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Corrections of indices of abundance of 0-group fish in the Barents Sea for varying capture efficiency

by

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ABSTRACTS

Each year since 1965 "The International 0-group Survey in the Barents Sea and Adjacent Waters" has provided indices of abundance of 0-group fish. During the 30 years of operation of the survey large improvements in capture efficiency have been introduced including larger trawls, instrumentation for monitoring trawl depth and geometry and larger and better equipped vessels. The time series of survey indices indicate an increasing trend throughout the period and thus it seemed reasonable that the improvements have effected the level of the abundance indices.

The present work is an attempt to correct the indices of abundance so that the comparability of indices from different parts of the time series is maintained. Corrections were made following two lines of approach:

1. Assuming that the annual average capture efficiency had increased proportional to the increase of the average area of the trawl mouth (opening).
2. Assuming that the main trend in the sum of indices of cod, haddock and redfish reflects the trend in overall capture efficiency.

Both methods generated a substantial increase in the indices for the early part of the time series.

INTRODUCTION

Since 1965 an international 0-group fish survey has been carried out annually in August-September in the Barents Sea and adjacent waters (Anon 1996). On the basis of catch rates (numbers per unit distance towed) in pelagic trawls in the upper 100 m layer two types of abundance indices are regularly computed for several species:
The area index, AI (Haug and Nakken 1977) is the sum of areas of high and low catch rates giving 10 times the weight to areas of high catch rates before adding up:

$$AI = \text{Total area of low catch rate} + 10 \times \text{Total area of high catch rate.}$$

The limit between high and low catch rates was established for each species separately based on a comparison of catch rates and echo recordings (Haug and Nakken 1977). In the annual reports (see Anon 1996) values of AI are given for cod, haddock, redfish, polar cod and capelin.

The logarithmic index (Randa 1984) is established by computing mean values and variances of the natural logarithm of the catch rates by strata. The proportions of non zero hauls and the variances of these proportions are also calculated. The procedure enables calculation of confidence limits at the approximate 90-95 percent levels. Values of logarithmic indices are reported for cod, haddock and herring (Anon 1996).

In addition to abundance indices the annual reports to ICES include distribution maps for each species, length distributions and mean lengths and a considerable amount of hydrographic information. Acoustic recordings have been made regularly but only to a limited extent used directly for abundance estimation (Nakken et.al. 1995).

During the 30 years period the survey has been conducted large improvements have been introduced regarding vessels, gears and instruments. The trawling procedure has also been changed. It was thought that these improvements and changes had generated an increase in catchability of 0-group fish and thereby a time dependant bias in the indices of abundance; the indices from later years not being directly comparable with those from the early part of the time series.

In the present paper we have corrected the area indices, AI, of cod, haddock and redfish applying two different methods. The first method is based on the assumption that the yearly average catch rate is directly proportional to the yearly average of the area of the trawl mouth (opening). The basic assumption for the second method is that the annual average catchability in the years 1965-1984 is related to time through a straight line relationship determined by a linear regression of the sum of indices for cod, haddock and redfish on time.

MATERIAL AND METHODS

Table 1 shows the area index for cod, haddock and redfish (Anon 1996). The distribution areas of these species are to a large extent overlapping while capelin, polarcod and Greenland halibut are distributed farther to the north and east. Fig.1. displays the values in Table 1 and in addition the sum of the three indices is presented in the lower part of the figure. For all species there is a tendency towards increasing abundance with time and this tendency

becomes particularly pronounced for the sum. When comparing 10 years means for the three periods 1965-1974, 1975-1984 and 1985-1994 it appears that the mean value increased by a factor of 2 from the first to the second period with an additional increase of about 30 percent from the second to the third period. Although it cannot be excluded it seems unlikely that the total amount of 0-group cod, haddock and redfish in the Barents Sea increased in such a systematic manner during a 30 years period as indicated in the bottom graph of Fig.1. We believe that the overall tendency in that graph, the increase from about 200 in the early part of the period to a level of about 1400 in later years is mainly caused by an increase in catchability through improved capture efficiency of the sampling gear and method used.

Vessels, gear and instrumentation.

Altogether 25 vessels have been used in the survey since the start in 1965 and 4-6 vessels have participated each year. Those which participated the first 5 years (1965-1969) were all built as sidetrawlers but on some of them arrangements had been made so that the pelagic sampling trawl could be operated from the stern. During the 15 years period, 1970-1985, these sidetrawlers were replaced by bigger and more well equipped stern trawlers capable of operating larger trawls as well as monitoring and controlling trawl depth, - geometry and trawling performance.

Prior to 1985 the various vessels used trawls of different size (Table 2) adjusted to the size and capacity of each vessel. From 1985 and onwards all vessels have used identical trawls with a rectangular mouth area (opening) of 20x15 m during towing (Godø et.al. 1993). Trawling operations were standardised at the end of the 1970's; trawlstations were then fixed prior to each survey and each haul covered 3-5 depth layers with 20 m depth difference and a fixed towing time (10 minutes) at each depth.

It is impossible to quantify the effects on the abundance indices from each of the main contributing factors (vessels, gear and instrumentation). However, fairly precise records exist in the annual reports regarding the types and sizes of trawls that were used between 1965 and 1985 and these data were used to correct the time series of area indices.

Analysis

Assume proportionality between the actual abundance, N, and the area index, AI:

$$AI = q \cdot N \qquad (I)$$

Assume further that the catchability coefficient, q, changed from the start of the survey in 1965 upto 1985 when the methodology and gear became equal for all vessels, and that q has been constant since 1985. Then we have

$$AI_{corr}/q_{1985+} = AI_{obs}/q \qquad (II)$$

and

$$AI_{corr} = (q_{1985}/q) \cdot AI_{obs} \qquad (III)$$

Where AI_{corr} and AI_{obs} denote corrected and observed area indices, respectively.

The correction factor, $K = q_{1985+}/q$ scales the index to a level as if it were observed with the tools (vessels, gear and instrumentation) used from 1985 and onwards.

Two different methods were used in order to arrive at annual values of K:

1. It was assumed that K for a particular year equals the ratio between the average area of the trawl openings in that year and the opening of the standard trawl used in 1985 and later years; i.e. the ratio between catchabilities equals the ratio between average trawl openings:

$$K = q_{1985+}/q = \text{Opening area}_{1985+}/\text{Opening area} \qquad \text{(IV)}$$

Values of trawl opening areas and K are listed in table 2.

2. It was assumed that the trend in the annual sum of indices between 1965 and 1984 (Fig.1) was caused exclusively by an increasing catchability coefficient so that a straight line fitted to the points in Fig.1 also shows the development of q. Then we have the following expression for the correction factor, K:

$$K = AI_{1985+} / AI = AI_{1985+}/a\,t + b \qquad \text{(V)}$$

where $AI = a\,t + b$, and a and b appear in Fig.2. where also the correlation coefficient R is given.

(Note that in Fig.2 is Y = AI and X = t)

RESULTS AND DISCUSSION

Table 3 and Fig. 3 show the results of the corrections. The index values in the first part of the time series were increased considerably as compared with the original values (Tab.1, Fig. 1). Both methods of correction have however some obvious weaknesses that ought to be discussed.

The choice of a simple arithmetic mean of trawl openings (method 1) as a measure of catchability implies the assumption that each trawl has contributed to the abundance index according to its opening area. Since the vessels (trawls) covered different parts of the distribution area and since the number of trawlstations varied a lot between vessels the procedure used is a rough approximation. Ideally, the catch rate for each single haul should have been corrected and abundance indices computed from the corrected catch rates. The availability of data from the 1960s and 1970s did not permit such a procedure with the available manpower since much of the work would have to be carried out manually. A simpler method would be to assume that each trawls contribution to the annual index was proportional to the number of non zero hauls and then used that number as weight in the computation of the annual average opening. But also this procedure demands a lot of manual labour the way the data are being stored.

The correction based on the trend in the sum of indices (method 2) is highly dependant on the trend in the redfish index (see Fig.1). The confidence in the results depends on whether or not

one believe that the general trend in the redfish index from 1965 to 1984 is generated by an increase in the catchablility of 0-group redfish.

The two series of corrected indices (Fig.3) compare reasonably well from 1970 to 1984, but for the five first years, 1965 - 1969 the differences are large; the trend correction (method 2) yielding much higher values than the correction for trawl opening (method 1). As pointed out previously the design and outfit of the vessels used were largely improved from 1970 and onwards. Since cod was a main target species the most capable vessels were attempted used in the typical distribution areas of 0-group cod (as well as haddock and redfish). This may have generated a steep increase in the efficiency during the first half of the 1970s as compared with 1965-1969 as indicated in the bottom graph of Fig.1. However, the large year to year variation of the cod index during the 1970s as compared with later years may indicate that the success of these attempts varied strongly from year to year. If the 1965-1969 points are excluded from the regression then the two correction methods yields almost similar results for the period 1970-1984, indicating that during that period the trend of increasing indices were mainly caused by the more of less continuos increase in the opening area of the trawls used. (Table. 2).

The sampling trawl used since 1985 is highly selective for 0-group cod and haddock (Godø et.al. 1993, Hylen et.al. 1995). Its capture efficiency of small individuals (4-5 cm) is much less than for bigger 0-group (8-12 cm). Hylen et. al. (1995) quantified this selection and showed that the catch rate of 5 cm long cod was to be multiplied by a factor 4-5 in order to compare with the catch rate of 9 cm long cod. In order to further increase the comparability of the abundance indices of 0-group cod and haddock the indices would have to be adjusted for each years length distribution in addition to the adjustments attempted in the present paper.

CONCLUSIONS

- As a result of increasing capture efficiency the indices of abundance of 0-group fish in the Barens Sea and adjacent waters increased from the start of the survey in 1965 until the mid 1980s when sampling trawls and procedure were fully standardized.

- This increase in capture efficiency probably accounted for more than a doubling of the index values between 1970 and 1984, a matter that should be recognized when the 0-group index is used in assessments or related works.

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Table 1. Abundance indices of 0-group fish in the Barents Sea and adjacent waters 1965-1995. (Source:Anon 1996).

Year	Redfish	Haddock	Cod	Sum
1965	159	7	6	172
1966	236	1	1	238
1967	44	42	34	120
1968	21	8	25	54
1969	295	82	93	470
1970	247	115	606	968
1971	172	73	157	402
1972	177	46	140	363
1973	385	54	684	1123
1974	468	147	51	666
1975	315	170	343	828
1976	447	112	43	602
1977	472	116	173	761
1978	460	61	106	627
1979	980	69	94	1143
1980	651	54	49	754
1981	861	30	65	956
1982	694	90	114	898
1983	851	184	386	1421
1984	732	255	486	1473
1985	795	156	742	1693
1986	702	160	434	1296
1987	631	72	102	805
1988	949	86	133	1168
1989	698	112	202	1012
1990	670	227	465	1362
1991	200	472	766	1438
1992	150	313	1159	1622
1993	162	240	910	1312
1994	414	282	899	1595
1995	220	148	1069	1437

Table 2. Number of trawls by opening area and by year, mean opening area and correction factor K as estimated by equation IV.

	Area of trawl opening (m^2)							
Year	6	60	270	300	Unknown	Mean	$\frac{1}{K}$	K
1965	0	2	2	0	0	165	0,55	1,81
1966	0	2	2	0	1*	165	0,55	1,81
1967	0	2	2	0	1*	165	0,55	1,81
1968	0	2	2	0	1*	165	0,55	1,81
1969	0	2	2	0	1*	133	0,44	2,27
1970	0	2	2	0	0	165	0,55	1,81
1971	1	2	2	0	1*	133	0,44	2,27
1972	0	3	2	0	0	186	0,62	1,61
1973	0	2	3	0	0	186	0,62	1,61
1974	0	2	3	0	0	186	0,62	1,61
1975	0	1	4	0	0	228	0,76	1,32
1976	0	1	4	0	0	228	0,76	1,32
1977	0	2	3	0	0	186	0,62	1,61
1978	0	2	2	0	0	165	0,55	1,81
1979	0	1	0	2	0	220	0,73	1,37
1980	0	1	0	3	0	240	0,80	1,25
1981	0	0	0	4	0	300	1,00	1,00
1982	0	1	0	4	0	252	0,84	1,19
1983	0	1	0	4	0	252	0,84	1,19
1984	0	1	0	5	0	260	0,87	1,15
1985	0	0	0	5	0	300	1,00	1,00

Table 3. Corrected abundance indices of 0-group fish in the Barents Sea and adjacent waters 1965-1995.

	Corrected for trawl opening Method 1				Corrected for trend Method 2			
	Redfish	Haddock	Cod	Sum	Redfish	Haddock	Cod	Sum
1965	288	13	11	320	1252	55	47	1354
1966	427	2	2	431	1352	6	6	1363
1967	80	76	62	218	435	415	336	1187
1968	38	14	45	97	414	158	493	1064
1969	670	186	211	1067	931	259	293	1483
1970	447	208	1097	1752	476	221	1167	1864
1971	390	166	356	912	531	225	484	1240
1972	285	74	225	584	558	145	441	1144
1973	620	87	1101	1573	633	89	1125	1847
1974	753	237	82	1072	937	294	102	1333
1975	416	224	453	1093	473	255	515	1243
1976	590	148	57	795	857	215	82	1154
1977	760	187	279	1226	779	191	286	1256
1978	833	110	192	1135	781	104	180	1065
1979	1343	95	129	1567	1306	92	125	1523
1980	814	68	61	943	930	77	70	1077
1981	861	30	65	956	1101	38	83	1222
1982	826	107	136	1069	856	111	141	1107
1983	1013	219	459	1691	942	204	427	1573
1984	842	293	559	1694	779	271	517	1568
1985	795	156	742	1693	795	156	742	1693
1986	702	160	434	1296	702	160	434	1296
1987	631	72	102	805	631	72	102	805
1988	949	86	133	1168	949	86	133	1168
1989	698	112	202	1012	698	112	202	1012
1990	670	227	465	1362	670	227	465	1362
1991	200	472	766	1438	200	472	766	1438
1992	150	313	1159	1622	150	313	1159	1622
1993	162	240	910	1312	162	240	910	1312
1994	414	282	899	1595	414	282	899	1595
1995	220	148	1069	1437	220	148	1069	1437

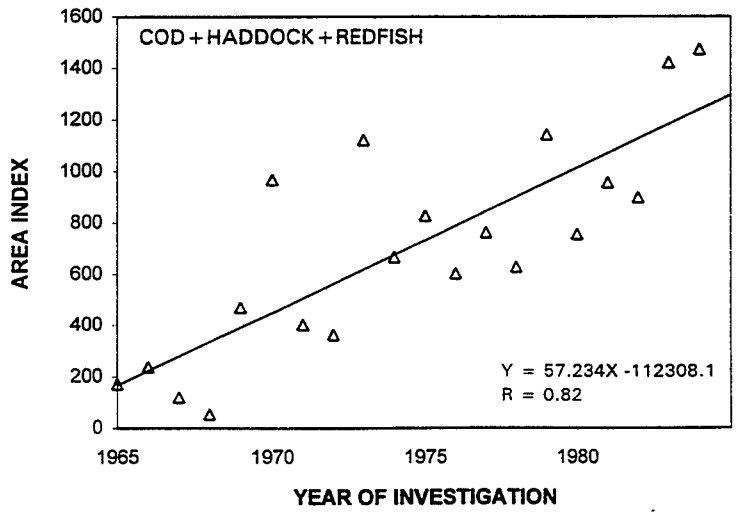

Fig. 2. The regression line fitted to the area index (triangles) for the period 1965-1984. Note that Y is area index and X is time (year).

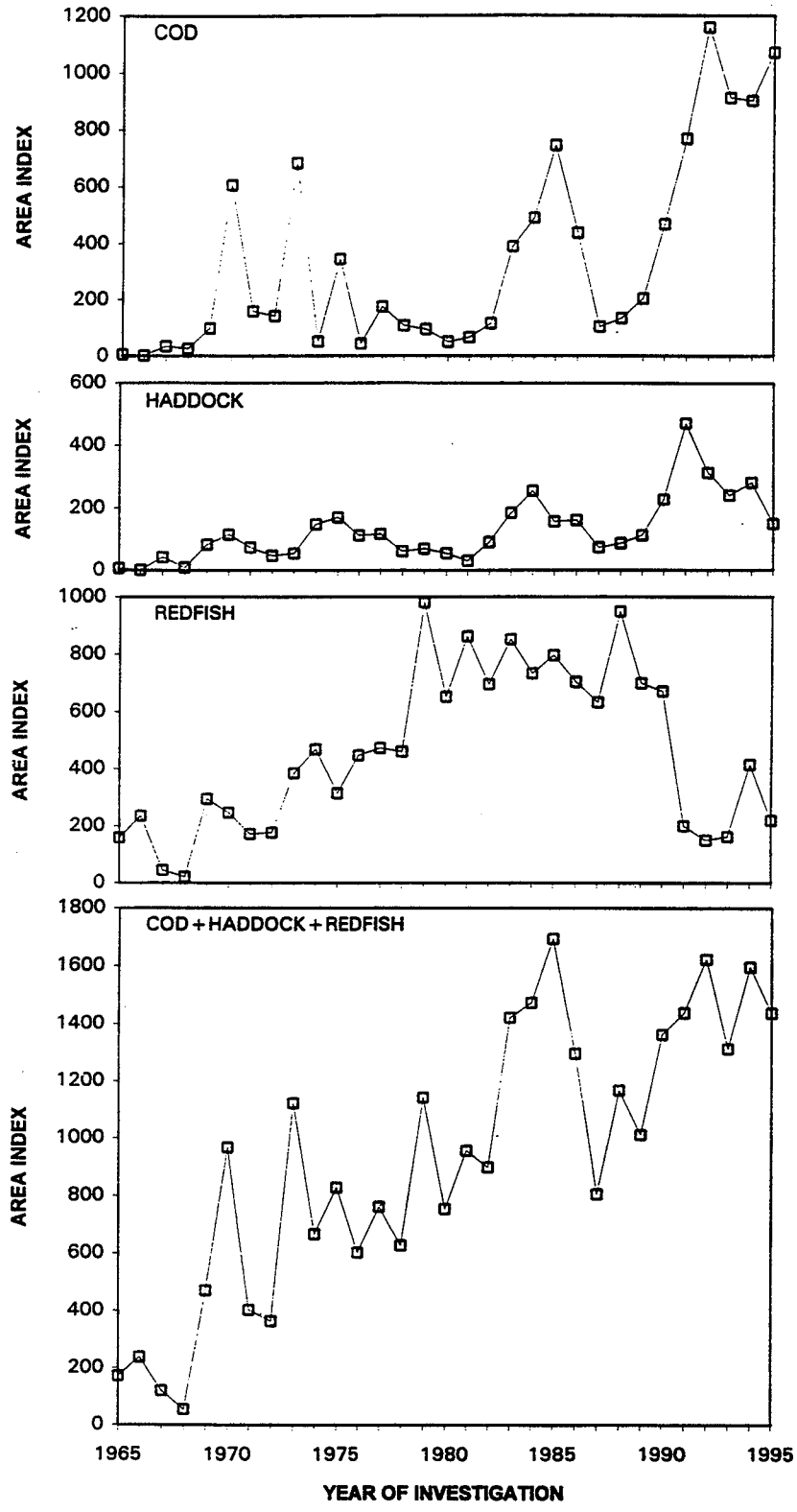

Fig.1. Abundance indices of 0-group fish in the Barents Sea and adjacent waters 1965-1995. (Source: Anon 1996).

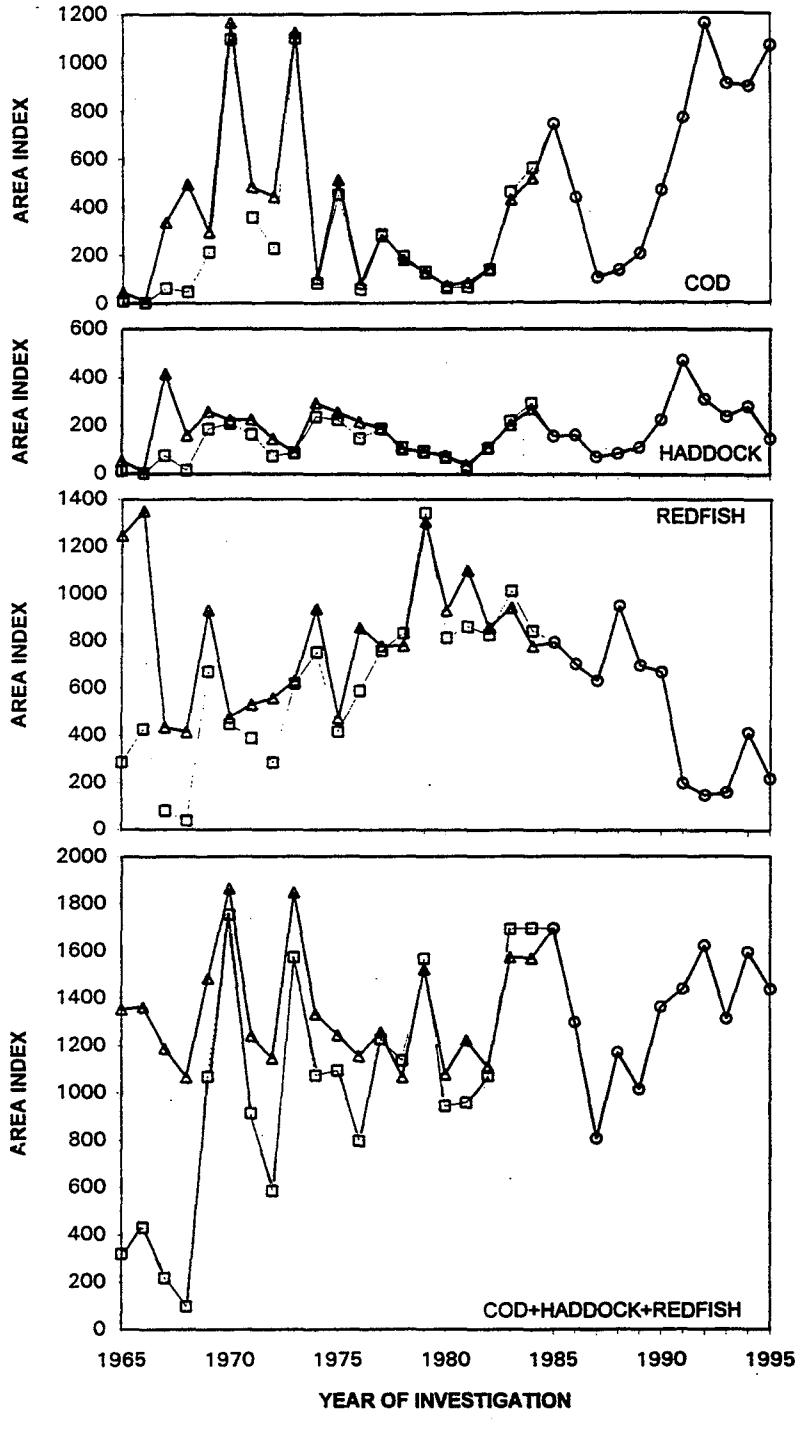

Fig.3. Corrected abundance indices of 0-group fish in the Barents Sea and adjacent waters 1965-1984.

□ Corrected for trawl opening
△ Corrected by using trend
○ No correction