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Northwest Atlantic Fisheries Organization

Serial No. N1649 NAFO SCR Doc. 89/69

SCIENTIFIC COUNCIL MEETING - JUNE 1989

On the Estimation on Stock Size and Mortality of the Subarea 1 Cod from Swept-area Estimates of Abundance

by

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1. Introduction

Since 1982, the Federal Republic of Germany has annually carried out a random-stratified trawl survey in Subarea 1. The purpose of the survey is to assess the size of the cod stock. The survey does not cover the inshore area where trawling in general is not possible. A pilot study in the inshore area in 1986 showed that a considerable number of cod is found inshore and in 1987 and 1988 the inshore area was covered by a longline survey. Inshore catch rates (numbers caught per 100 hooks) have been converted to swept-area units (numbers per square km) and in both years the inshore components were found to account for 22% of the total stock.

In the assessment of the Subarea 1 cod stock, the combined survey estimates (assuming 22% of the cod stock found inshore for all years) have been used face value (i.e. assuming a catchability factor of 1) to:

1) Establish the stock size for projections.
2) Estimate mortality parameters (Z,F) and emigration coefficients.

The purpose of the present work is to:

a) Derive a rough estimate of the catchability factor.
b) Discuss the variability in calculated mortalities as derived from the surveys.
c) Discuss the problems associated with estimating stock size by 1 Jan 1989.

2. Abundance Estimates from Surveys

In 1987, the swept-area estimate of the 1984 year-class was 800 mill. cod when back calculated to 1 Jan 1987, which meant that this year-class was considerably larger than any previous year-class as measured by VPA. The 1984 year-class was, however, not observed as abundant as 1-3-year-old cod as were former strong year-classes, nor was it distributed over as wide an area as these. The Scientific Council, therefore, considered the 1984 year-class as being of the same order of magnitude as former good year-classes, i.e. 500 mill. at age 3 (Anon, 1988).

Adjusting this year-class (500 mill. at 1 Jan 1987) by-catches in 1987 and 1988 and assuming a natural mortality (M) of 0.2 per year leads to 283 mill. by 1 Jan 1989. The survey estimate from the trawl survey in November 1988, raised by the inshore component (22% of total stock, Hovgård *et. al.*, 1989a) leads to a total swept-area estimate of 590 mill. cod of the 1984 year-class. This implies that the swept-area estimate is 2.08 times the estimate based on a year-class size of 500 mill.

Comparing catch rates of 4-year-old cod of the 1984 and 1973 year-classes (the latter being the only year-class within the latest 20 years with a significant contribution of 4-year-old cod to the fisheries) showed that the CPUE of the 1984 year-class was 2.05 times the CPUE of the 1973 year-class (Hovgård and Riget, 1989). Assuming that this ratio reflects the relative size of the two year-classes and applying the 1973 year-class size at age 4 as calculated by VPA (M = 0.2, E = 0.05 from age 6 onwards) lead to an estimate of the 1984 year-class size of 316 mill. (age 4). The swept-area estimate of the 1984 year-class from the combined trawl and longline surveys showed a year-class size of 681 mill., i.e. exceeding the VPA-CPUE estimate by a factor of 2.16.

Preliminary runs of ADAPT (Table 1-5) with integrated use of catch-at-age data and survey results (trawl raised by inshore component) for the 1982-88 period showed a relation between survey estimates and calculated numbers at age of 2:1 for the fully recruited age groups (above age 5) Table 4.

Available information, therefore, indicates that the swept-area abundance should be reduced by a factor of about 2. Reducing the swept-area estimate is equivalent to assuming that more fish is caught than are found immediately in front of the trawl wings, i.e. that fish are herded into the trawl path by doors and sweeplines at a higher rate than concurrent escapement. For cod above 50 cm (age 5 and older) this seems reasonable as the escapement of such cod from the trawl is in the order of only 10% (Walsh, S., 1989). Smaller cod do, however, escape below the ground rope of the trawl at much higher rates and their abundance is hence under estimated by the survey.

For the younger age groups a factor of about 2 can, therefore, not be applied as these fish are not fully recruited to the survey. The abundance of the 2-4-year-old cod can, however, be estimated relatively to each other from survey time series. These relative indices can then be scaled up as some of them have later been fully recruited to the fishery.

3. Variability in Mortality

Estimates of total mortality (Z) of any year-class is estimated from the abundance estimates from successive surveys ($\ln(N_1/N_2)$. This estimate is not influenced by the assumptions of catchability as long as this factor remains constant over time. However, the abundance estimate (N_1, N_2) are subjected to substantial variation (typically total abundance having a 95% confidence interval of ±40%) and this variability is carried on to the estimation of Z's.

Total mortality (Z) calculated from the survey for the fully recruited ages (5+) for 1983-88 leads to an average Z of 0.72 for the period but with large between year variations (Table 6).

In previous assessments (1984-1988) this difference in Z's was attributed to large scale migrations in or out of the West Greenland area. However, evaluation of the migration from West Greenland to East Greenland and Iceland from historical tag return data suggests that the migration is basically a one-way West to East migration (Hovgård *et al.*, 1989b) and that the magnitude of this migration is relatively constant over the years (Riget and Hovgård, 1989).

Assuming a constant migration the large variations in total mortality are then attributed to variability in survey results (statistical noise or year to year variations in availability of cod to the survey). The overall mean of Z's (0.72 per year) could, however, be a fair expression of the average Z in the 1983 to 1988 period. A natural mortality (M) of 0.20 per year and an emigration coefficient (E) of 0.05 per year leads to an average fishing mortality in the 1983-88 period of 0.45. This value is below the values for the 1970's (average F's of 0.6-0.7), which seems quite reasonable taking the depleted stock size and the restrictions on the fisheries in the 1983 and 1988 period into account. A VPA has been conducted using terminal F's of 0.45 on age 5+ to evaluate recent variation in fishing mortality (Table 7-8).

4. Estimation of the Stock Size by 1 Jan 1989

At present, the cod stock off West Greenland is dominated by the 1984 year-class which alone accounted for 90% of the catches in 1988. Assessing stock size is, therefore, in effect to estimate the size of this year-class.

The size of the 1984 year-class is vastly greater than any of the year-classes preceding it: 20-100 times as large as the 1980-83 year-classes (Table 1 and Table 8). At present, fisheries concentrates on this year-class and catches of older cod can be regarded as largely a by-catch. Using average fishing patterns derived from historical data therefore make little sense. Tuning the VPA by ADAPT does not solve this problem as a ADAPT implicit assumes a constant fishery pattern.

VPA techniques will therefore not be useful for estimating stock size to be used in projections. However, the VPAs can be used to generate historical F's and spawning stock biomasses.

In last years assessment (Anon, 1988) it was recognized that the 1984 year-class was very strong but it was not felt likely that the year-class was much larger than good year-classes in the 50's and 60's. For this reason, the year-class size was estimated to 500 mill. age 3. Although the survey results in 1988 confirms that the year-class is very strong, the actual size dependent on the assumptions of catchability. At present, the best approach might be to assume a year-class size of 500 mill. and reduce this number by natural mortality and catches taken in 1987 and 1988. By doing this, a catchability factor of around 2 is implicitly assumed. Although this factor might appear large, it is at least not in contradiction with factors derived by CPUE comparisons with previous periods or with the catchability estimated by the ADAPT tuning.

References

Anon. 1988. NAFO Scientific Council Reports, 1988.

Hovgård, H., and F. R. Riget. 1989. An estimation of the size of the 1984 year-class of cod off West Greenland from CPUE data in the trawl fisheries. NAFO SCR Doc. 89/22.

Hovgård, H., H. Lassen, K. M. Lehmann, K. Nygård, and F. Riget. 1989a. Distribution and abundance of the inshore stock component of the West Greenland cod stock in autumn 1988. NAFO SCR Doc. 89/33.

Hovgård, H., F. R. Riget, and H. Lassen. 1989b. Modelling cod migrations from Greenland to Iceland. NAFO SCR Doc. 89/32.

Riget, F., and H. Hovgård. 1989. Recaptures by year-class of cod in East Greenland/Icelandic waters from tagging experiments at West Greenland. NAFO SCR Doc. 89/24.

Walsh, S. J. 1989. The fish capture process of a groundfish survey trawl. NAFO SCR Doc. 89/46.

Table. 1. 1 Jan population numbers for cod in Subarea 1 as calculated by VPA, tuned by ADAPT.

POPULATION NUMBERS (000S)

	1982	1983	1984	1985	1986	1987	1988
3	66572	11403	11790	3558	15332	1298841	322055
4	6376	50784	8813	8657	2369	11930	1003926
5	55628	3898	28647	5083	5625	1745	7108
6	7346	27473	1261	13146	2808	3758	993
7	5331	3104	6192	375	5901	1907	2043
8	1791	2318	1022	1596	150	3543	919
9	1398	683	927	703	581	106	1844
10	132	550	228	400	510	160	73
	144574	100214	58881	33518	33276	1321988	1338960

Table 2. Fishing mortality as derived from the ADAPT tuning.

FISHING MORTALITY

	1982	1983	1984	1985	1986	1987	1988
3	0.021	0.008	0.059	0.157	0.001	0.008	0.003
4	0.242	0.323	0.300	0.181	0.056	0.268	0.058
5	0.455	0.879	0.529	0.343	0.153	0.314	0.184
6	0.611	1.240	0.963	0.551	0.137	0.359	0.813
7	0.583	0.861	1.106	0.667	0.260	0.480	0.437
8	0.715	0.666	0.125	0.760	0.095	0.403	0.982
9	0.682	0.846	0.591	0.070	1.042	0.125	0.599
10	0.482	1.165	0.643	0.497	0.194	0.380	0.390

Table 3. Standardized residuals for RV index (s.e. = 1 for log model)

	1982	1983	1984	1985	1986	1987	1988
3	0.675	0.025	¯0.472	¯0.378	¯0.180	0.330	0.000
4	1.180	0.253	¯1.090	0.178	¯0.952	0.742	¯0.311
5	¯0.108	1.083	¯0.819	¯0.698	0.254	0.990	¯0.703
6	0.860	0.119	0.148	¯0.554	¯1.348	0.905	¯0.130
7	0.309	0.366	¯0.156	0.441	¯0.548	¯0.121	¯0.291
8	0.440	0.248	¯2.087	0.058	¯0.007	0.616	0.732
9	1.378	0.582	¯0.422	¯3.059	1.125	¯0.162	0.558

Table 4. Estimates of numbers at age 1 Jan 1989 (age 3-9) and the catchability factor for each age (slope 3-9) as estimated by the ADAPT tuning.

ORTHOGONALITY OFFSET......... 0.000979
MEAN SQUARE RESIDUALS 0.930370

		PAR. EST.	STD. ERR.	T-STATISTIC	C.V.
Age	3	3.22914E5	3.40640E5	9.47961E¯1	105
	4	1.00775E6	7.38170E5	1.36520E0	73
	5	7.15341E3	4.05207E3	1.76537E0	57
	6	1.01213E3	4.02027E2	2.51756E0	40
	7	2.06707E3	1.06398E3	1.94277E0	51
	8	9.40155E2	3.42250E2	2.74698E0	36
	9	1.87167E3	9.51542E2	1.96698E0	51
Slope	3	4.70922E¯1	2.04782E¯1	2.29963E0	43
	4	1.09128E0	4.45509E¯1	2.44952E0	41
	5	2.01342E0	8.04495E¯1	2.50272E0	40
	6	2.37678E0	9.94162E¯1	2.39074E0	42
	7	1.92934E0	8.17776E¯1	2.35925E0	42
	8	1.26292E0	5.51205E¯1	2.29120E0	44
	9	1.17593E0	5.09459E¯1	2.30819E0	43

Table 5. Parameter correlation matrix as found in the ADAPT tuning.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	1.000	0.137	0.100	0.075	0.077	0.049	0.046	¯0.411	¯0.078	¯0.054	¯0.054	¯0.051	¯0.046	¯0.046
2	0.137	1.000	0.147	0.104	0.109	0.071	0.067	¯0.332	¯0.331	¯0.078	¯0.076	¯0.073	¯0.067	¯0.066
3	0.100	0.147	1.000	0.121	0.144	0.117	0.122	¯0.243	¯0.284	¯0.313	¯0.132	¯0.165	¯0.168	¯0.176
4	0.075	0.104	0.121	1.000	0.173	0.124	0.144	¯0.183	¯0.189	¯0.222	¯0.387	¯0.132	¯0.131	¯0.146
5	0.077	0.109	0.144	0.173	1.000	0.191	0.226	¯0.186	¯0.206	¯0.227	¯0.312	¯0.423	¯0.228	¯0.264
6	0.049	0.071	0.117	0.124	0.191	1.000	0.238	¯0.119	¯0.138	¯0.165	¯0.205	¯0.280	¯0.456	¯0.213
7	0.046	0.067	0.122	0.144	0.226	0.238	1.000	¯0.112	¯0.130	¯0.162	¯0.238	¯0.312	¯0.382	¯0.502
8	¯0.411	¯0.332	¯0.243	¯0.183	¯0.186	¯0.119	¯0.112	1.000	0.190	0.132	0.131	0.124	0.112	0.111
9	¯0.078	¯0.331	¯0.284	¯0.189	¯0.206	¯0.138	¯0.130	0.190	1.000	0.148	0.142	0.140	0.128	0.127
10	¯0.054	¯0.078	¯0.313	¯0.222	¯0.227	¯0.165	¯0.162	0.132	0.148	1.000	0.164	0.160	0.152	0.150
11	¯0.054	¯0.076	¯0.132	¯0.387	¯0.312	¯0.205	¯0.238	0.131	0.142	0.164	1.000	0.199	0.183	0.187
12	¯0.051	¯0.073	¯0.165	¯0.132	¯0.423	¯0.280	¯0.312	0.124	0.140	0.160	0.199	1.000	0.236	0.232
13	¯0.046	¯0.067	¯0.168	¯0.131	¯0.228	¯0.456	¯0.382	0.112	0.128	0.152	0.183	0.236	1.000	0.249
14	¯0.046	¯0.066	¯0.176	¯0.146	¯0.264	¯0.213	¯0.502	0.111	0.127	0.150	0.187	0.232	0.249	1.000

Table 6. Estimated Z from survey abundance by age groups and years*.

Year	1983	1984	1985	1986	1987	1988
Age 5	0.61	1.24	-.41	-.29	(-1.99)	1.27
6	1.10	1.98	0.37	0.87	-0.21	(2.02)
7	1.40	1.84	0.83	0.71	-0.29	2.09
8	1.81	(3.25)	1.22	(1.22)	-0.09	0.80
9	1.03	1.58	(1.36)	(0.30)	-	0.98
10	(2.32)	(2.84)	(2.59)	(0.10)	0.36	-
weighted mean	1.14	1.48	0.37	0.22	-0.37	1.47

* Estimates based on low abundances are given in brackets.

Table 7. Fishing mortality as derived by conventional VPA assuming F = 0.45 and a traditional fishing pattern.

	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
3	.007	.010	.029	.002	.020	.006	.060	.116	.002	.030	.050
4	.195	.444	.228	.238	.250	.311	.241	.183	.040	.528	.250
5	.489	.994	.369	.626	.458	.933	.500	.256	.156	.214	.450
6	.549	.715	.424	.355	.734	1.259	1.130	.502	.096	.366	.450
7	.500	1.088	.837	.449	.646	1.354	1.163	.994	.227	.302	.450
8	.438	1.062	.590	1.235	.814	.817	.284	.866	.178	.335	.450
9	.427	1.087	.454	.464	.832	1.166	.905	.183	1.530	.260	.450
10	.490	.811	.544	.596	.507	1.194	.599	.444	.191	.313	.450
5+	.490	.821	.568	.633	.512	1.205	.628	.457	.210	.314	.450

Table 8. Population numbers as generated by the conventional VPA.

	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
3	43571	32477	119196	7969	68612	13793	11663	4708	8789	334582	19261
4	35104	33680	25041	90184	6196	52372	10674	8558	3264	6835	252960
5	88052	22491	16826	15519	55353	3757	29884	6532	5548	2442	3139
6	2693	42065	6480	9062	6461	27259	1151	14110	3937	3697	1536
7	1466	1212	16020	3301	4948	2415	6026	290	6651	2786	1996
8	265	693	318	5404	1642	2019	486	1466	83	4127	1604
9	134	133	186	137	1224	566	695	285	480	54	2299
10	20	68	35	92	67	415	138	219	185	81	33
3+	171305	132819	184102	131668	144502	102597	60715	36166	28937	354604	282827
4+	127734	100342	64906	123700	75890	88805	49053	31459	20148	20022	263567
5+	92630	66662	39865	33516	69694	36432	38379	22901	16884	13188	10607
6+	4578	44171	23039	17997	14342	32675	8495	16369	11337	10745	7467