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The Redfish Resource in NAFO Div. 3M

by

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Introduction

Nominal landings for this stock have been in the range of 14,000 t - 35,000 t since 1976 (Table 1, Fig. 1). The present TAC of 20,000 t has been achieved each year since 1983. Provisional catch statistics provided by NAFO indicate the TAC was exceeded by 9,000 t in 1986 and by 15,000 t in 1987 due to increased landings reported by the EEC (primarily Portugal). Monthly catch statistics since 1976 indicate that redfish are landed throughout the year but catches are generally greater in the Jan. to Aug. period (Table 2).

Up until 1987 the USSR fleet has been predominant in this fishery accounting for at least half of the reported landings in each year and in some years as much as 77%. Catch statistics for which associated effort is available suggest that there has been a steady increase in the utilization of midwater trawls from 1976 to 1986 such that it is now the prominent gear in the fishery.

Insufficient commercial sampling within Canada precludes the use of sequential population analysis (SPA) on this stock and evaluation of the status of this resource has been based solely only on catch and effort data.

Methods and Results

A catch and effort database was compiled from ICNAF/NAFO Statistical Bulletins for the 1959-1985 period. Preliminary NAFO data for 1986 were appended to this database. Initially selected from this source were those observations where redfish comprised more than 50% of the total catch as these were considered to be redfish directed catches. This database was utilized in a multiplicative model (Gavaris 1980) to derive a standardized catch rate series for the 1959 to 1986 period. Catch and/or effort data less than 10 units as well as less than five samples of country-gear-tonnage class (CGT) or month categories were deleted before proceeding to run the model. In previous assessments (cf. Power and Atkinson 1987) the CGT category type had not separated a vessel as a side or stern trawler. In this assessment, for both bottom and midwater trawl data, vessels were further identified as side or stern because it was considered a possible source of variation in the data. In cases where this information was not specifically coded in the NAFO statistics, we reviewed: (1) NAFO lists of fishing vessels operating in the convention area, (2) Lloyd's Registry of Ships and consulted with the Foreign Observer Program (NF. Region) before deciding whether to code an observation as a side or stern.

In past assessments grouping of similar categories within a category type a posteriori had been questioned by some as being statistically invalid. This year, with the addition of the side or stern component to the data, it was decided not to do any grouping. Again an unweighted regression was chosen because of unknown percentages of pro-rating of effort data prior to 1984.

The regression (Table 3) was highly significant ($p<0.01$, $r^2=.64$). The CGT effect (type 1) and the year effect (type 4) are both highly significant ($p<0.01$ for each) but there was no significant month effect ($p>0.25$). The regression coefficients are listed for each category in Table 5. The codes for the composite CGT categories are those used by NAFO (cf. 20127 is a USSR - Bottom Trawl (Stern) - tonnage class 7 vessel). It is interesting to note that although

there is a significant year effect, only 1961, 1970 and 1971 seem to be significantly different from the reference chosen (1959). Standardized effort (Table 4, Fig. 2) has been in the range of 12,000 hours since 1983. The standardized catch rate series (Table 4, Fig. 3) shows a general decline from 1961 to 1967 followed by a sharp increase to the highest rate recorded in the series in 1970. Subsequently catch rates declined sharply to 1972 and since then have shown relative stability with the standardized catch rate between 1.6 and 2.1 tons per hour. Preliminary 1986 data indicate an increase in the catch rate from the 1985 value. However, there were almost 11,000 t caught by Portugal for which no effort data are available.

Catch rate and standardized effort from the multiplicative model were utilized in equilibrium general production analyses using values of effort lagged 6, 8 and 10 years (Gulland 1961). In general production analysis (Schaefer model) the usual relationship that has been used is a linear one between catch rate and effort (i.e. $C/f = a + bf$). However there is concern warranted here in that one may get spurious correlation because the effort term appears in both the dependent (C/f) and independent (f) variables. A quadratic relationship forced through the origin ($C = af + bf^2$) was therefore used to overcome this drawback, keeping in mind that one should examine the significance of the parameter estimates from the regression model to assess the appropriateness of this relationship. Both relationships were applied and the results are presented for comparative purposes (Table 6).

Using a linear relationship, the regression incorporating unlagged effort is marginally non-significant, however, these results were not taken any further as we felt than using lagged effort is more meaningful. The lag 6, 8 and 10 year effort relationships with catch rate were all significant ($p < 0.05$), however, as has been pointed out for a few years now (see cf. Power and Atkinson 1987) these relationships are all highly influenced by the 1970 and 1971 points. Regressions with these points removed from the unlagged effort data and their effect also removed in the lagging procedure were not significant in any instance ($p > 0.10$). The results using a quadratic relation between catch and effort were all significant ($p < 0.05$) but in all regressions the quadratic term was not significantly different from zero indicating a relationship other than a parabolic one. The general production results from the linear relationship are given in Table 7 and are quite similar indicating that MSY is in the range of 18000 t . Two-thirds of the effort to take MSY would result in a yield in the range of 16,000 t.

The catch and standardized effort calculated from the multiplicative model were also used as input to a non-equilibrium version of a general production model (Schaefer type) as outlined in Rivard and Bledsoe (1978). The final parameter estimates from last year's assessment (Power and Atkinson 1987) were used as starting input, however, the model would not converge when allowed to estimate the catchability coefficient (q). It is unclear to us why the model would not converge this year but one possibility is that previously the data only marginally meet the assumption of the model with regard to logistic growth. Given that the model did converge last year (Power and Atkinson 1987), projections were made to 1989 using the parameter estimates derived from that analysis. The actual catches for 1986 and 1987 were used and it was assumed that the catch in 1988 will equal the TAC of 20,000 t. The results are:

Parameter estimates used (from Power and Atkinson 1987):

B_∞ = 454,000 t (virgin stock biomass)
MSY = 21,053 t
q = 5.00767×10^{-6} (catchability coefficient)
Shape parameter = 2 (shape of the equilibrium curve)
Exploitable Biomass at the beginning of 1986 = 311,655 t

Projection for 1989:

Exploitable Biomass at the beginning of 1989 = 284294 t

	EFFORT (HRS)	YIELD (TONS)	EXPLOIT. BIOM. BEGINNING 1990 (TONS)
@MSY	18,504	26,050	278,109
@2/3 MSY	12,336	17,627	286,342

According to this model the high catches in 1986 and 1987 have reduced the exploitable biomass from about 312,000 t at the beginning of 1986 to about 284,000 t at the beginning of

1989. Another point to be noted is that fishing at MSY in 1989 will reduce the exploitable biomass available at the beginning of 1990 while fishing at 2/3 the effort at MSY allows for an increase at the beginning of 1990.

There was no commercial sampling of the catches by Canada from this stock in 1987. There has been no research conducted in the Div. 3M area by Canada since 1985.

Discussion/Prognosis

The standardized catch rate series, although showing some fluctuation in the late 1970s, indicates a fairly stable period from 1972 to 1985. Preliminary data for 1986 indicate a substantial rise in catch rate from 1985.This may be related to increased recruitment of the relatively strong year class(es) of the early 1980s. Also, there were no effort data available for Portugal which accounted for 11,000 t of the landings. Preliminary statistics for 1987 indicate that the TAC was exceeded by 15,000 t .

The results from the equilibrium general production analyses using a linear relationship between catch rate and lagged effort (6, 8 and 10 years) indicate an MSY level in the range of 18,000 t and yield at 2/3 effort at MSY to be in the range of 16,000 t. However, as was pointed out above, these results are to be considered with caution as the significance of these regressions were due to the 1970 and 1971 data and there may be spurious correlation because effort appears in both the dependent and independent variables.

Results projected for 1989 on the basis of parameters derived using a general production model under non-equilibrium conditions from the previous assessment (Power and Atkinson 1987) indicated a MSY of 26000 t and yield at 2/3 effort at MSY of about 17,600 t. According to this model the very high catches of 1986 and 1987 coincide with a reduction in exploitable biomass of about 27,000 t from 1986 to 1989.

References

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Table 1: Nominal catches (t) of redfish in Division 3M by country and year.

Country	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986*	1987*
Canada (M)+	4,040	1,402	486	443	218	12	-	-	-	-	-	-
Canada (N)	4,328	3,392	3,861	4,686	60	517	2	-	-	-	-	-
France (M)	-	546	242	67	15	7	-	-	-	-	-	-
France (SP)	-	25	-	-	-	-	-	-	-	-	-	-
FRG	44	10	300	-	73	-	41	-	769	848	145	-
GDR	-	-	-	-	1,290	15	-	40	98	-	88	-
Japan	-	138	321	636	976	386	392	390	389	313	400	354
Poland	30	11	83	13	292	-	-	-	-	-	-	-
Portugal	518	854	455	666	985	659	1,408	1,667	2,123	1,306	10,783	-
Romania	-	-	24	4	-	-	-	-	-	-	-	-
Spain	-	52	31	13	29	488	31	589	282	281	643	-
UK	-	376	20	-	-	-	3	-	-	-	-	-
USSR	8,038	9,507	9,251	10,441	10,430	10,434	10,916	14,517	15,005	15,703	15,045	13,596
Iceland	-	-	-	-	-	-	-	-	-	-	5	-
Ireland	-	2,503	767	-	-	-	-	-	-	-	-	-
Cuba	-	1,451	863	1,527	1,549	1,373	1,853	2,324	1,562	1,831	1,864	-
Bulgaria	-	-	58	1,578	50	-	-	-	-	-	-	-
Kor-S	-	-	-	-	-	-	38	-	-	-	-	-
EEC (Un.Sp.)	-	-	-	-	-	-	-	-	-	-	-	21,951
TOTAL	16,998	20,267	16,762	20,074	15,967	13,891	14,684	19,527	20,228	20,282	28,973	35,901

* Provisional.

Table 2: Nominal catches (t) of redfish in Division 3M by month and year.

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Total
1976	2	2	180	2,950	1,580	1,130	686	7,415	2,473	277	283	20	16,998
1977	417	532	2,786	1,847	1,821	3,649	4,284	1,416	590	243	81	98	20,267 a
1978	394	354	963	1,156	1,026	4,017	1,004	1,650	1,301	2,996	1,067	834	16,762
1979	790	1,560	896	4,237	5,147	2,394	1,393	56	111	1,486	1,369	635	20,074
1980	1,212	1,341	4,751	2,852	1,377	735	-	1,083	1,126	471	293	726	15,967
1981	198	849	2,671	5,120	1,615	711	698	952	847	7	149	74	13,891
1982	987	295	2,222	2,825	2,328	1,484	1,292	2,209	543	241	125	133	14,684
1983	2,393	1,014	1,128	2,260	2,395	3,099	3,384	1,529	1,500	691	51	83	19,527
1984	159	1,725	2,465	4,283	3,773	3,679	1,148	912	900	419	449	316	20,228
1985	267	422	445	656	2,172	79	3,135	7,308	1,046	614	2,051	2,087	20,282
1986*	3,892	3,563	2,852	1,844	4,176	117	2,582	5,942	2,501	742	322	440	28,973
1987*	3,423	5,244	1,594	1,296	1,036	811	254	4	4	-	93	138	35,901 b

* Provisional.
a includes a catch of 2,503 t from month 'unknown'.
b includes a catch of 22,004 t from month 'unknown'

Table 3. Analysis of variance results from the multiplicative model for redfish in Division 3M.

REGRESSION OF MULTIPLICATIVE MODEL

MULTIPLE R..... 0.801
MULTIPLE R SQUARED..... 0.642

ANALYSIS OF VARIANCE

SOURCE OF VARIATION	DF	SUMS OF SQUARES	MEAN SQUARES	F-VALUE
INTERCEPT	1	1.956E1	1.956E1	
REGRESSION	56	1.694E2	3.024E0	12.124
TYPE 1	18	1.120E2	6.223E0	24.948
TYPE 2	11	2.511E0	2.283E-1	0.915
TYPE 3	27	1.597E1	5.916E-1	2.372
RESIDUALS	379	9.454E1	2.495E-1	
TOTAL	436	2.835E2		

Table 4. Predicted standardized catch rate series for 3M redfish. (1986 is preliminary)

PREDICTED CATCH RATE

YEAR	LN TRANSFORM MEAN	LN TRANSFORM S.E.	RETRANSFORMED MEAN	RETRANSFORMED S.E.	CATCH	EFFORT
1959	0.5790	0.0259	1.996	0.320	51977	26044
1960	0.9470	0.1513	2.708	1.016	8388	3098
1961	1.2079	0.0902	3.625	1.066	15517	4281
1962	0.8276	0.0864	2.483	0.715	6958	2803
1963	0.7633	0.0757	2.341	0.633	7035	3006
1964	0.3717	0.2730	1.433	0.701	17647	12313
1965	0.6630	0.0700	2.123	0.553	33427	15743
1966	0.3335	0.2921	1.366	0.688	7241	5300
1967	0.1219	0.2916	1.106	0.557	729	659
1968	0.6963	0.0690	2.196	0.568	4963	2260
1969	0.6011	0.1003	1.966	0.608	2801	1425
1970	1.5406	0.0537	5.149	1.178	3168	615
1971	1.2084	0.0289	3.740	0.632	8033	2148
1972	0.7282	0.0207	2.323	0.333	41946	18056
1973	0.6512	0.0366	2.134	0.405	22352	10475
1974	0.6677	0.0187	2.189	0.298	34671	15839
1975	0.5031	0.0184	1.857	0.251	16075	8657
1976	0.4296	0.0225	1.722	0.257	16998	9872
1977	0.3533	0.0191	1.598	0.220	20267	12682
1978	0.4538	0.0181	1.768	0.237	16762	9481
1979	0.2549	0.0143	1.452	0.173	20074	13827
1980	0.5992	0.0170	2.046	0.266	15957	7801
1981	0.5369	0.0169	1.922	0.249	13891	7227
1982	0.5307	0.0162	1.911	0.242	14684	7684
1983	0.3845	0.0183	1.649	0.222	19527	11839
1984	0.3511	0.0212	1.593	0.231	20228	12699
1985	0.4096	0.0243	1.686	0.262	20282	12029
1986	0.7356	0.0308	2.329	0.406	28973	12442

AVERAGE C.V. FOR THE RETRANSFORMED MEAN: 0.223

Table 5. Regression coefficients from the multiplicative model for redfish in Division 3M.

REGRESSION COEFFICIENTS

CATEGORY	CODE	VARIABLE	COEFFICIENT	STD. ERROR	NO. OBS.
1	20127	INTERCEPT	0.579	0.131	436
2	4				
4	59				
1	2125	1	0.039	0.187	10
	2155	2	0.314	0.251	8
	3125	3	-0.696	0.165	12
	3154	4	0.120	0.197	8
	3155	5	0.501	0.136	21
	4127	6	-0.065	0.157	14
	4157	7	0.479	0.137	20
	10127	8	-0.135	0.197	8
	14125	9	-1.266	0.177	10
	14126	10	-0.922	0.136	20
	14127	11	-0.610	0.117	30
	14156	12	-0.982	0.225	6
	16127	13	-0.931	0.179	13
	17127	14	-0.644	0.190	9
	20114	15	-1.763	0.153	35
	20116	16	-0.512	0.204	12
	20157	17	0.484	0.082	102
	27125	18	0.236	0.222	6
2	1	19	-0.258	0.134	21
	2	20	-0.130	0.124	26
	3	21	-0.218	0.105	41
	5	22	-0.136	0.108	38
	6	23	-0.174	0.106	45
	7	24	-0.103	0.104	49
	8	25	-0.107	0.105	48
	9	26	-0.234	0.112	36
	10	27	-0.285	0.122	28
	11	28	-0.197	0.124	26
	12	29	-0.161	0.135	21
4	60	30	0.366	0.399	2
	61	31	0.629	0.309	4
	62	32	0.249	0.306	4
	63	33	0.184	0.284	5
	64	34	-0.207	0.535	1
	65	35	0.084	0.277	5
	66	36	-0.245	0.550	1
	67	37	-0.457	0.549	1
	68	38	0.117	0.275	5
	69	39	0.022	0.328	3
	70	40	0.962	0.248	7
	71	41	0.629	0.201	14
	72	42	0.149	0.188	17
	73	43	0.072	0.229	8
	74	44	0.089	0.186	21
	75	45	-0.076	0.186	21
	76	46	-0.149	0.198	22
	77	47	-0.226	0.189	26
	78	48	-0.125	0.184	31
	79	49	-0.324	0.175	43
	80	50	0.020	0.180	29
	81	51	-0.042	0.181	27
	82	52	-0.048	0.180	28
	83	53	-0.194	0.182	29
	84	54	-0.228	0.188	24
	85	55	-0.169	0.199	19
	86	56	0.157	0.210	14

Table 6: Summary of linear and quadratic regression results relating catch and effort derived from the multiplicative analysis

a) Linear regressions of CPUE on effort ($C/f = a + bf$)

LAG	a	b	r^2	p-value
0	2.599	-0.000049483	.1315	.0579
0[1]	2.103	-0.000012722	.0223	.4661
6	3.624	-0.000186979	.3547	.0027
6[1]	1.986	-0.000016698	.0132	.6205
8	3.530	-0.000173409	.2349	.0260
8[1]	2.148	-0.000033626	.0533	.3417
10	4.027	-0.000223563	.3365	.0092
10[1]	2.450	-0.000057548	.1655	.1052

b) Quadratic regressions of catch on (effort,effort^2) $C = af + bf^2$

LAG	a	b	p-value (a)	p-value (b)
0	1.789	0.00000950	.0001	.3616
0[1]	1.768	0.00001060	.0001	.3132
6	3.721	-0.00018137	.0098	.1827
6[1]	3.377	-0.00014261	.0146	.2410
8	3.294	-0.00014390	.0177	.2795
8[1]	3.325	-0.00014221	.0262	.2902
10	4.014	-0.00020537	.0077	.1583
10[1]	4.345	-0.00023160	.0126	.1411

[1]Indicates that the 1970 and 1971 points were removed and their presence in the lagged effort values were removed as well

Table 7. Equilibrium general production results derived from significant relationships obtained from Table 6.

RELATIONSHIP USED	MSY Effort (hr)	MSY Yield (t)	MSY CPUE (t/hr)	2/3 effort @MSY Effort (hr)	2/3 effort @MSY Yield (t)	2/3 effort @MSY CPUE (t/hr)
Linear, 6 yr lag	9690	17557	1.81	6460	15607	2.42
Linear, 8 yr lag	10179	17969	1.77	6786	15972	2.35
Linear,10 yr lag	9007	18136	2.01	6005	16121	2.68

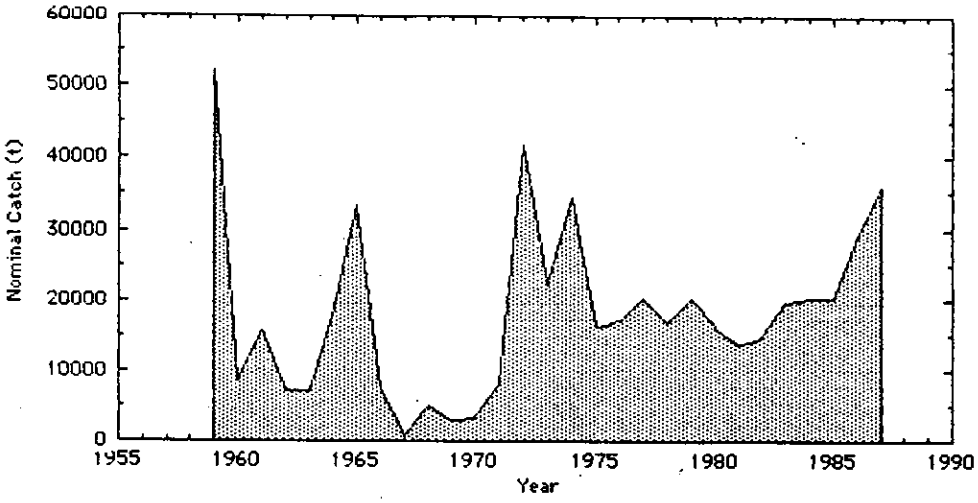

Figure 1 : Nominal catches of redfish in NAFO Division 3M, 1959-1987 (1986 and 1987 are provisional).

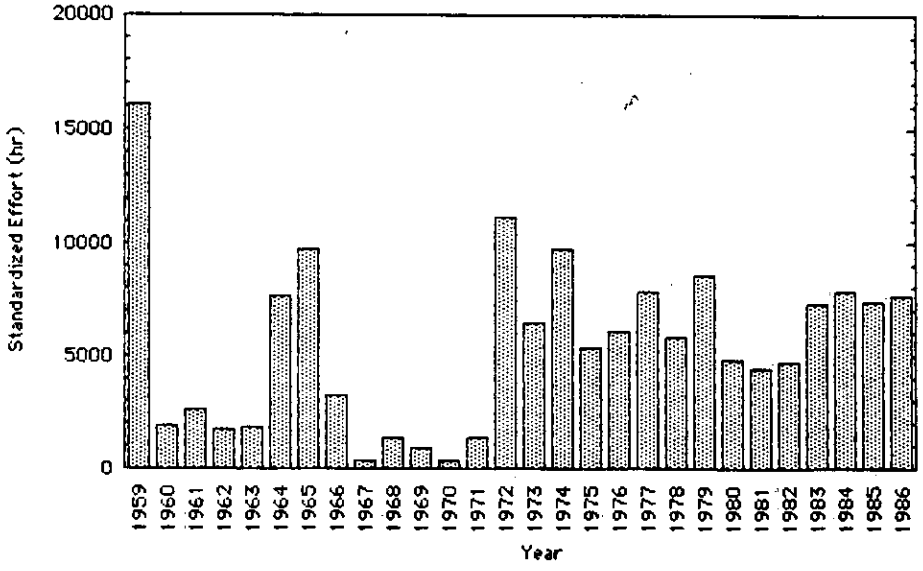

Figure 2 : Standardized effort for redfish in NAFO Division 3M derived from the multiplicative model (1986 and 1987 are provisional).

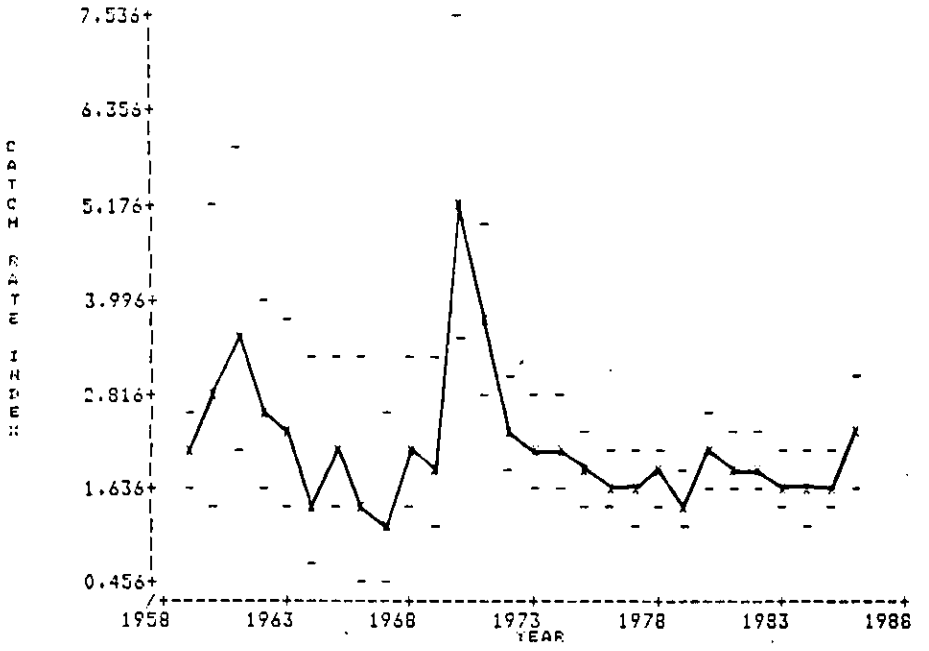

Figure 3. Plot of predicted standardized catch rates for redfish in Div. 3M for the period 1959 to 1986 as derived using a multiplicative model (1986 is preliminary)