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# Northwest Atlantic



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# Cod Biomass and Abundance Estimates for NAFO Division 2J from Stratified-Random Bottom Trawl Survey Results over a Time Series of 12 Years, 1972-1983

# by

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# Introduction

As a result of detailed discussions at scientific meetings of ICNAF during the early seventies on the possibilities of improving survey methods and design in order to arrive at greater reliability and higher accuracy of survey results (Grosslein, M. D. and R. G. Halliday, 1971) the stratifiedrandom sampling design for groundfish surveys was recommended by ICNAF's Standing Committee on Research and Statistics (STACRES) and introduced in parts of Subareas 2-6. Meanwhile, since the early eighties, groundfish surveys in Subarea 1 and off East Greenland (ICES Area XIVa) are also conducted accordingly on a routine basis.

After designing preliminary startification schemes for Subarea 2 and Division 3K (Messtorff, J., 1972 and 1974) groundfish surveys have been regularly conducted in late autumn by research vessels of the Federal Republic of Germany in Division 2J since 1972. The preliminary stratification of the survey area was soon replaced by a basically unchanged but revised and improved Canadian version published in the NAFO Manual on Groundfish Surveys in the Northwest Atlantic (Doubleday, W. G., 1981). Survey data obtained earlier have been adjusted to the revised stratification scheme.

#### Materials and Methods

The survey area in NAFO Division 2J comprises 23 strata covering the shelf and slope between the 100 m and 500 m isobaths (Figure 1). Stratum boundaries are fixed both by isobaths in 100 m steps and by longitudes or latitudes. Stratum areas in nautical square miles are given by depth zones in Table 1. For the purpose of random selection of fishing stations each stratum is divided into unit areas equivalent to 5' x 10' rectangles with each of these further subdivided into 10 smaller random units (2.5' x 2' rectangles). The length of the latter units is approximately equal to the distance trawled in one set. If the number of unit areas in one stratum was as large or even larger than the number of sets to be allocated to that stratum, than only one random unit per unit area was selected in order to arrive at a optimum coverage by sets.

The total number of sets conducted per survey varied with different availability of vessel time but generally increased after 1978. The number of sets per stratum was, however, always allocated in relation to stratum size.

Except for one year (1981) it was not possible to fish all strata. In most years, however, strata comprising close to 90% or more of the total survey area have been fished (Table 1). The plan to

always use the same research vessel for the survey operations throughout the time series could not be followed completely. In three years (1973, 1976 and 1979) RV *Anton Dohrn* had to be replaced by RV *Walther Herwig*. However, both vessels were of similar size and capable of operating the same standard trawl at the same towing speed in all conditions.

As standard survey trawl a medium sized 140 feet bottom trawl rigged with rollers for rough bottom conditions was chosen. The same gear is also successfully used in the commercial fishery, mostly by trawlers below 1000 ton, and provides enough fishing power to yield good average catches even within the standard towing time of only 30 minutes. In order to prevent escapement of prerecruit fish the survey trawl was additionally equipped with a small meshed liner (40 mm mesh size) inside the codend.

Experiments to quantify variations in the performance of the survey trawl under variable trawling conditions and especially to determine the influence of different towing speeds and fishing depths (warp lengths) on the head line height and wing spread were carried out with RV Walther Herwig in 1981 (Kroeger, M. and K.-H. Kock, 1982). It was clearly demonstrated that the variations of both net parameters decrease considerably with increasing towing speed and remain rather constant within survey depth ranges of 100-500 m from about 4.2 knots onwards. The average towing speed of 4.5 knots employed by both research vessels during the whole time series was therefore within the optimum range of comparatively stable trawl performance.

Survey operations were only conducted during day time (generally from 6 a.m. to 6 p.m.).

Estimates of the trawlable biomass and abundance of cod within the survey area of Division 2J were obtained by applying the "swept area" method. For each stratum the mean catch by weight and numbers, the variances and variances of the means were calculated and then combined into one mean and variance each for the whole survey area (Saville, A., 1977). In order not to exclude a stratum containing only one valid set from evaluation it was added to an adjacent stratum of the same depth range. Confidence intervals were calculated at the 95% significance level. Since a reliable estimate of the catchability coefficient was not available, it was taken as 1.0 to avoid overestimation of biomass and abundance. The trawl parameters used were the same for both vessels:

Towing time		30 minutes
Average towing	speed	4.5 knots
Horizontal not	opening (wing spread)	22 m

The vertical net opening (headline height), not considered in the calculations, amounted to 3.5 m.

#### Results

Summarized trawlable cod biomass and abundance estimates derived for each year of the survey time series in NAFO Division 2J are given in Tables 2 and 3 and are illustrated graphically in Figures 2 and 3 and 4 and 5 respectively. The estimates based on strata fished are not raised to the total survey area but apply to the summarized areas of strata actually fished. The estimates based on combined strata by depth zone, i.e. using only four basic strata (areas of 101-200, 201-300, 301-400 and 401-500 m) for comparison, however, apply to the total survey area. Both estimates reveal only minor differences except for years of insufficient area coverage (especially in 1972 and 1978).

Very high variances observed for 1979, 1979 and 1981 were mainly caused by some extremely high catches. Among all standard catches obtained throughout the survey time series (total of 593 sets) there were only five catches which were of at least twice the size by weight and by numbers against the next highest catch within one stratum. This arbitrarily chosen criterium concerned one set in 1972, one set in 1979 and three sets in 1981. Biomass and abundance estimates for the years in

question disregarding these sets are given additionally and marked with an asterisk. They are considered as being more reliable and more realistic.

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The biomass and abundance estimates derived by the different combinations of the original catch data as explained above have been averaged and are given separately in Tables 2 and 3 respectively. Further analyses presented in this paper are based on these average values.

The two adjacent strata 206 and 209, located more or less in the centre of the survey area and being parts of the 101-200 m and 201-300 m depth zones respectively in which always the highest densities of cod have been observed, were fished throughout the time series. Both stratum areas together comprise 19.4% of the total survey area. The combined biomass and abundance estimates of both strata are given in Table 4.

Biomass and abundance estimates for the whole survey area and those for strata 206 and 209 were found to be significantly correlated. The plots of the linear regressions for the respective estimates and corresponding regression coefficients are shown in Figure 6.

In order to find out whether the survey estimates are related to total stock sizes of cod in the whole management area of NAFO Divisions 2J+3KL and whether variations in stock size over longer time periods as estimated from survey results are comparable to those estimated by different stock assessment methods, a correlation of average survey estimates for Division 2J versus cod population estimates for Divisions 2J+3KL from a recent cohort analysis (Baird, J. W. and C. A. Bishop, 1985) was tested. In fact both series of estimates were significantly correlated as shown by the plots of their respective linear regressions in Figure 7.

In order to arrive at quantitative measures of the differences in magnitude between the correlated estimates (Figures 6 and 7) average "catchability coefficients" have been calculated and applied as defined and given in Table 5. The corresponding graphic illustrations are shown in Figures 8-11.

#### Conclusion

Survey biomass and abundance estimates obtained over a period of 12 years in Division 2J seem not only to reflect the trends in stock size of cod but even enable approximation of the total cod population size for the whole management area of NAFO Divisions 2J+3KL. The research vessel survey results obtained by the Federal Republic of Germany may therefore be used as assessment measures independent of commercial fisheries data.

## References

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		a ha a she Anna		$r = r r_{\rm eff}^{-1}$		1.1					1.1		
Depth zone Stratum	Area	AD	WH	AD	AD	WH	AD	AD	WH	AD	AD	AD	AD
(m) Nr.	nm²	047	007	060	069	022	084	090	037	104	113	121	126
		1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
101-200 201	1427		2	2	2	2	1	. <del></del> .	4	2	5	4	4
205	1823	1	4	5	5	4	4		6	5	5	4	4
206	2582	4	6	5	6	6	5	4	8	8	8	7	8
207	2246	2	3	3	3.	4	1	5	5	3	7	1 -	· ·
Total	8078	7	15	15	16	16	10	9	23	18	25	16	16
201-300 202	440	-	· - ·	· ·		2	1	11 - <u>-</u>	2	2	2	2	3
209	1608	3	4	3	4	4	3	3	5	4	3	4	5
210	771	_	1		ົ່	2	2	່າ	2	5	2	3	5

able	1	:	Number o	f sets	per	stratu	m carried	out in	stra	tified r	andom	botto	m trawl	. su	rve	ys by	
		-	RV ANTON	DOHRN	(AD)	and F	V WALTHER	HERWIG	(WH)	respect	ively	in Di	lvision	2J :	in '	1972-	83.
					- A								· •	-			

a da ang	$(1,1) \in [1,1]$	5 - S. 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 - 1997 -	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
101-200	201	1427		2	2	2	2	1		4	2	5	4	4
	205	1823	1	4	. 5	5	4	4		6	5	5	4	4
	206	2582	4	6	. 5	6	6	5	4	8	8	8	7	8
	207	2246	2	3	3	3.	4	1	5	5	3	7	1 .	-
	Total	8078	7	15	15	16	16	10	9	23	18	25	16	16
201-300	202	440		· - ·		. 1	2	1	- <u>-</u> ,	2	2	2	2	3
	209	1608	3	4	3	4	4	3	3	5	4	3	4	5
	210	774	-	· . 1 ·	-	2	3	2	2	3	5	2	3	. 5
	213	1725	2	3	2	3	4	3		5	5	4	5	3
	214	1171	- '	2	4	2	3	3	· - ·	. 3	2	4	9	10
	215	1270	3	2	2	1	3	3	-	4	. 4	4	10	6
	228	1428	-	4	6	5	4	4	4	4	7	3	5	- 5
	234	508				2	2	2	-	2	, <b>3</b> ,	2	-	2
	Total	8924	8	16	17	20	25	22	9	28	32	24	38	39
301-400	203	480			-	-	· · · · ·	-		·		2	2	3
우리 집에 나다.	208	448		. –	-	-	-	·	<u> </u>	-	-	1	2	3
	211	330	-	1	-	·	-	· · · ·	1	·	-	2	2	1
	216	384	1	2	2	4	2	2		2	1	2	1	3
	222	441		2	2	1		2	-	2	2	2	2	2
	229	567	-	2.	<del></del>	1	2	2	2	2	2	1	<u>,</u> З.,	1
	Motol	2650	1	7	٨	c	· .	c	2	c	 E	10	10	12
	IOLAI	2000			4	0		0	3	0	5	10	12	- 13
401-500	204	354		-	-	'	-	-	-	1. <b>-</b> 11.	-	2	2	3
	217	268		1	- 1			1	· · ·	2	2	2	1	-
	223	180		1	1		1	2		2	2	2	2	
	227	686	1	1	1	2	2	-	-	3	3	3	3	-
	235	420	-			·	-	1 - 1 - 1 - 1 - 1 - 1 - 1 - 1 - 1 - 1 -	-	· · ·	-	1	2	1
	'Ibtal	1908	1	3	2	2	3	3	0	7	7	10	- 10	4
Total su	rvey area	21560	17	41	38	44	48	41	21	64	62	69	76	72
Area cov of total	erage in % survey are	<u>57</u>	89	79	89	87	87	44	91	91	100	98	84	
				et 1997										

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Table 2 and 3 : Summarised results for cod by weight (Table 2 ) and numbers (Table 3 ) from stratified random bottom trawl surveys conducted annually in Division 2J in October/November 1972-83 mostly by R/V ANION DOHRN (AD) and three times by R/V WALTHER HERWIG (WH).

			ba	used on st	rata fish	ed	based on	combined	strata by	depth zone	average				
year	cruise nr.	sets	weighted mean catch kg/30 min.	biomass to	mean density to/nm²	confidence interval ±%	weighted mean catch kg/30 min.	biomass to	mean density to/nm²	confidence interval ±%	catch kg/30 min.	biomass to	density to/nm <sup>3</sup>		
1972	AD 047	17 16*	107.364 73.596	86 605 59 366	4.017 2.754	79.800 64.690	163.409 121.577	131 814 98 068	6.114 4.549	69.993 63.450	135.386 97.586	109 210 78 717	5.065 3.651		
1973	WH 007	41	92.226	74 394	3.451	40.070	92.542	74 649	3.462	39.978	92.384	74 522	3.456		
1974	AD 060	38	35.438	28 586	1.326	34.248	37.069	29 90 <b>2</b>	1.387	29.652	36.253	29 244	1.356		
1975	AD 069	44	42.577	34 344	1.593	24.695	32,865	30 458	1.413	32.865	37.721	32 404	1.503		
1976	WH 022	48	32.848	26 497	1.229	49.411	29.933	24 146	1.120	50.246	31.390	25 322	1.174		
1977	AD 084	41	33.136	26 729	1.240	35.874	32.280	26 039	1.208	44.182	32.708	26 384	1.224		
1978	AD 090	21	13.459	10 856	0.504	32.641	30.150	24 321	1.128	36.586	21.804	17 589	0.816		
1979	WH 037	64 63*	185.168 137.843	149 365 111 190	6.928 5.157	54.673 34.231	187.318 145.872	151 099 117 669	7.008 5.458	48.743 26.690	186.243 141.857	150 232 114 430	6.968 5.308		
1980	AD 104	62	96.291	77 672	3.603	24.986	94.434	76 175	3.533	34.657	95.362	76 924	3.568		
1981	AD 113	69 66*	253.041 170.533	204 115 137 560	9.467 6.380	47.615 24.344	276.556 169.950	223 083 137 089	10.347 6.358	54.169 24.219	264.798 170.241	213 599 137 325	9.907 6.369		
1982	AD 121	76	121.750	98 209	4.555	27.258	151.384	122 113	5.664	28.548	136.567	110 161	5.109		
1983	AD 126	72	147.836	119 251	5.531	34.625	147.183	118 725	5.507	24.659	147.509	118 988	5.519		

\*) Sets with catches of at least twice the size by weight and by numbers of the next highest catch within one stratum excluded.

Table 3:

			bas	ed on strat	a fished		based on co	mbined stra	ta by dep	oth zone	av	erage	
year	cruise nr.	sets	weighted mean catch nos./30min.	abundance nos.x10-3	mean density nos./nm²	confidence interval ± %	weighted mean catch nos./30min.	abundance nos.x10 <sup>-3</sup>	mean density nos./nm <sup>2</sup>	confidence interval ±%	catch nos./30min.	abundance nos.x10-3	density nos.:/mf
1972	AD 047	17 16*	134.755 87.344	108 700 70456	5 042 3 268	81.986 54.348	195.950 135.119	158 063 108 993	7 331 5 055	72.883 49.074	165.353 111.232	133 382 89 725	6 187 4 162
1973	WH 007	41	75.396	60 818	2 821	33.489	76.003	61 308	2 844	38.340	75.700	61 063	2 832
1974	AD 060	38	28.312	22 838	1 059	33.168	28,510	22 997	1 067	27.561	28.411	22 918	1 063
1975	AD 069	44	42.133	33 987	1 576	35.247	38.173	30 792	1 428	30.385	40.153	32 390	1 502
1976	WH 022	48	43.573	35 148	1 630	61.703	38,769	31 273	1 451	60.894	41.171	32 211	1 494
1977	AD 084	41	34.619	27 925	1 295	40.439	33.561	27 072	1 256	38.147	34.090	27 499	1 275
1978	AD 090	21	11.055	8 917	414	32.796	24.031	19 384	899	30.999	17.543	14 151	656
1979	WH 037	64 63*	90.690 73.662	73 155 59 419	3 393 2 756	43.128 34.285	90.965 75.504	73 377 60 905	3 403 2 825	40.185 19.068	90.828 74.583	73 266 60 162	3 398 2 790
1980	AD 104	62	45.864	36 996	1 716	26.951	45.169	36 435	1 690	38.676	45.517	36 716	1 703
1981	AD 113	69 66*	129.656 96.182	104 586 77 584	4 851 3 599	36.056 20.986	138.546 96.423	111 758 77 778	5 184 3 608	42.792 23.083	134.101 96.302	108 172 77 681	5 017 3 603
1982	AD 121	76	83.030	66 976	3 106	24.944	94.650	76 349	3 541	24.461	88.840	71 663	3 324
1983	AD 126	72	109.424	88 266	4 094	37.135	106.865	86 203	3 998	24.784	108.145	87 235	4 046

\*) Sets with catches of at least twice the size by weight and by numbers of the next highest catch within one stratum excluded.

Table 4: Summarised research vessel survey results for cod in Division 2J by weight and numbers relating to the neighbouring strata 206 and 209 only, which belong to the 101-200 and 201-300 m depth zones respectively.

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year	cruise nr.	sets	weighted mean catch kg/30 min.	biomass to	mean density to/nm²	confidence interval ± %	weighted mean catch nos./30min.	abundance nos.x10-3	mean density nos./nm²	confidence interval ± %
1972	AD 047	6*	84.504	13247	3.162	43.22	114.192	17901	4272	50.38
1973	WH 007	10	103.030	16156	3.856	97.61	93.315	14628	4391	96.95
1974	AD 060	8	43.107	6758	1.613	97.97	28.343	4443	1060	85.44
1975	AD 069	10	56.446	8849	2.112	60.80	48.884	7663	1829	42.32
1976	WH 022	10	13.937	2185	0.521	23.69	17.032	2670	637	34.14
1977	AD 084	8	20.165	3161	0.754	73.72	31.924	5004	1194	55.46
1978	AD 090	7	25.072	3931	0.938	53.21	23.216	3639	868	70.31
1979	WH 037	13	144.546	22660	5.408	65.32	88.999	13952	3330	60.66
1980	AD 104	12	43.210	6774	1.617	50.53	21.782	3415	815	61.50
1981	AD 113	11	133.611	20946	4.999	67.92	78.538	12312	2938	59.78
1982	AD 121	11	78.662	12331	2.943	74:25	62,987	9874	2357	67.79
1983	AD 126	13	223.221	34993	8.352	94.62	166.387	26084	6225	89.12

\*) one set in stratum 206 with an extremely high catch excluded!

Table 5: Population biomass and abundance estimates for Divisions 2J+3K, L derived from survey results in Division 2J only in relation to those from a recent cohort analysis, and survey biomass and abundance estimates for Division 2J derived from survey results of only two strata fished throughout the time series in relation to total survey estimates by applying average "catchability coefficients".

	Biomas	s estima	ates in	metric to	ms	Abundi	in nos. >	( 10 <sup>-3</sup>		
year	В	b	C	b/q <sub>b</sub>	c/q <sub>c</sub>	A	а	đ	a/g <sub>a</sub>	d/q <sub>d</sub>
1972	1178200	78717	13247	998212	73478	1431700	89725	17901	1526565	93023
1973	957000	75522	16152	945015	89591	1031800	61063	14628	1038915	76015
1974	663000	29244	6758	370844	37485	708300	22918	4443	389923	23088
1975	406700	32404	8849	410916	49083	469600	32390	7663	551078	39821
1976	303000	25322	2185	321109	12120	462700	33211	2670	565046	13875
1977	476300	26384	3161	334576	17533	570000	27499	5004	467863	26003
1978	568900	17589	3931	223046	21804	668000	14151	3639	240763	18910
1979	799800	114430	22660	1451089	125689	800200	60162	13952	1023585	72502
1980	928400	76924	6774	975475	37574	751800	36716	3415	624679	17746
1981	1004200	137325	20946	1741421	116182	777900	77681	12312	1321650	63979
1982	1401800	110161	12331	1396954	68397	1241500	71663	9874	1219261	51310
1983	1784400	118988	34993	1508889	194097	1470600	87235	26084	1484200	135546
1984	2086300				-	1597500		Enclosed and an and a second		1. 

Explanation of symbols and calculation:

B = Age 4+ Population Biomass A = Age 4+ Population Numbers Of Cod in Divisions 2J+3K,L from Cohort Analysis (Baird, J.W. and C.A. Bishop, 1985) b = Average Survey Biomass of Cod in Division 2 J (from Table 2) a = Average Survey Abundance of Cod in Division 2 J (from Table 3)

- c = Survey Biomass of Cod in Strata 206 + 209 (Div. 2J) (from Table 4) 88 d = Survey Abundance
- n = 12, number of years of survey time series (1972-83)
- q = Average "catchability coefficient", calculated as follows:

$$q_{b} = (b_{72} / B_{72} + b_{73} / B_{73} + \dots + b_{83} / B_{83}) / n$$

 $= (\sum b/B) / n = 0.078858$ 

correspondingly:

$$\begin{array}{l} q_{c} = (\sum c/b) / n = 0.180268 \\ q_{a} = (\sum a/A) / n = 0.0587757 \\ q_{d} = (\sum d/a) / n = 0.192437 \end{array}$$

- $b/q_b = Population Biomass in Divisions 2J+3K, L calculated from survey results$ in Division 2J
- $c/q_c$  = Survey Biomass in Division 2J calculated from strata 206+209 results
- $a/q_a$  = Population Numbers in Divisions 2J+3K,L calculated from survey results in Division 2J
- $d/q_d$  = Survey Abundance in Division 2J calculated from strata 206+209 results







Figures 2 and 3. Cod biomass estimates based on strata fished (Fig. 2) and based on strata (Fig. 3) from surveys conducted by R/V Anton Dohrn and R/V Walther Herwig respectively in NAFO Division 2J in 1972-83.











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