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LENGTH DEPENDANT CORRECTIONS OF SURVEY ESTIMATES OF COD AND HADDOCK IN THE BARENTS SEA

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ABSTRACT

This paper describes an attempt to utilize new information on gear selectivity and fish target strength to improve time series of survey estimates. Swept area estimates and acoustic estimates of cod and haddock in the Barents Sea have been obtained from combined bottom trawl/ acoustic surveys each winter since 1981. A part of the swept area time series have earlier been corrected for a change from bobbins to rockhopper ground gear (Godø and Sunnanå 1992). Here corrections for the remaining time series are presented. In addition a new time series is presented taking account of the fish size dependant trawl efficiency reported by Dickson (1993 a and b). The general effect of both corrections is an increase in the estimates of the youngest age groups relative to adult fish.

As the size (and age) distribution of the acoustic estimates directly depends on the size composition in trawl hauls, similar corrections were also made for the acoustic estimates. These revisions also took account of new target strength estimates which are considered more reliable than those used earlier. The relative age distribution of the old acoustic estimate was modified by applying the swept area conversion factor by age group, while the absolute level of the estimate was determined by keeping unchanged the total acoustic value (s_A). Hence the product of average acoustic cross-section and total estimated number of all age groups of cod and haddock should be unchanged. The change in average acoustic cross-section was estimated from the change in age distribution and the change in target strength function.

Ideally all corrections should have been made station by station. Some of the raw data were, however, not available in a standardized format. Mean length at age were available for nearly all years, and the corrections were therefore done on the total survey estimate by age group. For the conversion from bobbins to rockhopper the two procedures were compared, and they showed good agreement.

INTRODUCTION

The combined bottom trawl and acoustic surveys which have been carried out in the Barents Sea each winter since 1981, yield two types of indices of abundance of young cod and haddock; swept area estimates and acoustic estimates of fish numbers at age. Both types are used for VPA tuning and recruitment prediction in the annual stock assessments (Anon 1993). The swept area estimates are computed from catches in bottom trawl hauls at predetermined positions. Most of these hauls have been carried out by one (in the early years two) hired commercial trawler(s). The area covered was fixed until 1992, but extended significantly in 1993 and 1994 in order to cover the geographical distribution of the younger age-groups of cod. The acoustic estimates are computed from area back scattering values observed with the BEI-system (Knudsen 1990) and corresponding average target strengths of the recorded fish arrived at by using the length distributions in catches and an empirically determined relationship between target strength and fish length (MacLennan and Simmonds, 1991). All the acoustic data have been sampled with research vessels, one or two each year, and in addition to length- and species distributions from bottom and midwater hauls for the identification of acoustic scatterers extensive use has also been made of the length- and species distributions from the predetermined bottom trawl stations. As a rule the annual acoustic survey has covered a slightly larger area than the bottom trawl survey, but in 1993 and 1994 the areas were equal.

Extensive studies in the course of the 5-10 past years have largely improved our knowledge of the length and species specific capture efficiency of the standard sampling bottom trawl used in the surveys (Godø and Sunnanå, 1992). An outcome of these studies was the change from bobbins to rockhopper groundgear in the late 1980s which increased the catches of small-sized fish and necessiated the recalculation of swept area indices carried out by Godø and Sunnanå (1992) back to 1983. Recently Dickson (1993a and b) developed a theoretical model for the estimation of the capture efficiency of trawl gear and tested it using data from the Barents Sea surveys. He showed that also with rockhopper gear the standard trawls capture efficiency of small fish, 10-20 cm in length, was less than that of larger individuals both for cod and haddock, and he quantified the results in terms of effective spread (width of swept area) by length group.

In the present paper we have

- corrected the swept are estimates in 1981 and 1982 for the change from bobbins to rockhopper groundgear
- applied Dicksons results on effective spread by length group and computed a new time series of swept area estimates 1981-1994

- corrected the time series of acoustic estimates, 1981-1994, for
  - the change from bobbins to rockhopper
  - the effective spread as given by Dickson (1993b)
  - the change of target strength-length relationship.

Finally we have carried out a linear regression analyses between stock numbers at age as estimated by VPA and the various estimates obtained from the Barent Sea winter surveys for the period 1981-1990.

METHODS

Swept area estimate

The notations used are as follows:

I_{rhld} ; the abundance index (numbers at age) corrected for length dependant capture efficiency when using rockhopper groundgear
I_{rh} ; the uncorrected abundance index when using rockhopper groundgear
I_b ; the abundance index obtained with bobbins groundgear
A ; ratio between the capture efficiency of rockhoppers and the capture efficiency of bobbins (Table 1)
B ; ratio between the spread used for computing I_b and I_{rh} (25 m) and the effective spread (Table 1).

The values of A in Table 1 are those given by Godø and Sunnanå 1992, while the values of B are arrived at by dividing the constant spread used in previous computations (25 m) with the values of effective spread as given by Dickson 1993b.

The formula applied for the computation of numbers at age was:

$$I_{rhld} = (A \cdot I_b) \cdot B \qquad \text{(I)}$$

where the expression in paranthesis, $A \cdot I_b = I_{rh}$, is the recalculated abundance index (bobbins to rockhoppers) given by Godø and Sunnanå (1992) for the period 1983-1988. We have used Godø and Sunnanå's values of I_{rh} as input in equation (I) and to make the time series complete we have computed I_{rh} for 1981 and 1982.

Ideally, the computations (I) ought to be carried out for each separate catch and by 5 cm length groups as done by Godø and Sunnanå (1992). Due to difficulties in availability of raw data on a standard format for the earlier years in the series we chose to multiply the total survey estimate of numbers at age with the values of A and B corresponding to the mean length of the age group. These values were found by interpolation in Table 1.

Mean lengths by age of cod were available for all years but for haddock mean lengths were not readily available for the period 1983-1986, and for those years average values were used.

Acoustic estimates

The number of fish at age ,N, can be computed by the equation

$$N = (S_A / \bar{\sigma}) \cdot (f / \Sigma f) \qquad \text{(II)}$$

where

S_A ; is the area back scattering coefficient (of cod and haddock) measured with the acoustic system, BEI.
$\bar{\sigma}$; is the mean scattering cross-section of individual fish
$f / \Sigma f$; is the proportion of fish in the age group

S_A which is the observed acoustic value, is independant both of changes in the target strength-length relationship and of changes in the capture efficiency of the gear used to observe the age (or length) frequency distributions ($f/\Sigma f$). Hence, S_A should be kept constant, and

$$S_A = \Sigma (N_{b\sigma 1} \cdot \sigma_1) = \Sigma (N_{b\sigma 2} \cdot \sigma_2) \qquad \text{(III)}$$

where

$N_{b\sigma 1}$ is the number of fish in an agegroup as computed from equation (I) when trawl samples (length/age distributions) are collected with bobbins groundgear and when the "old" target strength-length relationship

$TS_1 = 10 \log[\sigma_1/(4\pi)] = 21.8 \log L - 74.9$ is used.

$N_{rhld\sigma 2}$ is the number of fish in an age group computed using trawlsamples obtained with rockhoppers corrected for length dependant capture efficiency and applying the "new" target strength-length relationship

$TS_2 = 10 \log [\sigma_2/(4\pi)] = 20 \log L - 68$. L is fish length in cm.

The sum (III) is taken over all age groups (cod and haddock).

The average individual scattering cross section, $\bar{\sigma}$, in equation II, is dependant both on the target strength-length relationship and on the age (length) distribution actually observed. This means that a change from bobbins to rockhopper groundgear in itself generate a large change in $\bar{\sigma}$ independant of the relationship between σ and length (age). Hence, for each particular year the "new" average individual scattering cross section was computed by the formula

$$\bar{\sigma}_{new} = \Sigma (A \cdot B \cdot N_{b\sigma 1} \cdot \sigma_2) / \Sigma (A \cdot B \cdot N_{b\sigma 1}) \qquad \text{(IV)}$$

where again the sum is taken over all age groups for cod and haddock. Note that A and B are not constants but dependant on age (i.e. mean lengths at age).

The proportion of fish in an age group after the correction for the change from bobbins to rockhoppers as well as for the length dependant capture efficiency when using rockhoppers groundgear is

$$f/\Sigma f = (A \cdot B \cdot N_{b\sigma 1}) / \Sigma (A \cdot B \cdot N_{b\sigma 1}) \qquad \text{(V)}$$

Combination of II, III, IV and V yields

$$N_{rhld\sigma 2} = N_{b\sigma 1} \cdot [A \cdot B \cdot \Sigma (N_{b\sigma 1} \cdot \sigma_1)] / \Sigma (A \cdot B \cdot N_{b\sigma 1} \cdot \sigma_2) \qquad \text{(VI)}$$

Equation VI was used for computations of the new acoustic estimates of numbers at age for the period 1981-1990. For the period 1991-1994 Mehl and Nakken (1994) have given estimates based on rockhopper trawl samples and the revised version of the target strength/length relationship, σ_2. Thus for these years we used those estimates as input in a slightly different version of equation VI:

$$N_{rhld\sigma 2} = N_{b\sigma 2} \cdot [B \cdot \Sigma (N_{rh\sigma 2} \cdot \sigma_2)] / \Sigma (B \cdot N_{rh\sigma 2} \cdot \sigma_2) \qquad \text{(VII)}$$

Linear regressions

Regressions were made between the numbers at age as estimated by VPA (Anon 1993) and the various abundance indices assuming relationships of the types

$$\text{VPA number} = a \cdot (\text{Index number}) - b$$

RESULTS AND DISCUSSIONS

Comparison of the results in Table 2 indicates only minor differences between the comprehensive correction procedure used by Godø and Sunnanå (1992) and the simplified version used in the present paper. We therefore assume that no systematic errors were introduced to the indices of numbers at age by the procedure we have used.

Swept area estimates/indices

The "old" time series of numbers at age of cod and haddock with addition of the years 1981 and 1982 are given in Tables 3 and 5 and the time series corrected for length dependant capture efficiency appear in Tables 4 and 6. The general trend is as expected; numbers at age were increased for the younger fish while the amount in the older agegroups decreased. Hence the unrealistic development that some cohorts, particularly for cod, increased in numbers by age was somewhat modified in the corrected series as compared with the uncorrected. However, from Table 4 it is evident that several year classes still tends to increase or maintain their numbers by age. Several causes might contribute to such a development:

Insufficient area coverage of the younger age groups

On the basis of observations made in earlier years the investigated area was largely extended in 1993 and 1994 (Korsbrekke et.al. 1993, Mehl and Nakken 1994). In both those years large amounts of fish, particularly 1-3 year olds, were observed east and north of the area sampled in the years prior to 1993. The distribution of cod in winter shows a westward displacement of fish by age; older fish is distributed further west and in warmer waters than the younger age groups, (Nakken and Raknes, 1987, Nakken 1993). Year classes for which the 1 (and 2) group have to a large extent been distributed east (and north) of the standard sampling area might thus show a development of increasing numbers by age in the indicies since they move westward and into the sampling area as they grow older.

Size (age) dependant compression of the fish vertical distribution profile during trawling

According to the acoustic observations most of the fish is distributed at greater distances from the bottom than 10 m (Hylen et al. 1986, Korsbrekke et al. 1993, Mehl and Nakken 1994), and thus well above the headline (4-5 m). A size dependant downward movement as a reaction to vessel passage, making the larger fish more available to the bottom trawl than the smaller ones might explain the apparent increase in numbers at age. The use of acoustic information station by station as recommended by Dickson 1993b would be an important tool to clarify this point in the future.

Density dependant catchability

Godø (1994) has shown that the catchability of cod in these surveys tends to increase with the abundance of cod. Observations of fish behaviour in the trawl opening has revealed one likely reason for this; When just a few fish occur in the trawl opening they are actively searching for openings below the ground rope and they have a high chance of escaping. Larger fish aggregations behave more like a school at the trawl opening; the individuals showing polarized swimming and the whole school keeping away from the edges of the net, thus reducing the chances of escapement. It is suggested that the increase in catchability caused by increased fish density overrides the effect of reduced availability which tend to occur due to more pelagic distribution at high overall fish density.

Mesh selection of small fish

The low estimates of particularly 1-group cod in many of the years may be partly caused by mesh selection. Prior to 1994 all estimates were based on catches with codends of 35mm mesh size having a 50 percent retention length for cod close to the median of the length distribution of the 1-group (13-15 cm). To some extent catches and estimates of 2 group cod and 1-group haddock also might have been affected, depending on the length distributions of these groups. In 1994 codends with mesh size 20 mm were used, and no significant mesh selection will occurr at this mesh size.

Acoustic estimates

Tables 7-12 presents 3 time series of acoustic estimates for each of the two species. The reduction in numbers at age in Tables 8 and 11 as compared to Tables 7 and 10 is caused by the change in the target strength-length relationship; the new relationship generating higher target strength and thus lower estimates of abundance. The introduction of rockhoppers groundgear (Table 8 and 11) and further the corrections for length dependant capture efficency (Tables 9 and 12) caused a change in age distributions towards lower age.

The correction of the acoustic estimates is carried out as if all length distributions (age distributions) were based on bottom trawl catches, which to a great extent was the case for the period 1981-1992. For 1993 and 1994 pelagic trawl sampling was greatly extended and for these years Korsbrekke et al. (1993) and Mehl and Nakken (1994) computed acoustic estimates based on pelagic trawl samples as well as bottom trawl samples with rockhoppers groundgear, which are presented in Tables 8 and 11. When correcting for length dependant capture efficiency we have assumed that correction factors (B) were the same for these years as for the previous ones.

Also we have assumed that the corrections made will not influence the average lengths of the age groups, which is an approximation. However, since average length at age mainly rely on samples of individual fish for which length and age are observed, changes in overall length- or age-distributions will only have minor effects on this parameter. Our corrections are also made under the "wrong" assumption that the mean scattering cross section of the fish at a given age is equal to the scattering cross section corresponding to the mean length of the age group. The error introduced is, however, of magnitude 1-5 percent, and can be neglected for all practical purposes.

For 1982 and 1988 the total echo abundances (ΣS_A) for cod+haddock as given in the annual reports (see Korsbrekke, et al. 1993) do not correspond with the estimated acoustic numbers at age. In 1982 the estimated numbers are too high and in 1988 too low. The reason for this discrepancy is unknown.

Linear regressions

The results of the linear regressions between numbers at age as estimated by VPA (Anon, 1994) and the abundance indices are given in Table 13. The VPAs reported do not include estimates of the age groups 1 and 2. Age group 6 and older are not properly covered by the surveys due to the spawning migration. Therefore, regressions were only made for the age groups 3,4 and 5. The years 1991-1994 were not included because the VPA is influenced by the most recent survey estimates. The acoustic estimates for 1982 and 1988 are not included due to the discrepancy between estimated numbers and total echo abundance mentioned above.

With few exceptions the regressions show a reasonably good fit, judging from the correlation coefficient (r square). The exceptions are the acoustic estimates of 5 year old cod. Here the regressions are spoiled by a very high acoustic estimate of the 1981 year class combined with a low VPA estimate of the same year class. None of the corrections seem to give significantly improved fit. For 4 year old cod the corrections of the acoustic estimates increased the correlation from 0.68 to 0.94, but in all other cases the changes were quite marginal.

All corrections resulted in an increased slope of the regression. The reason is that for these age groups the corrections generally reduced the survey estimates. There is a general pattern that the regressions for cod show a higher slope than those for haddock, which means that the survey estimates for cod are lower relative to the VPA than those for haddock. This is quite reasonable because the survey covers the entire distribution of haddock, while the cod distributed in the Svalbard area is not covered.

All regressions give a positive intercept. In case of the swept area estimates this could be caused by an increased catchability at increased abundance as suggested by Godø (1994). By inspecting the standard error of the intercept it appears that for cod the intercept tend to be significanly larger than zero, while those for haddock are not significantly different from zero.

The main advantage of the corrections is to remove a serious bias in the annual length (age) distributions. Corrections for length dependant capture efficiency should therefore be incorporated in future survey work on a station by station basis as adviced by Dickson (1993b). Since the acoustic estimates rely on pelagic trawl samples in addition to bottom trawl catches, figures of capture efficiency by length are needed also for the pelagic trawls used.

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Table 1. Correction factors used in the recalculation of abundance indices of cod and haddock in the Barents Sea.

A: Multiplier used to compensate for the change from bobbins to rockhopper groundgear (Godø and Sunnanå1992).
B: Multiplier used to compensate for the length dependant capture efficiency when using rockhopper groundgear (computed from results given by Dickson 1993b).

Length group (cm)	A		B	
	Cod	Haddock	Cod	Haddock
10-14	7.14	6.66		
15-19	5.00	4.34	1.32	1.56
20-24	3.57	1.69		
25-29	3.70	1.22	1.09	1.04
30-34	2.17	1.11		
35-39	1.88	1.11	0.96	0.83
40-44	1.69	1.15		
45-49	1.59	1.25	0.83	0.68
50-54	1.49	1.33		
55-59	1.41	1.33	0.76	
60-64	1.37	1.33		0.66
65-69	1.33	1.33	0.71	
70+	1.33	1.33	0.76	

Table 2. Comparison of results (numbers in millions) obtained when applying the correction factor A in Table 1 in two different ways. Each haul: Correcting catch numbers by 5 cm length groups in each trawl haul (Godø and Sunnanå 1992).
Tot.numb: Correcting total numbers at age by using correction factors for mean length at age.

Age years	1984			1987		
	Uncorrected	Each haul	Tot.numb.	Uncorrected	Each haul	Tot. numb.
1	321	2170	1990	4	25	26
2	121	366	387	94	387	385
3	57	122	115	100	233	229
4	21	33	32	231	415	416
5	18	25	25	42	61	56
6	11	14	14	11	15	15
7	3	4	4	1	2	2

Table 3. **Cod.** Abundance indices from bottom trawl surveys in the Barents Sea winter 1981-1994 (numbers in millions).

Year	Age (years)										Total
	1	2	3	4	5	6	7	8	9	10+	
1981	3.5	31.9	17.2	27.9	51.2	52.7	6.4	1.3	0.4	0.0	192.5
1982	0.6	2.7	30.6	33.7	31.0	21.6	21.0	1.9	0.3	0.0	143.4
1983	259.0	17.7	23.2	45.4	44.1	18.9	6.0	3.9	0.8	0.2	419.2
1984	2170.0	366.0	122.0	32.7	25.4	14.4	4.2	0.6	0.3	0.1	2735.7
1985	39.0	647.0	162.0	126.0	21.7	8.4	3.3	0.3	0.1	0.1	1007.9
1986	562.0	403.0	679.0	173.0	102.0	30.6	7.3	0.8	0.2	0.1	1958.0
1987	25.3	387.0	233.0	415.0	61.1	15.4	1.8	0.5	+	0.0	1139.1
1988	3.8	63.5	180.0	102.0	231.0	25.7	4.8	0.8	0.1	0.0	611.7
1989	7.1	12.7	37.9	73.2	43.3	104.0	11.7	1.0	0.2	0.2	291.3
1990	122.0	48.9	25.8	37.0	43.8	27.0	31.4	1.7	0.5	0.1	338.2
1991	356.7	212.7	37.0	24.6	23.9	21.7	12.2	12.7	0.7	0.1	702.3
1992	99.7	482.2	170.4	62.7	25.0	15.7	9.9	5.2	3.5	0.3	874.6
1993	423.0	304.8	313.8	195.3	91.1	20.4	9.2	5.7	2.9	2.9	1369.1
1994	632.4	410.0	293.4	378.2	202.4	67.1	11.6	2.7	1.4	1.7	2000.9

Table 4. **Cod.** Abundance indicies from bottom trawl surveys in the Barents Sea winter 1981-1994 (numbers in millions). Corrected for length dependant trawl efficiency.

Year	Age (years)										Total
	1	2	3	4	5	6	7	8	9	10	
1981	5	33	16	23	40	39	5	1	-	-	162
1982	1	3	29	27	24	15	16	2	-	-	117
1983	342	19	22	37	34	13	5	3	1	-	476
1984	2864	399	113	27	19	11	3	1	-	-	3437
1985	52	738	144	98	15	6	3	-	-	-	1056
1986	742	459	652	135	76	23	6	1	-	-	2094
1987	33	441	233	357	46	11	1	-	-	-	1123
1988	5	72	180	95	192	19	4	1	-	-	568
1989	10	13	35	65	35	80	9	1	-	-	248
1990	161	49	23	30	33	20	23	1	-	-	340
1991	471	221	32	19	18	16	10	10	1	-	799
1992	132	521	146	53	19	12	8	4	3	-	898
1993	588	347	292	152	67	15	7	4	2	2	1476
1994	865	506	298	318	159	50	9	2	1	1	2209

Table 5. **Haddock**. Abundance indices from bottom trawl surveys in the Barents Sea winter 1981-1994 (numbers in millions).

Year	Age (years)										Total
	1	2	3	4	5	6	7	8	9	10+	
1981	2.0	7.0	2.6	11.0	2.7	8.1	0.7	0.3	0.0	0.0	34.4
1982	2.5	1.4	2.0	2.4	2.9	7.3	3.6	0.3	0.0	0.0	22.4
1983	1780.0	5.7	3.1	3.5	1.9	1.9	4.2	1.9	0.0	0.0	1802.2
1984	3450.0	592.0	16.9	2.1	1.0	0.3	0.4	0.4	0.0	0.0	4063.1
1985	911.0	1180.0	436.0	8.2	0.6	0.3	0.4	0.4	0.0	0.0	2536.9
1986	416.0	312.0	385.0	166.0	6.7	0.7	0.2	0.2	0.0	0.0	1286.8
1987	86.1	78.2	187.0	355.0	75.3	0.2	0.3	+	0.0	0.0	782.1
1988	28.6	15.0	30.3	83.0	155.0	23.8	0.3	0.0	0.0	0.0	336.0
1989	51.8	6.0	10.1	19.2	37.9	40.9	4.4	0.0	0.0	0.0	170.3
1990	356.0	49.2	4.8	4.9	7.7	14.3	18.4	2.6	0.0	0.0	457.9
1991	978.2	404.7	90.5	17.6	4.7	3.6	4.6	8.5	0.0	0.0	1512.4
1992	821.9	1168.8	351.1	89.9	6.2	1.3	2.0	7.8	0.0	0.0	2449.01
1993	431.9	468.0	526.6	148.2	14.9	0.6	0.8	0.4	0.4	1.4	593.2
1994	369.9	156.5	316.8	572.7	76.0	4.9	0.3	0.2	0.2	1.0	1498.5

Table 6. **Haddock.** Abundance indicies from bottom trawl surveys in the Barents Sea winter 1981-1994 (numbers in millions). Corrected for length dependant trawl efficiency.

Year	Age (years)								Total
	1	2	3	4	5	6	7	8	
1981	3	7	2	8	2	6	1	-	29
1982	4	1	2	2	2	5	3	-	117
1983	2848	7	3	3	1	1	4	2	2869
1984	5520	651	17	2	1	-	1	-	6192
1985	1458	1298	436	6	1	-	1	-	3200
1986	666	343	385	133	5	1	-	-	1533
1987	138	86	187	284	53	-	-	-	748
1988	46	17	30	66	109	17	-	-	285
1989	83	7	10	15	27	29	3	-	174
1990	570	54	5	4	6	10	15	2	666
1991	1565	446	91	14	4	3	9	7	2139
1992	1315	1286	351	72	4	1	7	6	3042
1993	691	515	527	118	11	1	2	-	1865
1994	587	188	297	439	51	3	-	-	1378

Table 7. **Cod.** Abundance estimates from acoustic surveys in the Barents Sea winter 1981-1993 (numbers in millions). Old TS and bobbins gear.

Year	Age (years)										Total
	1	2	3	4	5	6	7	8	9	10+	
1981	3	73	58	124	243	270	41	8	3	4	827
1982	1	4	71	86	93	73	74	5	1	+	408
1983	-	15	17	45	65	38	17	10	2	1	210
1984	2382	506	174	80	63	46	16	1	+	+	3269
1985	69	878	550	510	109	48	20	2	1	1	2187
1986	625	578	1246	424	225	27	8	1	+	+	3136
1987	1	47	126	506	128	37	4	2	1	-	852
1988	1	23	79	74	179	26	6	+	+	-	389
1989	3	9	31	77	56	145	21	3	+	+	346
1990	145	58	32	61	81	73	138	10	2	+	599
1991	277	484	145	108	109	101	55	58	4	+	1341
1992	250	1004	490	205	67	46	28	15	11	+	2117
1993	2000	934	739	487	258	47	24	12	6	9	4516

Table 8. **Cod.** Abundance estimates from acoustic surveys in the Barents Sea winter 1981-1994 (numbers in millions). New TS and rockhopper gear.

Year	*Age (years)*										Total
	1	2	3	4	5	6	7	8	9	10+	
1981	4	61	34	59	106	109	16	3	1	2	395
1982	2	4	40	42	40	29	29	2	+	0	188
1983	0	14	11	23	28	16	7	4	1	+	104
1984	1735	175	42	16	12	8	3	+	+	0	1991
1985	84	696	209	169	32	13	6	1	+	+	1210
1986	958	503	602	154	73	8	2	+	+	0	2300
1987	2	53	81	249	51	14	2	1	+	0	453
1988	1	22	54	38	76	10	2	+	+	0	203
1989	5	7	18	39	26	60	8	1	+	0	164
1990	235	40	16	26	31	27	48	3	1	0	427
1991	140	227	62	40	37	33	18	20	1	2	578
1992	237	506	202	59	23	14	10	5	3	+	1059
1993	927	354	302	195	101	18	9	4	1	2	1916
1994	787	565	349	411	207	58	12	3	1	1	2394

Table 9. **Cod**. Abundance estimates from acoustic surveys in the Barents Sea winter 1981-1994. New TS and rockhopper gear and corrected for length dependant capture efficiency.

Year	*Age (years)*										Total
	1	2	3	4	5	6	7	8	9	10+	
1981	8	82	40	63	106	103	16	3	1	1	423
1982	4	5	49	43	40	26	28	2	+	0	197
1983	0	19	13	23	27	14	7	4	1	+	108
1984	1807	150	31	11	127	5	2	+	+	0	2013
1985	108	768	179	127	21	9	6	+	+	+	1218
1986	1302	590	595	124	56	7	2	+	+	0	2676
1987	3	72	96	256	46	12	1	1	+	0	487
1988	2	29	64	42	75	9	2	+	+	0	224
1989	9	9	20	43	27	57	8	1	+	0	174
1990	350	45	16	24	27	22	40	3	1	0	526
1991	187	234	55	31	28	25	14	16	1	0	591
1992	348	579	182	48	18	11	8	4	2	0	1201
1993	1686	432	300	163	80	14	7	3	1	3	2688
1994	1083	686	358	343	159	43	9	2	1	1	2685

Table 10. **Haddock.** Abundance estimates from acoustic surveys in the Barents Sea winter 1981-1993 (numbers in millions). Old TS and bobbins gear.

Year	Age (years)										Total
	1	2	3	4	5	6	7	8	9	10+	
1981	2	25	14	66	160	50	2	1	+	+	320
1982	3	4	7	10	12	29	14	1	+	+	80
1983	-	10	7	9	5	4	10	5	+	+	50
1984	2148	1002	53	15	7	2	2	2	+	+	3231
1985	1034	1975	1187	33	2	1	1	1	1	1	4233
1986	346	502	1720	751	2	1	1	+	+	+	3323
1987	37	29	175	640	166	+	+	+	-	+	1049
1988	8	7	20	70	150	23	+	-	-	+	279
1989	20	8	19	34	61	64	6	-	-	+	213
1990	202	86	12	11	15	27	36	5	+	+	394
1991	1662	914	217	36	9	9	11	20	+	-	2876
1992	717	2145	600	101	9	2	2	5	8	+	3588
1993	1212	1244	1852	381	38	+	+	2	+	10	4739

Table 11. **Haddock.** Abundance estimates from acoustic surveys in the Barents Sea winter 1981-1994 (numbers in millions). New TS and rockhopper gear.

Year	Age (years)										Total
	1	2	3	4	5	6	7	8	9	10+	
1981	4	11	5	22	63	19	1	+	+	+	125
1982	4	2	2	3	5	11	5	+	+	+	33
1983	0	3	2	3	2	1	3	2	+	+	16
1984	1334	199	7	2	1	+	+	+	+	+	1544
1985	1168	788	284	8	1	+	+	1	+	+	2250
1986	413	276	474	196	1	+	+	+	+	+	1360
1987	58	20	60	199	55	+	+	+	0	+	392
1988	10	3	7	21	46	8	+	+	0	+	95
1989	29	4	6	10	19	21	2	+	0	+	92
1990	273	36	4	3	5	9	12	2	+	+	344
1991	1344	247	61	10	3	3	3	6	+	0	1679
1992	580	652	129	27	3	+	+	1	3	+	1396
1993	832	537	614	134	14	+	+	1	+	3	2137
1994	538	182	257	663	114	12	+	+	+	1	1768

Table 12. **Haddock.** Abundance estimates from acoustic surveys in the Barents Sea winter 1981-1994 . New TS and rockhopper gear and corrected for length dependant capture efficiency.

Year	Age (years)										Total
	1	2	3	4	5	6	7	8	9	10+	
1981	7	14	5	21	60	18	1	+	+	+	125
1982	9	2	3	4	4	10	6	+	+	+	38
1983	0	5	2	3	1	1	4	2	+	+	18
1984	1685	173	6	2	1	+	+	+	+	+	1866
1985	1809	839	274	6	+	+	+	1	+	+	2928
1986	680	312	488	162	+	+	+	+	+	+	1644
1987	111	26	71	190	47	+	+	+	0	+	446
1988	20	5	8	20	38	6	+	+	0	+	97
1989	58	6	8	10	17	19	2	+	0	+	119
1990	493	44	4	3	4	7	11	1	+	+	568
1991	1938	265	49	7	2	2	2	4	+	0	2269
1992	859	685	110	19	2	+	+	1	2	+	1714
1993	1424	690	565	99	10	+	+	1	+	2	2790
1994	848	228	240	506	77	8	+	+	+	+	1908

Table 13. Results of linear regressions of numbers at age from VPA on indices of abundance from the Barents Sea winter surveys for the years 1981-1990. Acoustic estimates for 1982 and 1988 are not included. T refers to table number were the estimates are given. r^2 is the correlation coefficient. se( ) is the standard error. SS(resid) is residual sum of squares.

Species Age group	Estimated Parameters	Swept area		Acoustics		
		I_{rh} (T3,5)	I_{rhld} (T4,6)	$N_{b\sigma 1}$ (T7,10)	$N_{rh\sigma 2}$ (T8,11)	$N_{rhld\sigma 2}$ (T9,12)
Cod 3-gr	Slope (a)	**1,169**	1,992	**0,631**	1,309	1,322
	se(a)	**0,155**	0,173	**0,051**	0,146	0,171
	interc.(b)	**142**	146	**172**	183	185
	se(b)	**38**	41	**25**	33	38
	r^2	**0,876**	0,857	**0,963**	0,930	0,909
	SS(resid)	**70367**	81149	**19746**	37044	48267
Cod 4-gr	Slope (a)	**1,703**	1,977	**0,875**	2,340	2,627
	se(a)	**0,054**	0,098	**0,245**	0,375	0,273
	interc.(b)	**71**	76	**71**	51	51
	se(b)	**8**	13	**74**	46	31
	r^2	**0,991**	0,981	**0,680**	0,872	0,939
	SS(resid)	**3016**	7143	**112429**	44804	21429
Cod 5-gr	Slope (a)	**2,134**	2,548	**0,301**	0,654	0,514
	se(a)	**9,244**	0,295	**0,362**	0,876	0,895
	interc.(b)	**41**	50	**112**	119	128
	se(b)	**22**	21	**50**	47	44
	r^2	**0,905**	0,903	**0,103**	0,084	0,330
	SS(resid)	**16772**	17075	**30009**	30627	31723
Haddock 3-gr	Slope (a)	**0,678**	0,677	**0,193**	0,726	0,714
	se(a)	**0,066**	0,066	**0,010**	0,047	0,053
	interc.(b)	**2,7**	2,8	**13,2**	13,8	13,6
	se(b)	**12,8**	12,8	**7,7**	9,31	10,5
	r^2	**0,929**	0,929	**0,983**	0,975	0,968
	SS(resid)	**9006**	9007	**2038**	2972	3787
Haddock 4-gr	Slope (a)	**0,746**	0,932	**0,3**	1,087	1,230
	se(a)	**0,060**	0,075	**0,036**	0,083	0,054
	interc.(b)	**7,4**	7,6	**3,5**	1,8	0,9
	se(b)	**7,6**	7,6	**12,5**	8,2	4,8
	r^2	**0,951**	0,951	**0,921**	0,966	0,989
	SS(resid)	**3405**	3379	**5205**	2225	758
Haddock 5-gr	Slope (a)	**0,792**	1,128	**0,458**	1,203	1,269
	se(a)	**0,128**	0,183	**0,062**	0,226	0,275
	interc.(b)	**12,5**	12,3	**3,8**	5,6	7,2
	se(b)	**7,2**	7,2	**5,3**	6,9	7,6
	r^2	**0,826**	0,826	**0,900**	0,825	0,780
	SS(resid)	**2999**	3013	**822**	1439	1807