Northwest Atlantic Fisheries Organization

Serial No. N1570

NAFO SCR Doc. 89/06

SCIENTIFIC COUNCIL MEETING - JUNE 1989

Estimation of the Stock Status and TAC for Redfish in Div. 3M and 3LN for 1990

by

A. A. Vaskov, G. B. Rudneva and I. A. Oganin

Polar Research Institute of Marine Fisheries and Oceanography (PINRO)
6 Knipovich Street, Murmansk 183763, USSR

ABSTRACT

The VPA method was used to estimate abundance and biomass of the exploited part of the redfish stock in Divs. 3M and 3LN in 1968-1988. The fishing and natural mortality coefficients were calculated by age groups. The TAC estimate for 1990 is obtained.

The redfish stock on Flemish Cap Bank is at the high level: in 1988 redfish biomass estimated by using the natural mortality coefficients differentiated by ages amounted to 301,1 thousand tons, and to 344,8 thousand tons with M=0.1 for all age groups.

The total redfish biomass from the trawl-acoustic survey in Div. 3M was 457,0 x 10^{-3} tons.

From 1979 to 1988 the redfish abundance and biomass in Divs. 3LN tended to increase. In 1988 the biomass was 351,3 thousand tons.

Trawl-acoustic surveys yielded the total redfish biomass of 196,5 thousand tons in Divs. 3LN.

INTRODUCTION

In recent years the redfish catch in Divs. 3M and 3LN has increased mainly because of the extended fishery by the EEC countries. Regular investigations aimed at estimation of the redfish stock status in these Divs. are important for its rational exploitation. Species stock status, undoubtedly, depends on the stock age composition, year class strength, natural and fishing mortality.

The main aim of this paper is to obtain objective redfish stock estimates and TAC using both age-differentiated and constant coefficients of natural mortality. The stock assessment and TAC value for redfish in Div. 3LN are only referred to together with age-dependent coefficients of natural mortality.

MATERIAL AND METHODS

The VPA method was used to estimate abundance and biomass of the exploited part of commercial redfish stocks under consideration. Quantitative composition of catches by age-groups and years of fishery is given in Tables 1 and 2. The data on redfish catches in Divs. 3M and 3LN in 1988 come from NAFO circular letters (89/II, 88/73). Foreign fishing effort per each year is fitted to the one rendered by a standard Soviet vessel of BMRT-type.

The natural mortality coefficients by age groups calculated in accordance with methods described in papers by Tretyak and others (Tretyak, 1983; Efimov et al, 1986), as well as the constants equal to 0.1, for each age group were used for the stock estimation.

Methods of "tuning" outlined in the paper by Pope and Shepperd, 1983, were applied to calculate the inital fishing mortality coefficients. Such criteria as maximum values of correlation coefficients by age groups between fishing mortality and effort and minimum values of the "tuning" method errors calculated with the dependent and nondependent data served as the ground in choosing this or that method.

The stock status prognosis and TAC for 1990 were made with due regard for partial recruitment coefficients calculated by the Rivard's method (Rivard, 1980). Optimum exploitation parametres for commercial redfish stocks under consideration were obtained by using the Thompson-Bell method (Ricker, 1975). Stock status prediction and TAC for 1990 was made in 3 versions: a) sparing regime of exploitation; b) exploitation rate at the 1988 level; c) exploitation rate at the MSY level.

RESULTS

Div. 3M. Appropriate stock estimates for age groups 5 to 23 were obtained using 2 versions of natural mortality coefficient estimates in VPA calculations. A modified gamma method showed the best criteria in both versions under the VPA tuning. The basic

age groups 10 to 23 had the correlation coefficients within the range of 0,55-0,82. Constant natural mortality coefficients give excessive fishing mortality coefficients (Tables 3,4) for age groups 17 to 23, besides, the stock size is overestimated without affecting the TAC.

The analysis of abundance (Tables 5,6) and biomass (Tables 7,8) shows the increase of the redfish stock on Flemish Cap. From 1979 the commercial stock biomass has kept to the level of 220 thousand tons. In 1988 the abundance taking into account age-differentiated coefficients of natural mortality by age amounted to 1239,1 x 10^6spec., the biomass to 302,1 thousand tons.

Tables 9 and 10 show that the application of constant mortality coefficients leads to overestimation of the stock size for 1989--1990.

The trawling data from research and fishery vessels indicate that the bulk of the redfish catch in 1988 consisted of fish ranged from 22 to 27 cm in length (Fig.1). A relativly high number of 9-13 cm fish is indicative of appearence of strong year-classes in 1987-1986. The trawl survey yielded the redfish abundance of 183,1 x 10^6fish and the biomass of 47,0 thou.t (Table 11). The trawl survey showed that a decrease in abundance and biomass of redfish was due to inaccessibility of the main part of the stock for bottom trawl fishing. The results of the acoustic survey conducted in June 1988 indicate that the main redfish concentrations were distributed pelagically (Fig.2). According to the data from the acoustic survey the redfish abundance was 1660,0 x 10^6fish and biomass - 410,0 thou.t (Figure 11).

The results of the trawl-acoustic survey are in agreement with the abundance and biomass calculated through the VPA method.

Div. 3LN. Estimated abundance of the commercial redfish stock in 1988 was 1768,0 x 10^6fish (Table 12) and the biomass - 351,3 thou.t (Table 13).

When applying the VPA method in accordance with all methods of "tuning" (Pope, Shepperd, 1983) the correlation coefficients were low and for some age groups even negative. The best estimates were obtained from the method of weighted mean of fishing mortality coefficients (F). The correlation coefficients for all age groups from 8 to 18 were 0.47-0.60. The fishing mortality coefficients are shown in Table 14.

The results from sampling tows together with data from fishing vessels indicate that the bulk of catches in 1988 consisted of fish of 20-30 cm long and at age 7-16 (Figs.3,4)

The redfish abundance in Div. 3LN estimated from the data of the 1988 trawl-acoustic survey was 1035,1 x 10^6 fish, and the biomass - - 196,5 thou.t (Table 11, Fig.5). In our opinion, the acoustic survey gave underestimated results which don't reflect the actual situation due to undersampling of fish because of complicated bottom topography in these Divisions. Besides, we believe that this may be caused by migrations of the warm-loving redfish within the boundaries of Div. 3LN depending on temperature variations in this area.

The VPA estimates and the results of trawl-acoustic surveys point to the high level of commercial fish stock on the Grand Newfoundland Bank.

CONCLUSIONS

The redfish stock on Flemish Cap is at a high level, the biomass and abundance are increasing. In 1990 the biomass will exceed the 1979-1988 average level and amount to 380 thou.t. TAC in 1990 may be 30 thou.t at $F_{0.1}$=0.22.

The redfish biomass on the Grand Newfoundland Bank in 1990 is expected to be about 400 thousand tons. TAC will amount to 40 thou.t at $F_{0.1}$=0.18 (Table 15).

The results of abundance, biomass and TAC estimations point to the preferable use of age-differentiated coefficients of natural mortality in mathematical models.

REFERENCES

DOUBLEDAY, W.G. (Editor). 1981. Manual on groundfish surveys in the Northwest Atlantic. NAFO Sci, Coun. Studies, 2: 1-55.

EFIMOV,N.I., A.N.SAVATEEVA, and V.L.TRETYAK. MS 1986. On a feasible formal description of the natural mortality rate variation in relation to age of beaked redfish and capelin from the Northwest Atlantic. NAFO SCR Doc. 86/64.

MAMYLOV, V.S. 1988. Experimental trawl-acoustic survey in NAFO Subarea 3 from March to July 1987. NAFO SCR Doc. 88/22, Serial No. 1460, 27 p.

POPE,J.G. and I.G.SHEPPERD, 1983. Comparison of the performance of various methods for tuning VPAs using effort data. ICES C.M.1983/G:9.

RICKER, W.E. 1975. Computation and interpretation of biological statistics of fish populations. Bull.Fish.Res.Bd.Can., 191, 382 p.

RIVARD, D. 1980. All programs for stock assessment. Can.Tech.Rep. Fish.Aquat.Sci.,93, 103 p.

TRETYAK, V.L. 1983. Recomendations on estimating the natural and fishing mortality coefficients for fish at different age. (exampliFied by Arcto-Norwegian cod). Murmansk, PINRO, 76 p. (in Russian).

Table 1 The total international Sebastes mentella catch of in Div. 3M, specimens ($\times 10^{-3}$)

Age, years	I979	I980	I98I	I982	I983	I984	I985	I986	I987	I988
5	6I8	I23	32I	I4	I3	I294	II94I	533I	7266	-
6	2II8	8I8	II94	233	I55	III0	5644	I3I79	23768	459
7	357I	2708	2925	II37	837	I94I	99I	824I	59247	4I05
8	3665	3672	4533	3050	3320	3308	498	2806	44404	5804
9	3I46	4399	5877	5II9	603I	4875	I898	24I8	I7203	3463
I0	3020	3855	64I2	7334	9792	7635	3688	47I4	6793	2789
II	3364	2827	4855	6387	9095	7836	3824	5643	8488	4543
I2	3632	2280	2699	3569	529I	5473	5002	7874	5673	4I08
I3	4492	2838	2223	2350	3643	4562	5889	7256	6777	5706
I4	3985	2740	I666	I600	2523	328I	4745	594I	5I06	4559
I5	33I6	2409	I235	II87	I783	2272	2483	3367	3024	3026
I6	2508	I867	850	963	I28I	I558	243I	2870	2730	2782
I7	I364	II34	454	6I5	684	722	8I4	I000	947	I369
I8	986	853	3II	454	457	443	695	885	536	878
I9	795	658	237	383	356	3I7	278	478	3I5	532
20	558	47I	I64	264	229	200	406	584	247	292
2I	376	324	I08	I70	I54	I24	288	354	I53	220
22	I43	I33	4I	50	48	32	98	I25	6I	9I
23	68	37	I4	7	5	5	50	59	I4	27

Table 2 The total international Sebastes mentella catch of in Div. 5LN, specimens ($\times 10^{-3}$)

Age, years	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
5	4786	2773	7618	9346	5213	3043	11080	25458	4562	5764
6	4294	2803	8771	13616	10933	5076	11530	24565	17096	21930
7	3633	2486	6911	11328	10743	5350	9342	14939	31267	34692
8	5397	3572	8252	11949	11646	6698	12167	26926	35187	23567
9	4014	3430	7972	10964	9411	5809	8895	17628	27011	8966
10	3441	4297	7531	9042	9270	6570	7387	14316	23172	6250
11	2238	3019	4123	3159	3593	3497	2817	5823	11428	3054
12	1998	3539	4086	2175	2493	2794	2188	5681	8800	2575
13	1396	2924	2639	1016	1102	1393	1147	5951	7753	2994
14	908	1915	1493	534	587	737	739	3554	5696	1771
15	796	1453	1305	385	344	512	789	1378	3801	1047
16	614	783	797	227	213	311	550	885	2905	838
17	421	462	517	94	86	145	374	652	2136	596
18	535	496	548	102	58	159	401	612	1233	385
19	395	370	495	48	15	77	283	411	688	271
20	962	1144	1406	79	28	106	423	318	677	410
21	214	217	310	16	20	19	131	199	284	264
22	247	323	417	25	20	3	26	156	137	252
23	127	153	220	25	20	3	13	61	57	148

Table 3 The redfish natural (M_τ) and fishing mortality coefficients in Div. 3M within one year of life

Age, years	M_τ	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
5	0.140	0.0057	0.0012	0.0037	0.0002	0.0002	0.0072	0.0311	0.0138	0.0763	0.0013
6	0.110	0.0229	0.0087	0.0131	0.0030	0.0021	0.0155	0.0364	0.0403	0.0730	0.0057
7	0.080	0.0432	0.0331	0.0348	0.0140	0.0121	0.0292	0.0155	0.0614	0.2271	0.0145
8	0.060	0.0592	0.0499	0.0623	0.0405	0.0450	0.0531	0.0082	0.0486	0.4543	0.0272
9	0.040	0.0758	0.0800	0.0900	0.0794	0.0898	0.0737	0.0335	0.0428	0.3865	0.0484
10	0.020	0.1112	0.1047	0.1337	0.1290	0.1778	0.1307	0.0615	0.0911	0.1354	0.0822
11	0.010	0.1770	0.1185	0.1521	0.1563	0.1904	0.1721	0.0737	0.1038	0.1916	0.1036
12	0.010	0.2290	0.1422	0.1293	0.1301	0.1526	0.1364	0.1291	0.1731	0.1177	0.1090
13	0.010	0.3286	0.2270	0.1631	0.1295	0.1546	0.1550	0.1730	0.2255	0.1795	0.1357
14	0.030	0.3687	0.2770	0.1656	0.1394	0.1641	0.1668	0.1958	0.2160	0.2003	0.1449
15	0.040	0.4228	0.3272	0.1614	0.1426	0.1894	0.1818	0.1534	0.1731	0.1359	0.1463
16	0.070	0.4280	0.3750	0.1558	0.1557	0.1919	0.2136	0.2552	0.2260	0.1765	0.1525
17	0.110	0.3268	0.3067	0.1291	0.1432	0.1402	0.1397	0.1463	0.1402	0.0960	0.1119
18	0.160	0.4632	0.3232	0.1196	0.1714	0.1402	0.1182	0.1802	0.2176	0.0968	0.1130
19	0.230	0.5336	0.6432	0.1380	0.2101	0.1957	0.1354	0.1005	0.1799	0.1111	0.1305
20	0.320	0.6486	0.7833	0.3515	0.2430	0.2026	0.1736	0.2781	0.3419	0.1436	0.1541
21	0.420	0.8060	1.3611	0.5019	0.9564	0.2626	0.1928	0.4929	0.5097	0.1680	0.2204
22	0.560	0.8892	1.1826	0.9120	0.6609	0.0786	0.1073	0.3155	0.5877	0.2076	0.1936
23	0.720	0.7919	1.1400	0.6083	0.6532	0.1977	0.1733	0.3955	0.5327	0.1877	0.2125
5-23		0.0899	0.0684	0.0668	0.0631	0.0815	0.0706	0.0541	0.0609	0.1828	0.0503

Table 4 The redfish natural (M_t=0,1) and fishing mortality coefficients in Div. 3M within one year of life

Age, years	M_t	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
5	0.100	0.0043	0.0009	0.0027	0.0001	0.0001	0.0060	0.0248	0.0108	0.0596	0.0010
6	0.100	0.0170	0.0063	0.0093	0.0022	0.0015	0.0120	0.0292	0.0312	0.0547	0.0043
7	0.100	0.0322	0.0245	0.0253	0.0099	0.0087	0.0208	0.0119	0.0490	0.1708	0.0108
8	0.100	0.0451	0.0379	0.0470	0.0299	0.0327	0.0389	0.0060	0.0383	0.3540	0.0204
9	0.100	0.0603	0.0632	0.0708	0.0619	0.0687	0.0555	0.0255	0.0327	0.3063	0.0374
10	0.100	0.0934	0.0880	0.1109	0.1066	0.1449	0.1048	0.0489	0.0734	0.1088	0.0665
11	0.100	0.1605	0.1067	0.1369	0.1382	0.1673	0.1484	0.0631	0.0885	0.1642	0.0888
12	0.100	0.2294	0.1398	0.1265	0.1269	0.1459	0.1292	0.1198	0.1603	0.1085	0.1004
13	0.100	0.3641	0.2518	0.1763	0.1390	0.1656	0.1621	0.1790	0.2279	0.1808	0.1362
14	0.100	0.4256	0.3512	0.2056	0.1664	0.1946	0.1975	0.2258	0.2464	0.2220	0.1594
15	0.100	0.5120	0.4375	0.2354	0.1981	0.2522	0.2404	0.2016	0.2215	0.1712	0.1778
16	0.100	0.5989	0.5378	0.2413	0.2597	0.3026	0.3241	0.3871	0.3355	0.2512	0.2104
17	0.100	0.5102	0.5277	0.2131	0.2461	0.2650	0.2487	0.2499	0.2423	0.1573	0.1724
18	0.100	0.6041	0.6155	0.2372	0.3042	0.2603	0.2449	0.3569	0.4165	0.1773	0.1918
19	0.100	0.7312	0.9421	0.3036	0.4521	0.3882	0.2587	0.2138	0.3943	0.2276	0.2392
20	0.100	0.8426	1.2134	0.5665	0.5722	0.4742	0.3236	0.5393	0.8000	0.3232	0.3034
21	0.100	1.1548	1.8461	0.9181	1.9931	0.6877	0.4513	0.9290	1.1565	0.4399	0.4703
22	0.100	1.0885	1.8653	1.3809	1.4550	0.2238	0.2587	0.6875	1.3190	0.5396	0.4512
23	0.100	0.8310	0.8310	1.0187	0.8310	0.4555	0.3403	0.7093	1.0669	0.4179	0.4311
5-23		0.0745	0.0564	0.0540	0.0515	0.0676	0.0600	0.0457	0.0509	0.1470	0.0414

Table 5 Abundance of redfish in Div. 3M by different age groups and years of fishery (specimens x 10^{-6}). Calculated by VPA with natural mortality coefficients changes considered.

Age, years	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
5	114.94	115.75	111.15	93.36	90.45	87.46	193.16	417.77	415.52	105.87	283.06
6	99.34	98.84	100.05	96.51	80.87	78.62	76.02	166.72	352.07	356.27	85.27
7	72.46	87.95	86.54	88.86	85.33	72.22	70.28	67.05	144.01	302.93	296.69
8	47.86	65.71	77.75	77.29	79.22	77.68	65.87	63.02	60.95	125.03	222.82
9	31.92	43.96	58.33	69.66	68.39	71.64	69.93	58.82	58.86	54.68	74.76
10	24.98	28.98	39.16	51.73	61.17	60.69	62.92	62.41	54.65	54.19	35.69
11	22.95	20.83	25.42	34.57	44.36	52.70	49.80	54.12	57.53	48.91	46.39
12	20.77	17.83	17.28	22.35	29.39	37.57	43.13	41.51	49.78	51.34	39.28
13	17.81	16.12	14.04	14.84	19.45	25.55	31.93	37.26	36.12	41.45	45.19
14	13.76	13.11	11.49	11.08	12.48	16.92	21.67	27.07	31.03	28.54	34.29
15	10.40	9.80	8.80	8.45	9.11	10.54	13.93	17.89	21.60	24.26	22.67
16	7.38	7.44	6.17	6.09	6.91	7.59	8.38	11.16	14.67	17.45	20.35
17	4.18	5.15	4.52	3.95	4.86	5.51	5.84	6.31	8.06	10.91	13.64
18	3.17	2.86	3.33	2.98	3.11	3.77	4.29	4.55	4.88	6.28	8.88
19	2.18	2.13	1.53	2.05	2.25	2.23	2.80	3.25	3.24	3.35	4.86
20	1.42	1.34	0.99	0.64	1.42	1.45	1.46	1.94	2.34	2.15	2.38
21	0.66	0.81	0.51	0.33	0.33	0.81	0.86	0.89	1.07	1.20	1.35
22	0.37	0.30	0.24	0.09	0.13	0.08	0.41	0.47	0.36	0.42	0.67
23	0.28	0.17	0.07	0.04	0.02	0.04	0.04	0.21	0.19	0.11	0.20
	496.8	539.1	567.4	584.9	599.3	613.1	722.7	1042.3	1316.9	1235.3	1239.1

Table 6 Abundance of redfish in Div. 3M by different age groups and years of fishery (specimens x 10^{-6}). Calculated by VPA with natural mortality coefficients, amounted to 0,1

Age, years	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
5	151.99	149.18	124.67	121.24	108.52	229.13	511.41	523.63	131.86	349.01
6	132.09	136.94	134.87	112.50	109.69	98.18	206.09	451.39	468.73	112.41
7	118.35	117.51	123.13	120.90	101.57	99.10	87.78	181.12	395.91	401.54
8	87.27	103.70	103.75	108.63	108.31	91.11	87.82	78.48	156.05	301.98
9	56.43	75.48	90.34	89.57	95.40	94.85	79.29	78.99	68.35	99.10
10	35.57	48.07	64.12	76.16	76.18	80.59	81.19	69.94	69.18	45.53
11	23.81	29.32	39.84	51.92	61.94	59.63	65.66	69.96	58.81	56.14
12	18.59	18.35	23.84	31.43	40.92	47.41	46.52	55.78	57.94	45.15
13	15.42	13.37	14.43	19.01	25.05	32.00	37.70	37.34	43.00	47.04
14	12.04	9.69	9.41	10.95	14.97	19.21	24.62	28.52	26.90	32.47
15	8.66	7.12	6.17	6.93	8.39	11.15	14.27	17.78	20.17	19.49
16	5.82	4.70	4.16	4.42	5.14	5.90	7.93	10.55	12.89	15.38
17	3.57	2.89	2.48	2.96	3.08	3.44	3.86	4.87	6.83	9.07
18	2.27	1.94	1.54	1.81	2.09	2.14	2.43	2.72	3.46	5.28
19	1.60	1.12	0.95	1.10	1.21	1.46	1.52	1.54	1.62	2.62
20	1.02	0.70	0.40	0.63	0.63	0.76	1.02	1.11	0.94	1.17
21	0.57	0.40	0.19	0.20	0.32	0.36	0.50	0.54	0.45	0.61
22	0.22	0.16	0.06	0.07	0.03	0.15	0.21	0.18	0.15	0.26
23	0.13	0.07	0.02	0.01	0.01	0.02	0.10	0.09	0.04	0.08
	675.4	720.7	744.4	760.4	763.5	876.6	1259.9	1614.5	1523.3	1544.3

Table 7 Biomass (thousand tons) of redfish in Div. 3M by different age groups and years of fishery. Calculated by VPA with natural mortality coefficients changes considered

Age, years	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
5	12.15	14.45	9.34	11.94	8.75	19.70	42.19	51.52	9.95	26.326
6	18.29	19.31	19.59	16.17	15.80	18.20	30.01	69.01	44.53	11.512
7	21.37	20.25	20.61	18.18	16.90	15.46	14.22	32.83	45.44	51.031
8	16.76	19.83	18.78	17.82	19.26	15.81	15.06	15.12	22.88	45.455
9	11.74	18.55	18.81	16.69	18.91	17.90	17.35	16.48	12.90	19.063
10	8.64	12.69	17.33	20.80	19.91	21.21	21.22	17.98	17.50	11.814
11	7.21	10.45	13.48	16.64	20.45	19.42	22.08	22.09	18.73	18.556
12	8.97	8.21	10.37	12.20	15.78	20.14	18.64	22.90	22.13	17.829
13	8.19	7.37	7.69	9.39	12.90	17.62	19.78	19.36	21.18	23.678
14	8.13	6.51	6.35	7.43	10.32	13.93	16.16	18.99	16.72	19.822
15	6.47	5.78	5.14	6.36	7.38	9.99	12.37	14.95	15.97	15.053
16	5.63	4.36	4.48	5.06	5.65	6.16	7.92	10.87	12.55	14.772
17	4.07	3.42	3.06	3.81	4.32	4.47	4.92	6.34	8.39	10.531
18	2.47	2.60	2.33	2.63	3.18	3.56	4.00	4.15	5.37	7.618
19	2.00	1.33	1.86	2.03	2.09	2.61	2.97	3.05	3.16	4.200
20	1.48	0.93	0.64	1.40	1.42	1.45	2.01	2.37	2.11	2.422
21	0.90	0.52	0.35	0.36	0.87	0.92	0.99	1.16	1.26	1.444
22	0.35	0.28	0.10	0.15	0.09	0.50	0.53	0.41	0.50	0.772
23	0.22	0.09	0.05	0.03	0.05	0.05	0.26	0.24	0.15	0.241
	145.0	156.9	160.4	169.1	184.0	206.1	252.7	329.8	281.4	302.1

Table 8 Biomass (thousand tons) of redfish in Div. 3M by different age groups and years of fishery. Calculated by VPA with natural mortality coefficients amounted to 0.1

Age, years	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
5	15.96	19.39	12.47	16.00	10.85	23.37	51.65	64.93	12.39	32.458
6	24.44	26.43	27.38	22.50	22.05	19.64	37.10	88.47	58.59	15.175
7	28.76	27.50	28.57	25.75	23.77	21.80	18.61	41.29	59.39	69.065
8	22.25	26.44	25.21	24.44	26.86	21.87	20.99	19.46	28.56	61.604
9	15.07	24.00	24.39	21.85	25.18	24.28	23.39	22.12	16.13	25.271
10	10.60	15.58	21.48	25.89	24.99	27.16	27.60	25.01	22.34	15.070
11	8.24	12.05	15.54	19.47	24.03	23.26	26.79	26.86	22.52	22.457
12	9.35	8.71	11.06	13.05	17.19	22.14	20.89	25.66	24.97	20.138
13	7.83	7.02	7.48	9.18	12.65	17.66	20.02	20.01	21.97	24.647
14	7.46	5.50	5.39	6.52	9.13	12.35	14.70	17.46	15.76	18.768
15	5.71	4.68	3.75	4.84	5.87	7.99	9.92	12.30	13.23	12.943
16	4.41	3.32	3.06	3.23	3.83	4.34	5.63	7.82	9.27	11.166
17	2.82	2.19	1.92	2.32	2.41	2.63	3.01	3.83	5.25	7.003
18	1.97	1.52	1.21	1.53	1.76	1.78	2.13	2.31	2.96	4.529
19	1.51	0.97	0.86	1.00	1.13	1.36	1.38	1.45	1.53	2.269
20	1.13	0.66	0.40	0.62	0.62	0.75	1.06	1.12	0.92	1.191
21	0.64	0.41	0.20	0.23	0.35	0.38	0.55	0.58	0.47	0.656
22	0.26	0.19	0.06	0.08	0.03	0.18	0.25	0.21	0.18	0.302
23	0.17	0.09	0.03	0.02	0.02	0.02	0.13	0.12	0.06	0.100
	168.6	186.6	190.4	198.5	212.7	233.0	285.8	379.0	316.5	344.8

Table 9. The estimate of redfish stock size and TAC in Div. 3M for 1990

Age, years	Natural mortality coefficients	Instantenious fishing mortality coefficients	Initial abundance in 1988, spec. ($\times 10^{-6}$)	Stock at the beginning of 1989		Stock size (thousand tons) at the beginning of 1990 at various vallues (F_{1989})			Catch size (thousand tons) in 1990 at		
				Abundance, spec. ($\times 10^{-6}$)	Biomass, thousand tons	$F_{0.1}$= 0.22	F_{1989}= F_{1988}	F_{msy}= 0.32	$F_{0.1}$= 0.22	F_{1990}= F_{1988}	F_{msy}= 0.32
5	0.140	0.0013	283.08	283.08	26.326	26.326	26.326	26.326	0.16	0.03	0.23
6	0.110	0.0057	85.27	245.78	33.180	33.009	33.180	32.912	0.39	0.18	0.56
7	0.080	0.0145	296.69	75.96	13.065	37.402	37.655	37.192	1.04	0.52	1.49
8	0.060	0.0272	222.82	269.94	55.067	13.890	14.098	13.706	0.68	0.37	0.96
9	0.040	0.0484	74.76	204.21	52.075	61.561	63.086	60.132	4.21	2.92	5.88
10	0.020	0.0822	35.69	68.43	22.652	60.419	61.876	58.467	5.68	4.83	7.82
11	0.010	0.1036	46.39	32.23	12.890	24.284	24.714	23.207	2.79	2.42	3.77
12	0.010	0.1090	39.98	41.41	18.468	12.588	12.829	11.906	1.40	1.32	1.87
13	0.010	0.1357	45.19	35.49	18.597	19.088	19.263	18.090	2.58	2.43	3.45
14	0.030	0.1449	34.29	39.06	22.577	17.546	17.732	16.418	2.49	2.36	3.27
15	0.040	0.1463	22.67	28.79	19.118	21.547	21.774	20.078	3.03	2.91	3.97
16	0.070	0.1525	20.35	18.82	13.661	17.201	17.350	16.031	2.43	2.37	3.19
17	0.110	0.1119	13.64	16.29	12.575	11.563	11.629	10.761	1.19	1.17	1.57
18	0.160	0.1130	8.88	10.93	9.375	11.158	11.194	10.589	1.14	1.11	1.53
19	0.230	0.1305	4.86	6.76	5.845	7.165	7.194	6.794	0.79	0.79	1.06
20	0.320	0.1541	2.38	3.39	3.447	4.794	4.797	4.517	0.57	0.59	0.76
21	0.420	0.2204	1.35	1.48	1.582	2.262	2.251	2.114	0.37	0.37	0.48
22	0.560	0.1936	0.67	0.71	0.821	0.900	0.900	0.815	0.13	0.12	0.16
23	0.720	0.2125	0.20	0.31	0.389	0.412	0.414	0.377	0.05	0.06	0.07
			1239.1	1383.1	341.7	383.1	388.3	370.4	31.1	26.9	42.1

Table 10 The estimate of redfish stock size and TAC in Div. 3M for 1990

Age, years	Natural mortality coefficients	Instantenious fishing mortality coefficients	Initial abundance in 1988, spec. ($\times 10^{-6}$)	Stock at the beginning of 1989		Stock size (thousand tons) at the beginning of 1990 at various vallues (F_{1989}) in			Catch size (thousand tons) in 1990 at		
				Abundance, spec. ($\times 10^{-6}$)	Biomass, thousand tons	$F_{0.1} = 0.30$	$F_{1989} = F_{1988}$	$F_{msy} = 0.58$	$F_{0.1} = 0.30$	$F_{1990} = F_{1988}$	$F_{msy} = 0.58$
5	0.100	0.0010	349.01	349.01	32.458	32.458	32.458	32.458	0.13	0.03	0.26
6	0.100	0.0043	112.41	315.48	42.590	42.450	42.590	42.280	0.29	0.17	0.56
7	0.100	0.0108	401.54	101.27	17.419	48.745	48.888	48.417	0.81	0.50	1.55
8	0.100	0.0204	301.98	359.42	73.322	18.366	18.493	18.064	0.57	0.36	1.06
9	0.100	0.0374	99.10	267.73	68.270	80.250	81.257	77.822	3.35	2.84	6.16
10	0.100	0.0665	45.53	86.38	28.591	76.665	77.241	73.516	4.30	4.73	7.76
11	0.100	0.0888	56.14	38.55	15.418	29.423	29.252	27.800	2.14	2.37	3.77
12	0.100	0.1004	45.15	46.48	20.731	14.370	14.233	13.343	1.06	1.29	1.83
13	0.100	0.1362	47.04	36.95	19.364	20.339	19.934	18.870	1.95	2.42	3.34
14	0.100	0.1594	32.47	37.14	21.468	17.378	16.866	15.735	1.90	2.37	3.16
15	0.100	0.1778	19.49	25.05	16.634	19.747	19.027	17.616	2.34	2.95	3.81
16	0.100	0.2104	15.38	14.76	10.719	14.410	13.776	12.729	1.97	2.49	3.15
17	0.100	0.1724	9.07	11.28	8.705	8.832	8.357	7.640	0.96	1.26	1.52
18	0.100	0.1918	5.28	6.91	5.927	7.754	7.368	6.922	0.90	1.23	1.46
19	0.100	0.2392	2.62	3.94	3.410	4.751	4.463	4.210	0.67	0.91	1.07
20	0.100	0.3034	1.17	1.87	1.902	3.096	2.859	2.667	0.54	0.71	0.82
21	0.100	0.4703	0.61	0.78	0.834	1.477	1.333	1.224	0.36	0.48	0.52
22	0.100	0.4512	0.26	0.35	0.400	0.604	0.509	0.456	0.15	0.18	0.19
23	0.100	0.4311	0.08	0.15	0.187	0.290	0.247	0.220	0.06	0.08	0.08
			1544.3	1703.5	388.3	441.4	439.1	422.0	24.4	27.4	42.1

Table 11 The redfish abundance and biomass in Divs. 3 of NAFO area in accordance with the trawl-acoustic survey data of 1988

Area	Trawl survey		Acoustic survey		Total	
	Abundance, Ispec. x I10^{-6}	Biomass, thou.t	Abundance, Ispec. x I10^{-6}	Biomass, thou.t	Abundance, Ispec. (x I10^{-6})	Biomass, thou.t
3M	183.1	47.0	1660.0	410.0	1843.1	457.0
3LN	167.3	40.0	867.8	156.5	1035.1	196.5

Table 12 Abundance of redfish in Div. 3LN by different age groups and years of fishery, spec. (x10^{-6}). Calculated by VPA with natural mortality coefficients changes considered.

Age, years	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
5	112.54	124.34	124.90	140.61	153.95	184.14	342.78	644.55	393.21	391.17
6	85.84	97.28	109.87	105.77	118.35	134.34	163.72	299.63	559.02	351.45
7	71.04	75.12	87.11	93.00	84.57	98.75	119.14	140.07	253.01	499.62
8	65.11	63.38	68.33	75.34	76.60	69.23	87.81	103.14	117.42	207.96
9	40.98	57.27	57.40	57.57	60.68	62.19	59.95	72.45	72.73	78.37
10	31.89	35.82	52.20	47.85	45.07	49.62	54.63	52.96	52.96	44.01
11	21.31	27.85	30.86	43.71	37.95	35.01	42.13	46.24	34.28	28.99
12	28.52	18.87	24.57	26.45	40.14	34.80	31.18	38.91	39.98	22.57
13	27.65	25.98	15.00	20.04	23.77	36.87	30.56	28.40	32.52	30.48
14	25.86	25.46	22.33	11.96	18.45	21.98	34.41	28.53	21.70	23.92
15	14.74	23.96	22.58	19.99	10.96	17.15	20.40	32.34	23.93	15.27
16	14.67	12.98	20.94	19.80	18.27	9.89	15.50	18.26	28.82	18.65
17	6.05	12.56	10.89	18.00	17.52	16.16	8.37	13.36	15.52	23.07
18	6.45	4.82	10.38	8.89	15.41	15.00	13.78	7.03	10.90	11.38
19	10.20	4.75	3.46	7.93	7.12	12.44	12.01	10.81	5.15	7.73
20	8.41	7.37	3.27	2.19	5.95	5.36	9.33	8.84	7.81	3.30
21	3.99	5.02	4.15	1.12	1.45	4.09	3.62	6.10	5.84	4.84
22	2.83	2.28	2.91	2.30	0.67	0.87	2.49	2.12	3.58	3.36
23	1.50	1.33	0.99	1.25	1.21	0.35	0.46	1.31	1.02	1.81
	579.6	626.4	672.1	703.8	738.1	807.4	1052.5	1551.5	1679.4	1768.0

Table 13 Biomass (thou.t) of redfish in Div. 3LN by different age groups and years of fishery. Calculated by VPA with natural mortality coefficients changes considered.

Age, years	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
5	20.26	15.54	23.61	22.78	22.63	25.78	42.85	77.35	35.00	34.814
6	18.80	21.11	24.94	24.01	26.27	30.09	30.29	41.35	75.47	40.066
7	16.77	18.33	21.34	22.78	19.71	24.29	28.59	27.59	37.95	72.945
8	18.75	16.10	19.68	24.48	24.28	17.65	23.71	26.40	24.54	40.344
9	14.06	18.79	19.40	20.50	21.48	22.51	18.89	21.59	19.78	20.534
10	13.01	12.50	22.50	19.04	18.57	19.75	22.56	18.78	17.21	14.258
11	9.23	11.87	13.95	19.32	16.40	16.07	18.62	20.11	13.30	11.248
12	13.75	9.78	13.02	13.94	18.86	18.19	15.75	19.65	17.95	10.315
13	16.01	14.65	9.18	12.27	12.67	20.72	17.42	16.36	16.75	15.973
14	17.48	16.14	14.78	7.96	11.53	15.06	22.50	18.54	13.26	14.330
15	10.70	17.35	17.34	14.49	7.86	12.42	14.89	23.61	16.32	10.415
16	11.65	10.42	17.54	15.72	14.41	7.22	12.71	14.61	21.59	13.929
17	5.19	10.43	9.58	15.63	14.51	13.33	7.49	11.46	12.55	18.597
18	6.31	4.62	9.59	8.30	13.90	13.56	12.29	6.42	9.52	10.402
19	10.06	4.95	3.68	8.06	6.92	11.64	11.89	10.77	4.86	7.604
20	8.66	7.61	3.63	2.40	6.35	5.42	9.61	9.30	8.39	3.559
21	4.49	5.85	4.83	1.32	1.66	4.59	3.88	6.87	6.66	5.574
22	3.36	2.66	3.43	2.74	0.80	1.02	2.92	2.53	4.23	4.124
23	1.80	1.60	1.23	1.50	1.45	0.41	0.56	1.59	1.26	2.307
	220.3	220.3	253.3	257.2	260.2	279.7	317.4	374.9	356.6	351.3

Table 14 The redfish natural (M) and fishing mortality in Div. 3LN within one-year of life

Age, years		1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
5	0.100	0.0457	0.0237	0.0662	0.0724	0.0362	0.0175	0.0345	0.0424	0.0123	0.0370
6	0.080	0.0534	0.0304	0.0867	0.1437	0.1010	0.0401	0.0761	0.0891	0.0323	0.0671
7	0.060	0.0541	0.0347	0.0852	0.1340	0.1402	0.0574	0.0842	0.1163	0.1361	0.0742
8	0.040	0.0883	0.0592	0.1314	0.1764	0.1684	0.1039	0.1523	0.3093	0.3643	0.1228
9	0.030	0.1047	0.0627	0.1519	0.2147	0.1712	0.0996	0.1632	0.2834	0.4725	0.1234
10	0.020	0.1154	0.1291	0.1574	0.2117	0.2327	0.1435	0.1468	0.3459	0.5825	0.1548
11	0.010	0.1115	0.1153	0.1442	0.0754	0.1000	0.1058	0.0696	0.1353	0.4079	0.1119
12	0.020	0.0734	0.2099	0.1838	0.0867	0.0648	0.0866	0.0735	0.1595	0.2513	0.1224
13	0.030	0.0526	0.1213	0.1967	0.0528	0.0482	0.0391	0.0388	0.2390	0.2769	0.1059
14	0.040	0.0365	0.0798	0.0706	0.0466	0.0330	0.0348	0.0221	0.1358	0.3113	0.0785
15	0.070	0.0575	0.0648	0.0617	0.0201	0.0330	0.0314	0.0409	0.0451	0.1795	0.0736
16	0.110	0.0452	0.0658	0.0410	0.0122	0.0124	0.0338	0.0382	0.0525	0.1124	0.0486
17	0.150	0.0778	0.0404	0.0525	0.0056	0.0053	0.0097	0.0481	0.0539	0.1601	0.0282
18	0.210	0.0962	0.1210	0.0602	0.0128	0.0042	0.0118	0.0328	0.1014	0.1337	0.0382
19	0.280	0.0454	0.0933	0.1784	0.0070	0.0024	0.0071	0.0274	0.0445	0.1657	0.0410
20	0.370	0.1465	0.2041	0.7002	0.0441	0.0056	0.0239	0.0557	0.0440	0.1091	0.1603
21	0.490	0.0700	0.0561	0.0989	0.0182	0.0176	0.0059	0.0468	0.0421	0.0633	0.0713
22	0.630	0.1243	0.2092	0.2124	0.0147	0.0407	0.0047	0.0142	0.1041	0.0528	0.1060
23	0.800	0.1300	0.1803	0.3803	0.0294	0.0243	0.0127	0.0417	0.0699	0.0846	0.1254
5-23		0.0678	0.0627	0.1077	0.1164	0.0978	0.0559	0.0722	0.1084	0.1304	0.0809

Table 15 The estimate of redfish stock size and TAC in Div. 3LN for 1990

Age	Natural mortality coefficients	Instanteous fishing mortality coefficients	Initial abundance in 1988, spec.(x 10^{-6})	Stock at the beginning of 1989		Stock size (thou.t) at the beginning of 1990 at various vallues (F) in 1989			Catch size (thou.t) in 1990 at		
				Abundance, spec. (x 10^{-6})	Biomass, thou.t	$F_{0.1}$ = 0.18	F_{1989} = F_{1988}	F_{msy} = 0.26	$F_{0.1}$ = 0.18	F_{1990} = F_{1988}	F_{msy} = 0.26
5	0.100	0.0370	391.17	391.17	34.814	34.814	34.814	34.814	1.26	1.20	1.83
6	0.080	0.0671	351.45	341.09	38.884	38.818	38.884	38.120	2.43	2.43	3.46
7	0.060	0.0742	499.62	303.38	44.293	42.973	42.987	41.635	3.22	2.98	4.51
8	0.040	0.1228	207.96	436.88	84.754	51.144	51.464	49.251	5.99	5.83	8.24
9	0.030	0.1234	78.37	176.72	46.299	96.833	97.265	91.223	12.17	11.13	16.33
10	0.020	0.1548	44.01	67.23	21.782	48.478	49.113	45.474	7.79	6.98	10.31
11	0.010	0.1119	28.99	36.95	14.336	21.420	21.901	19.714	2.65	2.31	3.48
12	0.020	0.1224	22.57	25.66	11.728	14.636	14.948	13.751	1.89	1.71	2.53
13	0.030	0.1050	30.48	19.58	10.257	11.463	11.662	10.736	1.24	1.15	1.67
14	0.040	0.0785	23.92	26.63	15.953	10.127	10.245	9.588	0.87	0.76	1.19
15	0.070	0.0736	15.27	21.25	14.493	15.919	16.134	15.248	1.27	1.11	1.76
16	0.110	0.0486	18.65	13.23	9.882	13.574	13.751	13.035	0.77	0.62	1.08
17	0.150	0.0282	23.07	15.91	12.825	8.977	9.098	8.720	0.35	0.24	0.49
18	0.210	0.0382	11.38	19.31	17.647	11.998	12.169	11.761	0.60	0.41	0.85
19	0.280	0.0410	7.73	8.88	8.737	14.547	14.823	14.163	0.64	0.52	0.91
20	0.370	0.1603	3.30	5.61	6.054	6.882	6.957	6.717	0.86	0.87	1.20
21	0.490	0.0713	4.84	1.94	2.234	3.794	3.800	3.517	0.21	0.21	0.28
22	0.630	0.1060	3.36	2.76	3.390	1.358	1.358	1.314	0.10	0.10	0.14
23	0.800	0.1254	1.81	1.61	2.051	1.685	1.686	1.603	0.14	0.14	0.19
			1768.0	1915.8	400.4	449.4	453.1	430.4	44.5	40.7	60.4

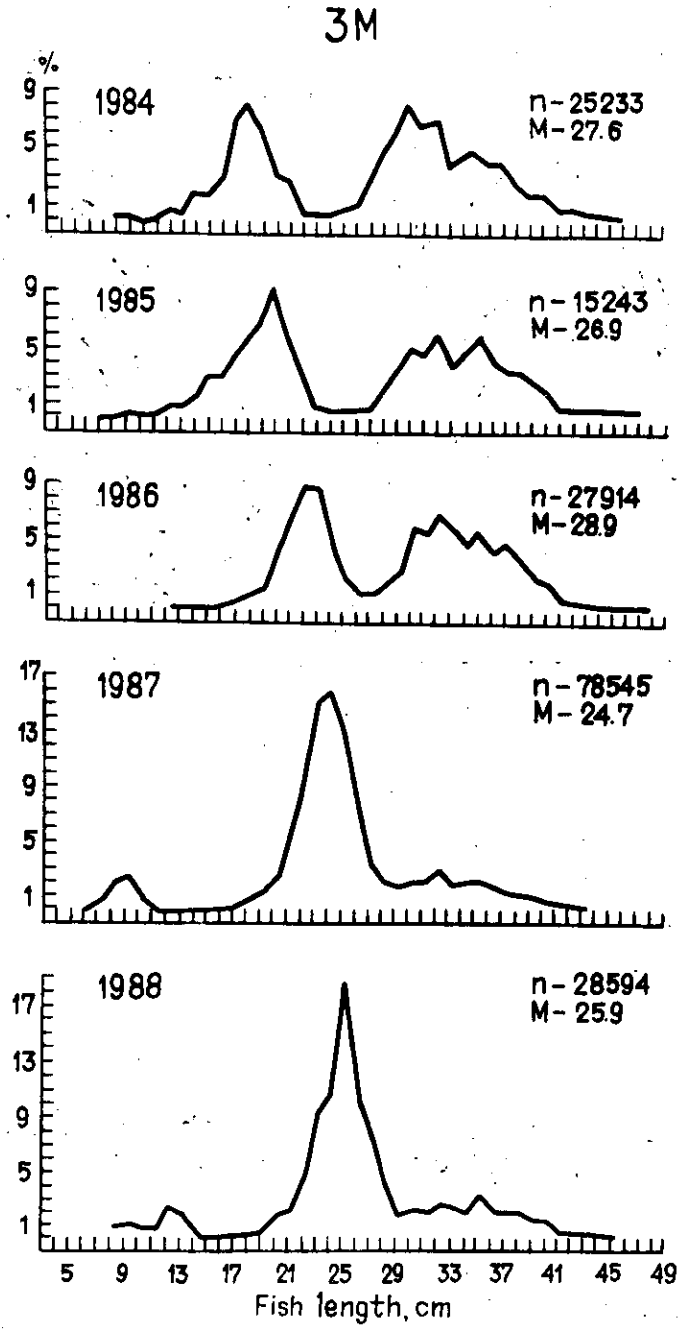

Fig.1. The redfish length composition from the catches by small-meshed trawl in the Flemish Cap area in 1984-1988

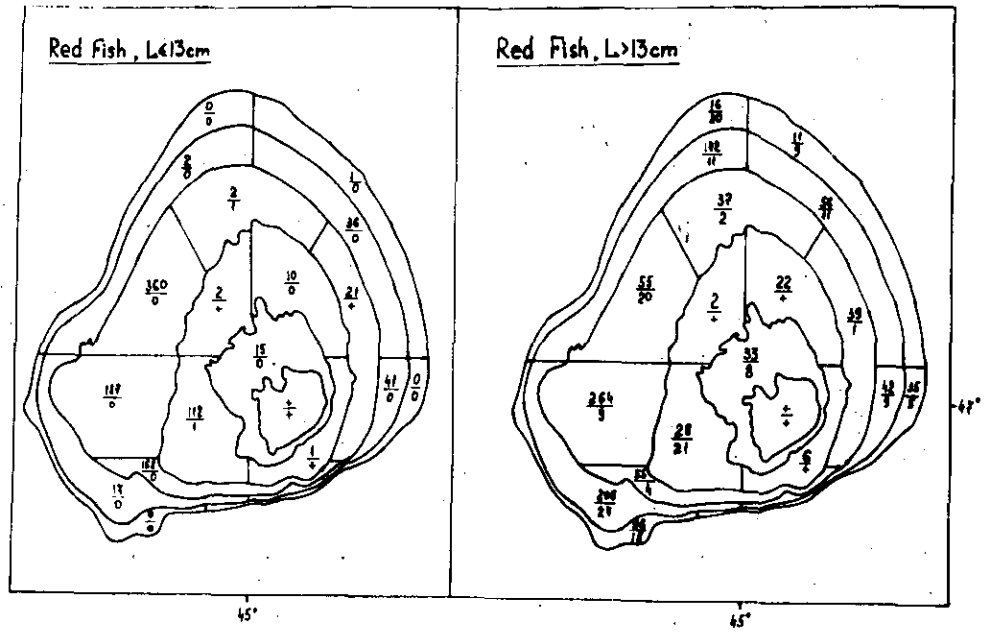

Fig.2 The redfish distribution in Flemish Cap area during the acoustic survey conducting in June of 1988

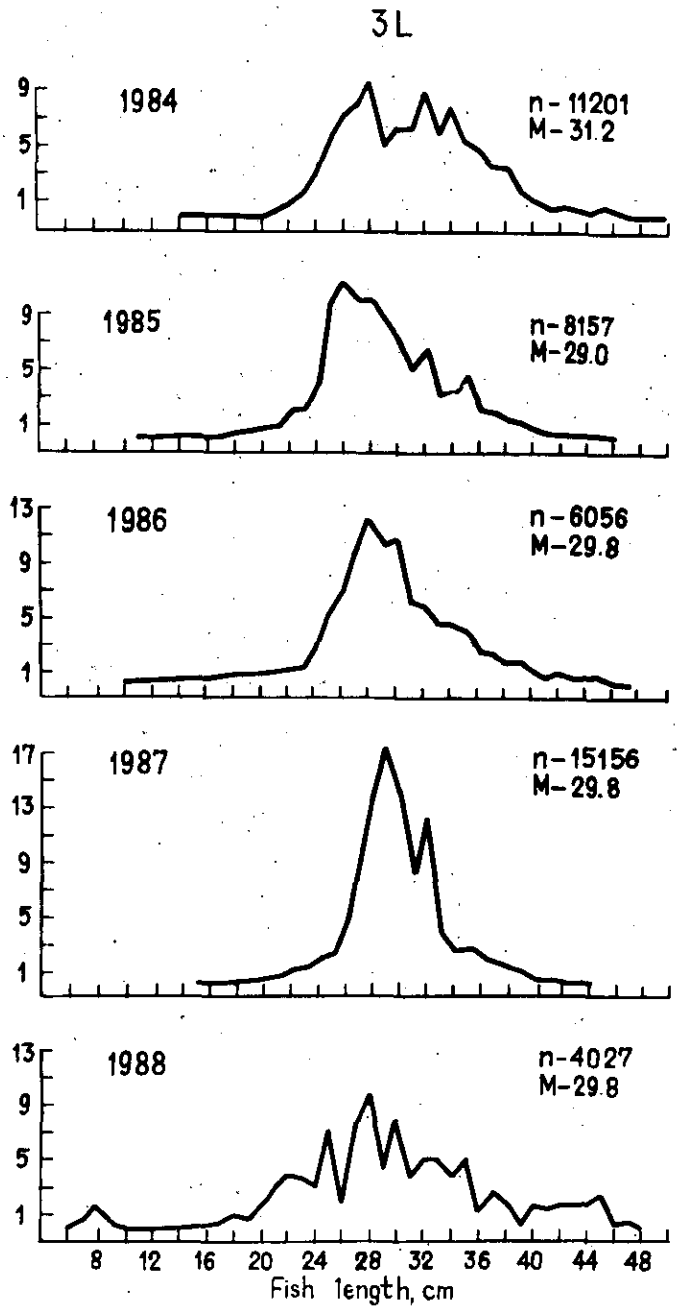

Fig.5 The redfish length composition from the catches by small-meshed trawl in Div. 3L in 1984-1988

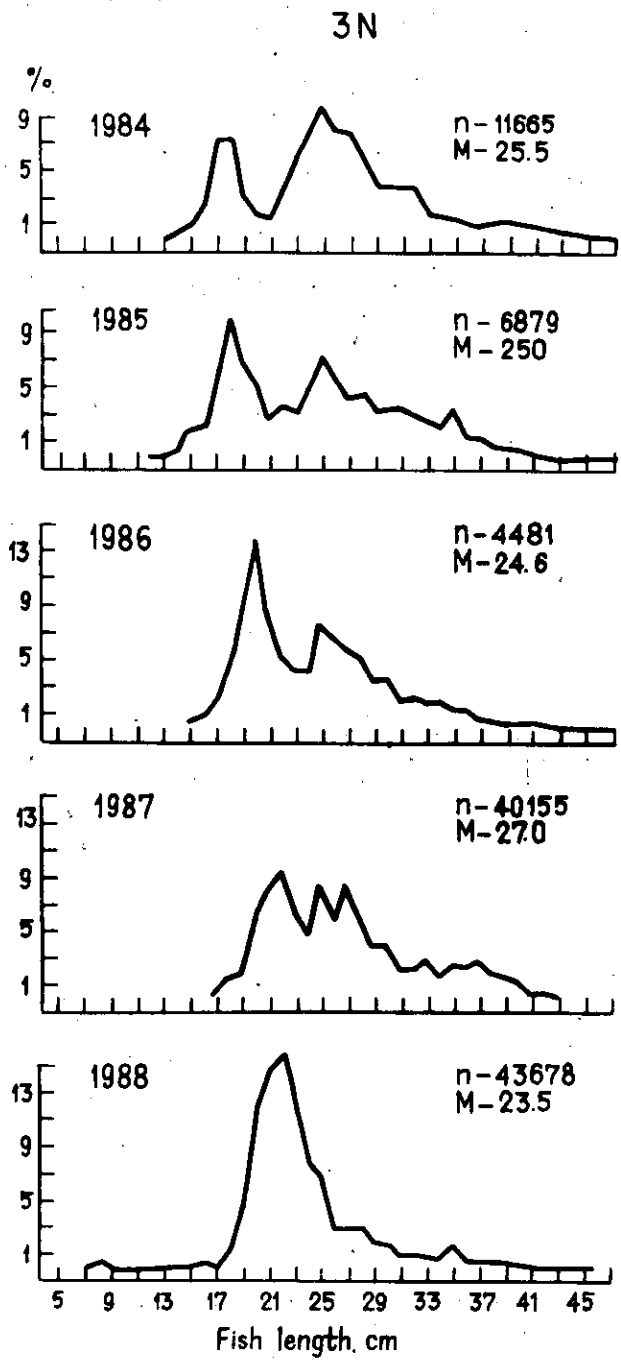

Fig.4 Redfish length composition from catches by small-meshed trawl in Div. 3N in 1984-1988

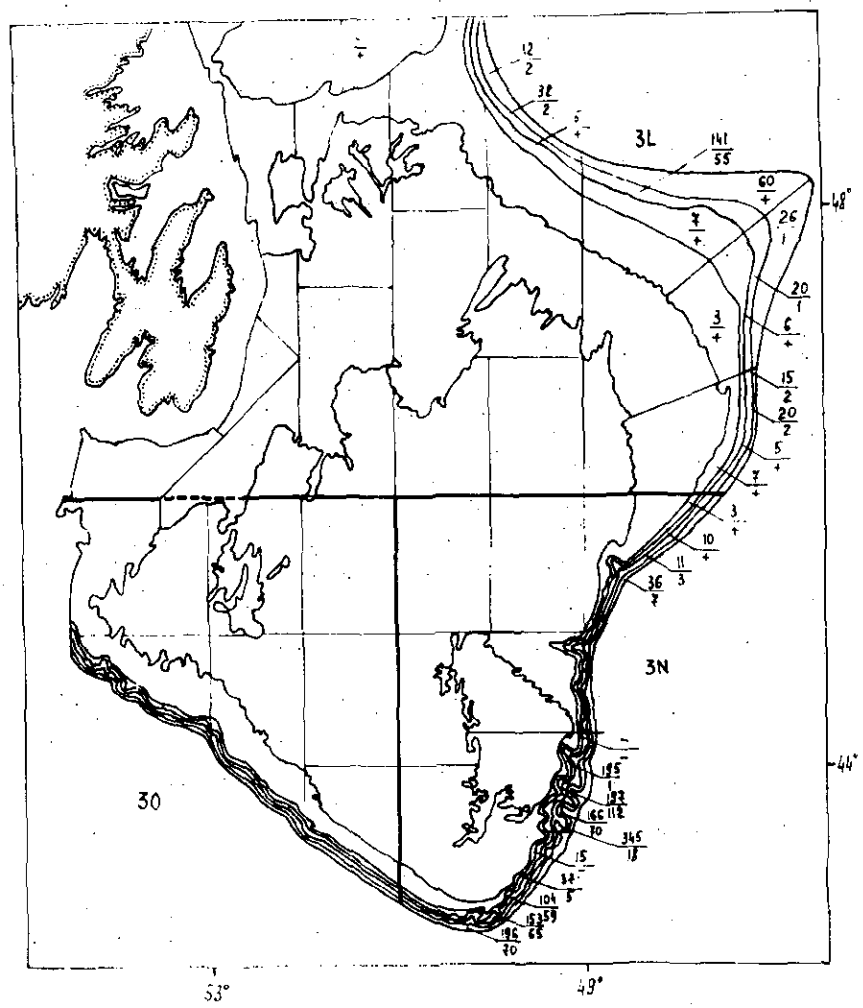

Fig.5 Redfish distribution in Div. 3LN during the acoustic survey in March-June of 1968