.05	0.01	0.00	0.03
1975	0.45	0.32	0.65	0.08	0.02	0.23
1976	0.00					
1977	2.82	1.93	4.12	0.24	0.10	0.46
1978	8.93	5.86	13.63	0.36	0.16	0.66
1979	6.25	4.14	9.44	0.68	0.37	1.09

B-Eastern area.

YEAR	RETRANSFORMED INDEX	CONFIDENCE LIMITS(95%)		LOGARITMIC INDEX	CONFIDENCE LIMITS(95%)	
1965	0.14			0.01		
1966	0.18	0.18	0.19	0.04	0.02	0.08
1967	0.47	0.41	0.55	0.11	0.05	0.20
1968	0.33	0.28	0.37	0.03	0.01	0.09
1969	3.14	2.67	3.68	0.36	0.24	0.51
1970	452.26	307.18	665.86	2.72	2.17	2.36
1971	37.27	28.35	49.00	1.12	0.82	1.45
1972	8.85	6.34	12.35	0.89	0.58	1.25
1973	240.12	161.35	357.36	2.35	1.86	2.87
1974	9.09	6.56	12.61	0.64	0.41	0.92
1975	222.26	143.48	344.28	1.61	1.19	2.09
1976	1.77	1.31	2.39	0.30	0.15	0.50
1977	16.89	13.04	21.87	0.69	0.48	0.95
1978	1.58	1.35	1.87	0.24	0.15	0.36
1979	2.18	1.68	2.82	0.35	0.21	0.54

C-Total area.

YEAR	RETRANSFORMED INDEX	CONFIDENCE LIMITS(95%)		LOGARITMIC INDEX	CONFIDENCE LIMITS(95%)	
1965	0.10			0.01		
1966	0.14	0.14	0.15	0.03	0.02	0.05
1967	0.34	0.30	0.37	0.06	0.03	0.11
1968	0.24	0.22	0.26	0.02	0.01	0.05
1969	2.51	2.20	2.87	0.31	0.22	0.43
1970	369.19	268.89	506.91	2.54	2.07	3.01
1971	28.13	21.73	36.40	0.83	0.61	1.08
1972	6.47	5.10	8.19	0.62	0.42	0.86
1973	170.69	126.90	229.60	1.33	1.04	1.66
1974	6.50	5.13	8.15	0.35	0.22	0.51
1975	157.87	114.13	218.39	0.97	0.71	1.27
1976	1.26	1.01	1.56	0.15	0.07	0.26
1977	12.81	10.37	15.81	0.51	0.37	0.69
1978	3.72	3.15	4.39	0.28	0.18	0.39
1979	3.36	2.71	4.17	0.44	0.30	0.61

Table 7. Results of the regression analysis between VPA estimates and the estimated indices (1965-1975) (Numbers in mill.).

YEAR	VPA	PREDICTED RETRANSFORMED INDEX	CONFIDENCE LIMITS		PREDICTED LOGARITMIC INDEX	CONFIDENCE LIMITS	
1965	172	400	167	632	278	45	501
1966	114	400	167	632	284	59	509
1967	200	401	168	633	302	81	522
1968	408	400	168	633	279	52	505
1969	1030	408	178	639	446	256	636
1970	1888	1706	1137	2275	1732	1253	2211
1971	567	499	287	710	746	567	924
1972	686	422	195	649	625	451	797
1973	705	1003	732	1274	1034	797	1271
1974	421	418	190	647	468	282	656
1975	824	958	702	1214	826	637	1016

Confidence limits 95%

Table 8. Results from regression analysis between VPA estimates and the estimated indices and between VPA and the old 0-group indices. 1969 yearclass removed from the analyses (Numbers in mill.).

YEAR	VPA	PREDICTED RETRANSFORMED INDEX	CONFIDENCE LIMITS		PREDICTED LOGARITMIC INDEX	CONFIDENCE LIMITS		OLD 0-GROUP INDEX	PREDICTED OLD 0-GROUP INDEX
1965	172	313	137	490	190	38	341	6	288
1966	114	314	137	490	202	53	352	1	281
1967	200	314	138	491	221	74	367	34	332
1968	408	314	137	491	196	45	347	25	318
1970	1888	1740	1333	2146	1742	1440	2044	606	1224
1971	567	421	261	582	693	576	809	157	524
1972	686	338	165	511	564	450	679	140	497
1973	705	973	778	1167	1000	849	1150	684	1346
1974	421	334	161	508	398	274	523	51	358
1975	824	923	739	1107	779	657	901	343	814
1976		317	142	494	275	137	414		
1977		362	194	531	497	380	613		
1978		327	153	502	356	227	484		
1979		326	151	501	453	334	573		

Confidence limits 95%

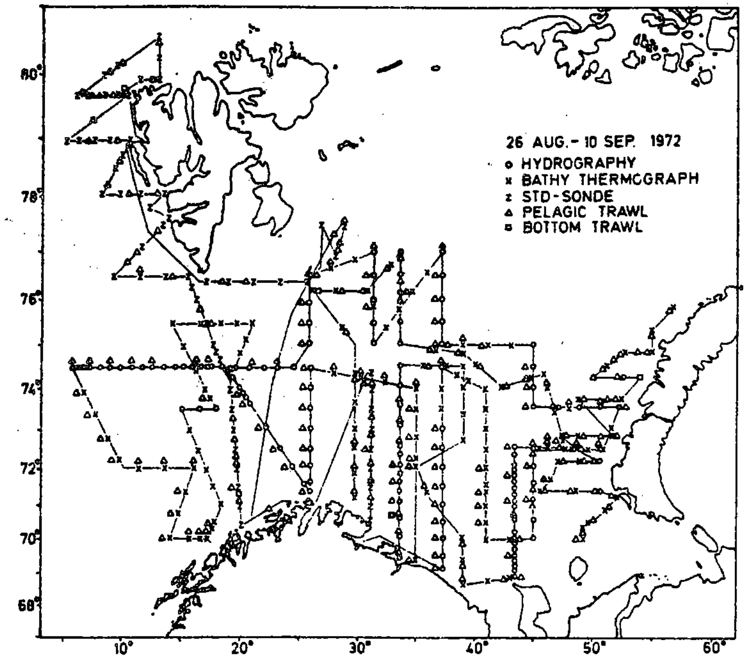

Figure 1. Survey tracks and trawl stations in 1972. (From HAUG and NAKKEN 1977).

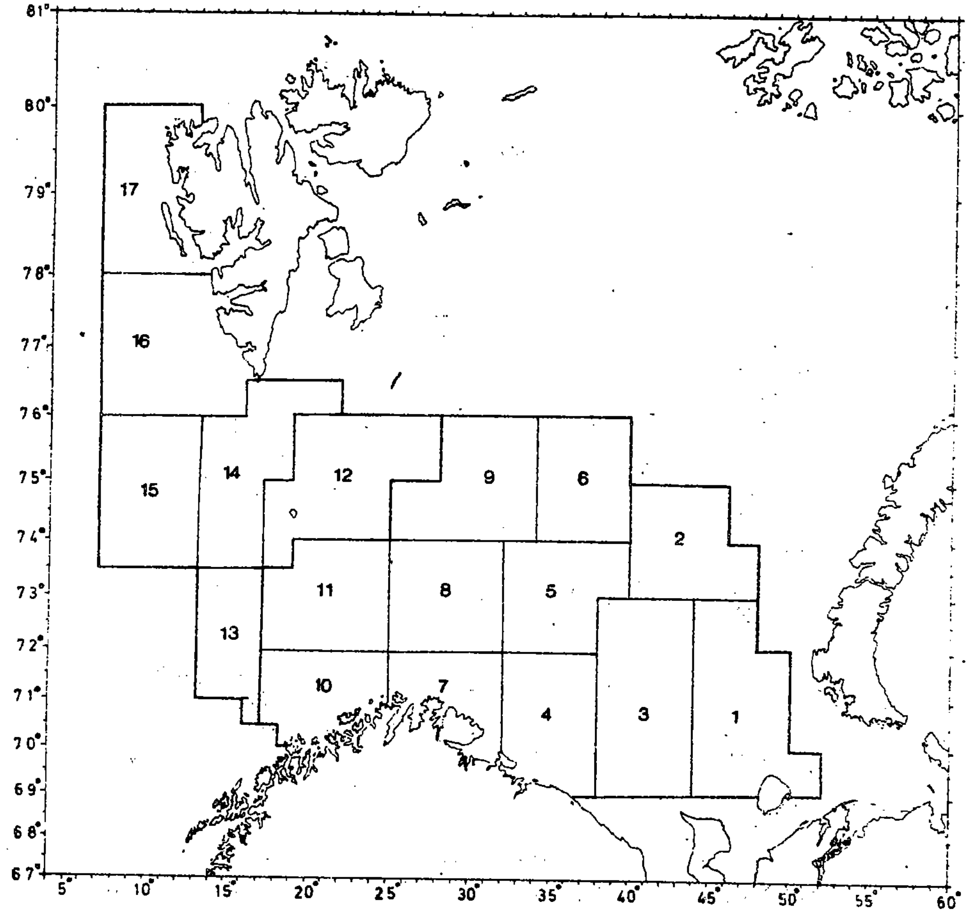

Figure 2. The strata used in estimating abundance indices.

Easter Barents Sea: Strata 1 - 11
Spitsbergen/Bear Island: Strata 12 - 17

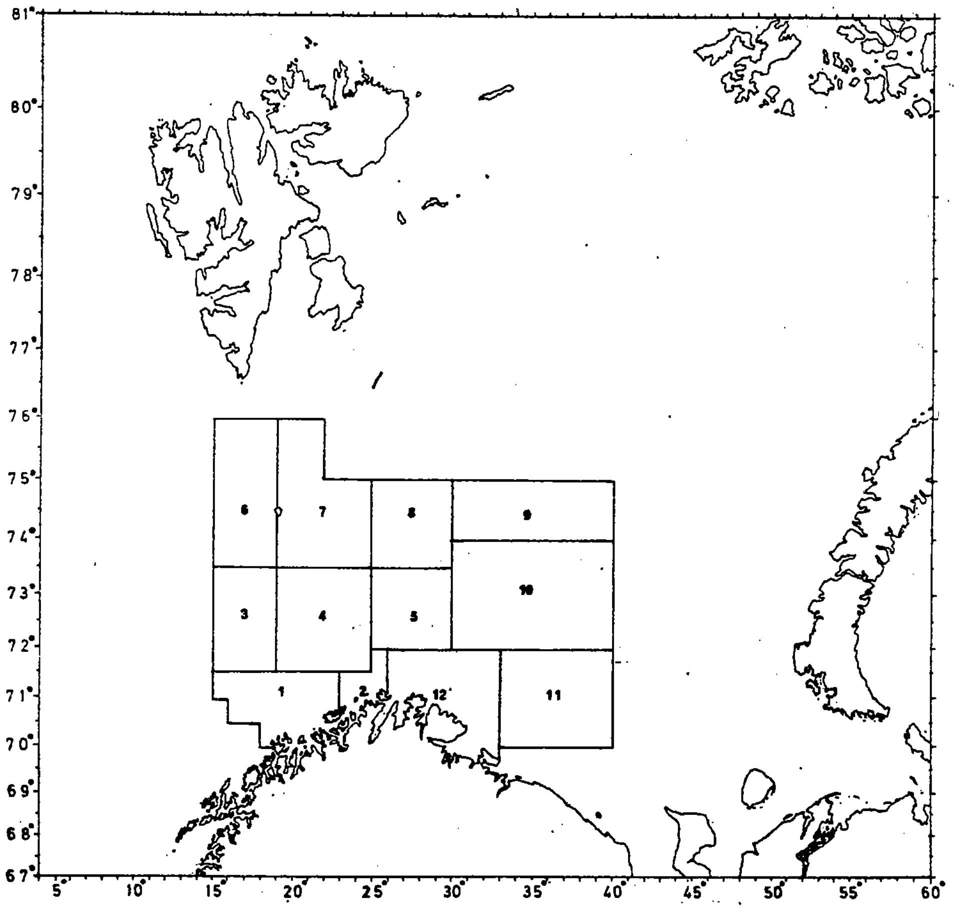

Figure 3. The areas used to estimate the relative fishing power of the different vessels.

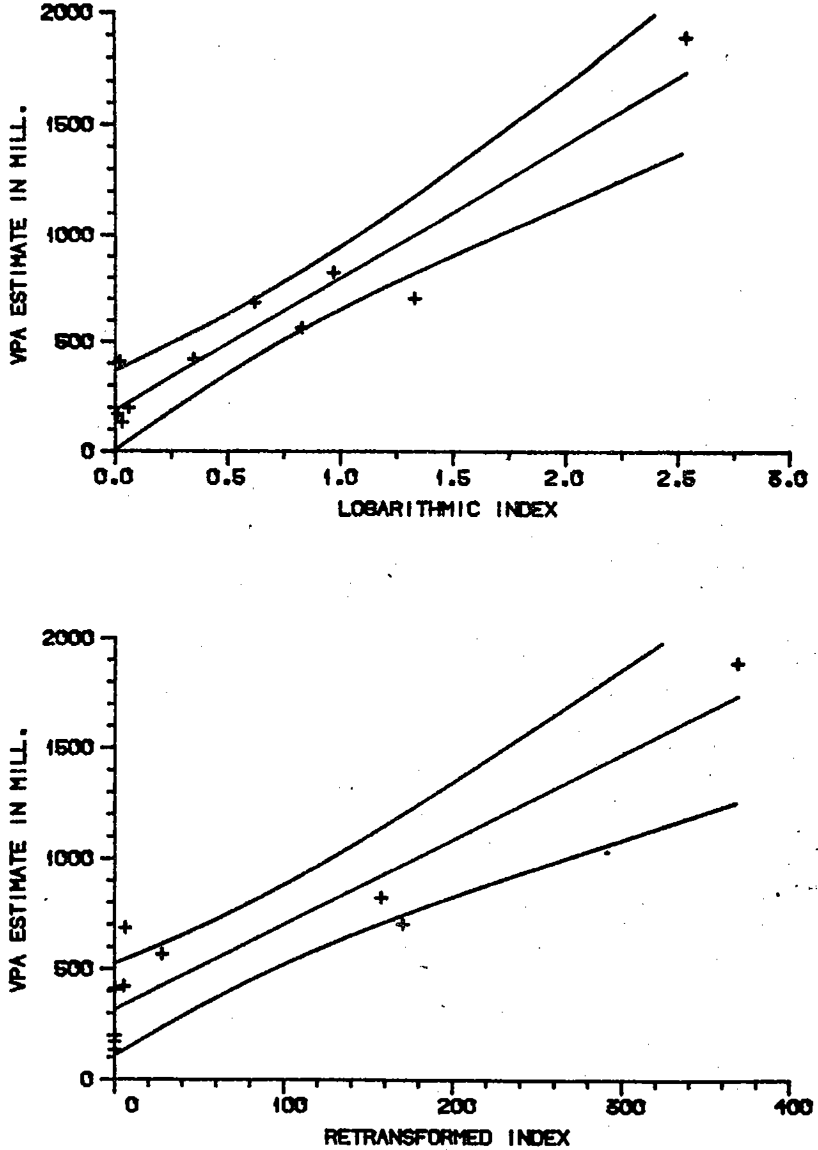

Figure 4. Regression lines with confidence lines between the estimated indices and VPA estimates of 3 years old cod.

Confidence lines 95%.