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Redfish Stock Size in Division 3M in 1990 and Estimated TAC for 1992

by

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INTRODUCTION

The assessment of the redfish stock state in the 3M divisions is a traditional problem which is carried out for many years. The 1991 TAC was established by Scientific Council at 43,000 t based on F 0.1, as applied to average biomass for the recent 3 years resulted from the USSR trawl and acoustic surveys.

Further studies aimed at the stock assessment and TAC estimates were recommended to be assisted by a sequential population analysis.

The paper attempts at making the above assessment using data since 1968 and involving standardization of fishing effort, VPA's tuning, determination of optimum fishing parameters and TAC estimate for 1992.

2. MATERIAL AND METHODS

2.1. Fishery

Fishery pattern for redfish since 1990 was described by Power and Atkinson (1989). The 3m redfish catch amounted to 39456 tons in 1990.

2.2. Age composition of catches and average weight of redfish

VPA was made on the basis on catch at age date in 1968-1990. The 1968-1977 data were obtained from PINRO and information for 1978- 1989 was derived from the paper by Vaskov et al (1990). Catch at age data were obtained from age determinations made by the scientists from PINRO (table 1). Table 2 provides information on average weight at age. Average weight in 1990 was assumed as the average long-term value.

2.3. Standartized catch rate and fishing effort

Data on catch and catch rate were obtained from Statistical Bulletins of ICNAF and NAFO of 1968-1987. Information for 1988-1990 was provided by the Soviet fishing fleet exclusively.

The above date were broken dawn by years and months with account taken of fishing States, types of gear and vessel tonnages. Catch rate was determined as hours of trawlings, due to which the information devoid of these parametrs was omitted. The criterion of data selection was the redfish catch exceeding 2/3 of the total 3M yield, which comprised 402 enteries.

Standartization was based on a multiplicatie model developed by Gavaris (1980). The model parameters were calculated using an alsorithm of multiple regression without weighing. Results of estimates are presented in Tabeles 3, 4 and 5. The multiple correlation coefficient appeared to equal 0.66.

The temporal dynamics of standardized catch rate values is presented on Fig.1.The data analysis has shown that the catch rate viewed as an indicator of stock size demonstrates a stable of redfish population with a certain upward trend since 1985, which was noted by Power and Atkinson (1990).

A certain deviation from the stable state recorded in 1970-1971, seemed to be related to spatial distribution pattern of redfish. The curve shape Fig.1 is in a good agreement with the results obtained by Power, Atkinson(1989)

Figure 2 and 3 provide a diagram of the multiplicative model remainders and a graph of expected normal values.

3. POPULATION PARAMETERS

Natural fishing mortality rate of 3M redfish is assumed as age-constant and it equales 0.1 (Power & Atkinson, 1989).

4. SEQUENTIAL POPULATION ANALYSIS

A great variety of methods can be involved in the analysis,the most common of which are adaptive approach developed by Gavaris (1988) and VPA's tunings on the basis of catch rate (Pope & Shepard, 1985).

Adaptive approach presents difficulties in catch rates during the period examined.

The stability of redfish stock size as evidenced from temporal dynamics of standardized catch rates is indicative of the applicability of method decribed by Pope and Shephard (1985).

However long-term data should be interpreted with account taken of catch rate and temporal dynamics.

Based on the results of a number of original calculations accompanied by the analysis of some statistical parameters such as correlation coefficient between fishing mortality at individual age and fishing effort and comparison between biomass estimates derived from VPA and from trawle and acoustic surveys it is concluded that redfish population analysis demands the approach which involves catchability rate.

Based on fitting an equation of regression between logarithms of catchability rate and values of fishing effort followed by calculating of catchability rate values in the terminal year. This method was implemented in the Lowestoft laboratory programme (Flatman, Stevens, 1988).

Taking into account that the standardized values of catch rate in 1970-1971 are apparently abnormal the VPA adjustment was made using the 1972-1990 data. The final VPA analysis, however, covers the entire time period beginning from 1968.

The rates of fishing mortality, abundance and biomass by ages and fishing years resulting from the estimations are given in Tables 6, 7 and 8.

Some numbers in tables were corrected. In particular, the abundance, biomass and fishing mortality rates for age group 5 in 1989 and 1990 were corrected; as a consequece, similar parameters for age group 6 in 1990 were corrected too. The correction included substitution of estimated abundancies with the mean geometrical value respectively for 1968-1987 and 1968-1988. This was done because there were unbelievable high values of estimates obtained (N = 637155, N = 2184146, N = 570705). After the correction, fishing mortality rates and biomass by the beginning of the year were separately recalculated.

Table 9 shows statistical characteristics of catchability rate determination, and correlation coefficients between fishing mortality rates by age groups and fishing effort. High values of correlation coefficients for age groups 12-16 are notable.

The degree of relationship between the average weighted fishing mortality rate and fishing effort can serve as another characteristic of VPA adjustment. The curve of such relationship for age groups 10-16 is given in Figure 4; its degree for this case expressed by correlation coefficient of 0.92. Figure 5 shows the curve of such relationship for age groups 6-17; correlation coefficeent for this case is 0.73.

It may by concluded from the above facts the VPA adjustment using the suggested method was done satisfactorily. It can be concluded therefore that the 3M redfish stock was stable indeed beginning from 1968, and that there was some increase in its biomass and abundance after 1985. The stock size by the beginning of 1990 was 1840902 thousand which corresponds to biomass of 434.8 thousad tons.

5. YIELD-PER-RECRUIT ANALYSIS

Partial recruitment rates were found by the method of separable Virtual Population (Pope, Shepherd, 1982).Using the results of VPA adjustment we chose age group 12 for which the age selectivity coefficient was assumed to be 1 while the overall fishing mortality rate was taken as 0.263.

Separable VPA estimations (Flatman, Stevens, 1988) gave the following characteristics:

- initial sum of residuals sguares - 388.68;
- final sum of residuals squares - 235.16;

there were 123 iterations made there.The calculated values of age selectivity are given in Table 10. As their analysis indicates, the curve of age selectivity of redfish is dome-shaped.

After calibration these values were used to assess yield-per-recruit by Thompson and Bell technique (Ricker, 1975). The average multiannual weights of fish needed for calculations are given in Table 11. The results of estimations made with the aid of a set of programmes (Rivard, 1982) are given in Tables 11 and 12.

Thus it is assumed that F 0.1 = 0.2514, F msy = 0.4759.

6. ESTIMATED TAC FOR 1992

The TAC for 1992 was estimated under the following assumptions:

- the average weight of fish will be on the level of average multiannual values;
- partial recruitment rates correspond to those given in Table 11;
- the abundance of age group 5 in 1991 and 1992 will remain on the level of the mean geometrical value for the past ten years;
- the total catch of redfish in 1991 will be on the level of recommended TAC reaching 43 thousand tons;
- fishing intensity in 1992 will correspond to values F 1990; F 0.1 and F msy.

The results of calculations of TAC are given in Tables 13, 14 and 15. They indicate that the estimated stock of 3M redfish by the beginning of 1992 will be 451.4 thousand tons, TAC - 32.5-58.9 thousand tons.

These results have to be examined more thorougly. If the 1991 1992 fishing regimes are compared, might point out a rather low value of TAC for 1992 corresponding to F 01. At the same time fishing intensity assumed for 1991 exceeds F 0.1 providing for a TAC of 43 thousand tons which nevertheless does lead to a stock decrease by early 1992. This indicates that under a stable population F 0.1 regime is too "sparing", and could be somewhat increase. That is why the standard set of TAC estimations was supplemented by another set which would correspond to fishing regime determined by the following rate of fishing mortality:

$$F^* = \frac{F0.1 + Fmsy}{2} = 0.364$$

The results are shown in Table 16. Under such a fishing regime the TAC will be 46 thousand tons.

Table 17 provides TAC values for 1992 under various regimes of 1993. These results show that virtually no biomass decrease occurs when the recruitment is on the level of the mean geometrical value. This makes it possible for us recommend TAC for 1992 in the amount of 46 thousand tons.

7. CONCLUSION

Standardization of fishing effort at NAFO 3M redfish fishery, sequenteal analysis of the catch at age resulted in stock assessment and optimal fishing mortality estimation (F0.1= 0,2514, Fmsy=0,4759). Given those fishing mortality and current (1990) fishing explotaition rate the TACis estimated at 32.5-58.9 thousand tons. Additional calculations showed that even MSY level of exploitation rate would not cause a decrease in biomass by the beginning of 1993. It is suggested to utilize a regime of fishery that would correspond to the average value of fishing mortality rate between F0.1 and Fmsy which makes it possible to recommend TAC of 46000 tons.

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Table 1. Catch numbers at age Numbers*10**-3

REDFISH,DIVISION 3M,1968-1990, AGES 5-23

YEAR	1968	1969	1970
AGE			
5	4	6	108
6	29	29	212
7	114	108	204
8	183	228	725
9	287	370	1279
10	440	517	976
11	633	549	801
12	779	467	809
13	1133	531	640
14	1139	457	538
15	1009	358	364
16	769	251	225
17	465	120	125
18	339	70	68
19	272	48	90
20	174	31	87
21	101	18	144
22	32	5	133
+gp	3	5	41
TOTALNUM	7905	4168	7569
	4763	2066	3168

Table 1.(Continue) Catch numbers at age Numbers*10**-3

REDFISH,DIVISION 3M,1968-1990, AGES 5-23

YEAR	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
AGE										
5	23	363	322	67	2658	16	39	1160	618	123
6	54	997	2221	1184	2735	135	99	1104	2118	818
7	96	2107	6417	4825	3667	462	308	1228	3571	2708
8	270	2428	8488	8562	3937	1342	706	1140	3665	3672
9	629	2811	9773	12245	4537	2827	1581	1718	3146	4399
10	1305	3728	8551	13254	6449	5794	3445	3690	3020	3855
11	1611	4676	6266	10985	5967	7025	4736	4913	3364	2827
12	1421	4985	4319	7008	3811	5323	4238	4467	3632	2280
13	1624	6597	4264	6474	2558	4533	4662	4550	4492	2838
14	1428	7007	3302	5088	1623	3093	4014	3611	3985	2740
15	1293	7072	2372	3959	1062	2016	3483	2609	3316	2409
16	1048	6644	1532	3093	789	1410	2929	1799	2508	1867
17	561	4766	614	1705	482	703	1671	936	1364	1134
18	439	3913	352	1149	371	449	1263	623	986	853
19	399	3533	205	809	370	333	982	437	795	658
20	284	2688	92	515	258	211	705	259	558	471
21	230	1840	64	315	241	136	491	165	376	324
22	162	684	35	85	176	61	210	57	143	133
+gp	155	291	7	14	145	17	61	49	68	37
	13032	67130	59196	81336	41836	35886	35623	34515	41725	34146
	8033	41946	22352	34671	16075	16998	20267	16762	20074	15967

Table 1.(Continue) Catch numbers at age Numbers*10**-3

YEAR	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
AGE										
5	321	14	13	1294	11941	5331	7266	0	6118	3780
6	1194	233	155	1110	5644	13179	23768	511	1881	4780
7	2925	1137	837	1941	991	8241	59247	4628	9439	16710
8	4533	3050	3320	3308	498	2806	44404	6544	25316	28610
9	5877	5119	6031	4875	1898	2418	17203	3906	16417	30060
10	6412	7334	9792	7635	3688	4714	6793	3145	9087	13230
11	4855	6387	9095	7836	3824	5643	8488	5125	2943	5000
12	2699	3569	5291	5473	5002	7874	5673	4632	5327	7050
13	2223	2350	3643	4562	5889	7256	6777	6437	4977	7620
14	1666	1600	2523	3281	4745	5941	5106	5144	2137	4450
15	1235	1187	1783	2272	2483	3367	3024	3413	1714	2820
16	850	963	1281	1558	2431	2870	2730	3139	1081	2570
17	454	615	684	722	814	1000	947	1544	416	590
18	311	454	457	443	695	885	536	990	275	600
19	237	383	356	317	278	478	315	600	49	100
20	164	264	229	200	406	584	247	329	53	80
21	108	170	154	124	288	354	153	248	16	120
22	41	50	48	32	98	125	61	102	10	70
+gp	14	7	5	5	50	59	14	30	30	30
	36119	34886	45697	46988	51663	73125	192752	50467	87286	128270
	13891	14684	19527	20228	20282	28873	44411	23189	29649	39456

Table 2. Catch weights at age (kg)
REDFISH, DIVISION 3M, 1968-1990, AGES 5-23

YEAR	1968	1969	1970
AGE			
5	.1610	.1680	.1100
6	.2150	.1830	.2030
7	.2420	.2260	.2100
8	.2450	.2600	.2200
9	.2800	.3040	.2750
10	.3310	.3290	.3400
11	.3920	.3760	.3650
12	.4690	.4300	.4450
13	.5350	.5100	.5780
14	.6150	.6010	.6600
15	.7020	.7200	.7170
16	.7490	.8050	.7890
17	.7920	.8450	.8030
18	.8590	.8600	.8960
19	.9380	.9260	.9560
20	.9950	.9300	.9920
21	1.0750	1.0220	1.0940
22	1.1350	1.0810	1.1150
+gp	1.2640	1.2600	1.1300

Table 2.(Continue). Catch weights at age (kg)
REDFISH, DIVISION 3M, 1968-1990, AGES 5-23

YEAR	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
AGE										
5	.1350	.1450	.1650	.1020	.1380	.1250	.1050	.1150	.1050	.1300
6	.2150	.1860	.1960	.2030	.1940	.2010	.1830	.1850	.1850	.1930
7	.2430	.2230	.2260	.2320	.2220	.2260	.2330	.2280	.2430	.2340
8	.2530	.2380	.2390	.2680	.2380	.2800	.2500	.2350	.2550	.2550
9	.2900	.2630	.2520	.3010	.2750	.2960	.3020	.2950	.2670	.3180
10	.3050	.2920	.3010	.3770	.3570	.3350	.3320	.3280	.2980	.3240
11	.3820	.3540	.3560	.3970	.3910	.4030	.4080	.3740	.3460	.4110
12	.4760	.4110	.5020	.4800	.5080	.4630	.4590	.4520	.5030	.4750
13	.4980	.5270	.5800	.5410	.5360	.4950	.5620	.5360	.5080	.5250
14	.6090	.5860	.5990	.6360	.6000	.6020	.6470	.6140	.6200	.5670
15	.6750	.6770	.7000	.7770	.6600	.7030	.6770	.7080	.6600	.6570
16	.7150	.7420	.7050	.7900	.7300	.7200	.7190	.7340	.7570	.7070
17	.8020	.7750	.7450	.8090	.7400	.7820	.7560	.8000	.7900	.7570
18	.8870	.8180	.8700	.8420	.8500	.8150	.8500	.8600	.8650	.7810
19	1.0250	.9930	.9290	1.0000	.9170	.9350	.9300	.9240	.9410	.8650
20	1.0350	1.1000	1.0220	1.0340	.9800	.9920	.9910	.9400	1.1020	.9410
21	1.0840	1.1250	1.0530	1.1350	1.0000	1.0650	1.0690	1.0300	1.1140	1.0220
22	1.1980	1.1640	1.1160	1.2040	1.1000	1.1240	1.2000	1.1830	1.1560	1.1750
+gp	1.2540	1.2500	1.3100	1.2550	1.1500	1.3020	1.2400	1.3010	1.3500	1.2540

Table 2.(Continue). Catch weights at age (kg)
REDFISH, DIVISION 3M, 1968-1990, AGES 5-23

YEAR AGE	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
5	.1000	.1320	.1000	.1020	.1010	.1240	.0940	.0930	.0510	.0990
6	.2030	.2000	.2010	.2000	.1800	.1960	.1250	.1350	.1260	.1620
7	.2320	.2130	.2340	.2200	.2120	.2280	.1500	.1720	.1960	.1820
8	.2430	.2250	.2480	.2400	.2390	.2480	.1830	.2040	.2470	.2210
9	.2700	.2440	.2640	.2560	.2950	.2800	.2360	.2550	.2950	.2710
10	.3350	.3400	.3280	.3370	.3400	.3290	.3230	.3310	.3440	.3350
11	.3900	.3750	.3880	.3900	.4080	.3840	.3830	.4000	.3890	.3860
12	.4640	.4150	.4200	.4670	.4490	.4600	.4310	.4460	.4440	.4560
13	.5180	.4830	.5050	.5520	.5310	.5360	.5110	.5240	.5210	.5280
14	.5730	.5950	.6100	.6430	.5970	.6120	.5860	.5780	.6360	.6060
15	.6080	.6980	.7000	.7170	.6950	.6920	.6560	.6640	.6960	.6880
16	.7360	.7320	.7450	.7350	.7100	.7410	.7190	.7260	.7510	.7350
17	.7750	.7840	.7830	.7650	.7800	.7860	.7690	.7720	.8060	.7780
18	.7810	.8450	.8420	.8300	.8790	.8500	.8550	.8580	.8920	.8400
19	.9060	.9080	.9340	.9320	.9140	.9410	.9450	.8650	1.0440	.9500
20	.9980	.9850	.9800	.9930	1.0380	1.0130	.9830	1.0180	1.0810	1.0360
21	1.0600	1.1080	1.0720	1.0740	1.1140	1.0830	1.0470	1.0680	1.1150	1.0900
22	1.1320	1.1300	1.1360	1.2220	1.1340	1.1560	1.1990	1.1530	1.2390	1.1600
+gp	1.2240	1.2750	1.2600	1.2430	1.2580	1.2610	1.3030	1.2350	1.3810	1.2650

Table 3. Statistical chracteristics of standardized catch rate of Div.3M redfish

REGRESSION OF MULTIPLICATIVE MODEL

MULTIPLE R............. .665
MULTIPLE R SQUARED..... .442

ANALYSIS OF VARIANCE

SOURCE OF VARIATION	DF	SUMS OF SQUARES	MEAN SQUARES	F-VALUE
INTERCEPT	1	8.371E0001	8.371E0001	
REGRESSION	51	9.536E0001	1.870E0000	5.429
TYPE 1	22	1.942E0001	8.827E-001	2.563
TYPE 2	11	1.557E0000	1.415E-001	0.411
TYPE 3	4	7.452E0000	1.863E0000	5.410
TYPE 4	3	9.595E0000	3.198E0000	9.287
TYPE 5	11	3.734E0001	3.394E0000	9.855
RESIDUALS	350	1.205E0002	3.444E-001	
TOTAL	402	2.996E0002		

Table 4. Coefficients of a multiplicative model

REGRESSION COEFFICIENTS

CATEGORY	CODE	VARIABLE	COEFFICIENT	STD. ERROR	NO. OBS.
1	68	INTERCEPT	0.029	0.008	402
2	4				
3	3				
4	6				
5	20				
1	69	1	0.267	0.442	2
	70	2	1.124	0.258	8
	71	3	0.990	0.211	11
	72	4	0.452	0.175	16
	73	5	0.403	0.239	7
	74	6	0.444	0.162	21
	75	7	0.344	0.161	20
	76	8	0.241	0.166	22
	77	9	0.074	0.150	29
	78	10	0.427	0.145	32
	79	11	0.114	0.131	35
	80	12	0.375	0.141	31
	81	13	0.414	0.145	25
	82	14	0.352	0.139	27
	83	15	0.112	0.139	27
	84	16	0.251	0.160	22
	85	17	0.390	0.182	16
	86	18	0.352	0.204	11
	87	19	0.811	0.164	18
	88	20	0.388	0.310	4
	89	21	0.468	0.310	4
	90	22	0.117	0.195	12
2	1	23	0.112	0.164	17
	2	24	-0.004	0.137	27
	3	25	-0.090	0.120	37
	5	26	-0.013	0.115	41
	6	27	0.101	0.119	44
	7	28	0.092	0.123	40
	8	29	0.136	0.121	41
	9	30	0.071	0.133	32
	10	31	0.018	0.143	25
	11	32	-0.065	0.149	22
	12	33	0.008	0.165	17
3	1	34	-0.226	0.440	2
	2	35	-0.588	0.252	14
	4	36	-0.025	0.286	6
	6	37	0.268	0.066	197
4	4	38	-0.924	0.203	23
	5	39	-0.590	0.150	61
	7	40	0.079	0.060	285
5	1	41	0.505	0.352	3
	2	42	0.831	0.213	22
	3	43	0.579	0.187	39
	4	44	0.083	0.114	35
	10	45	-0.335	0.268	6
	11	46	0.011	0.240	8
	14	47	-0.669	0.106	54
	16	48	-0.518	0.313	4
	17	49	0.979	0.314	5
	21	50	-1.372	0.379	3
	23	51	0.130	0.329	4

Table 5. Standardized catch rates of redfish

PREDICTED CATCH RATE

STANDARDS USED VARIABLE NUMBERS: 4 6 7 20

YEAR	TOTAL CATCH	PROP.	CATCH RATE MEAN	CATCH RATE S.E.	EFFORT
68	4763	0.309	1.725	0.141	2761
69	2066	0.983	2.046	0.869	1010
70	3168	0.970	5.152	1.310	615
71	8033	0.670	4.555	0.959	1763
72	41946	0.940	2.674	0.483	15687
73	22352	0.921	2.512	0.607	8897
74	34671	0.874	2.665	0.422	13011
75	16075	0.746	2.408	0.392	6675
76	16998	0.927	2.172	0.354	7824
77	20267	0.721	1.843	0.271	10997
78	16762	0.826	2.625	0.372	6385
79	20074	0.888	1.925	0.245	10429
80	15967	0.910	2.495	0.344	6400
81	13891	0.904	2.593	0.358	5357
82	14684	0.864	2.439	0.331	6021
83	19527	0.861	1.916	0.274	10191
84	20228	0.856	2.197	0.346	9205
85	20282	0.884	2.519	0.434	8052
86	28873	0.580	2.414	0.466	11963
87	44411	0.488	3.847	0.611	11546
88	23189	0.576	2.438	0.722	9513
89	29649	0.469	2.641	0.782	11228
90	39456	0.827	1.912	0.349	20636

AVERAGE C.V. FOR THE MEAN: .187

Table 6 Fishing mortality (F) at age
REDFISH, DIVISION 3M, 1968-1990, AGES 5-23

YEAR / AGE	1968	1969	1970
5	.0000	.0001	.0011
6	.0004	.0004	.0023
7	.0021	.0018	.0028
8	.0042	.0047	.0135
9	.0078	.0095	.0295
10	.0142	.0157	.0281
11	.0262	.0200	.0275
12	.0404	.0219	.0334
13	.0819	.0316	.0340
14	.1114	.0388	.0366
15	.1141	.0418	.0354
16	.1382	.0338	.0301
17	.1196	.0259	.0191
18	.1772	.0214	.0166
19	.1141	.0308	.0312
20	.1230	.0154	.0648
21	1.1856	.0151	.0827
22	.3976	.1340	.1324
+gp	.3976	.1340	.1324
FP 6-17	.0230	.0110	.0170
FP 10-16	.0530	.0250	.0310
FB 5-22	.1477	.0257	.0345

Table 6.(Continued). Fishing mortality (F) at age
REDFISH, DIVISION 3M, 1968-1990, AGES 5-23

YEAR / AGE	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
5	.0003	.0054	.0059	.0012	.0384	.0002	.0004	.0111	.0065	.0016
6	.0006	.0128	.0376	.0243	.0550	.0022	.0012	.0113	.0228	.0096
7	.0011	.0254	.0964	.0963	.0881	.0106	.0056	.0165	.0416	.0332
8	.0040	.0323	.1217	.1614	.0956	.0380	.0182	.0231	.0565	.0494
9	.0131	.0478	.1576	.2310	.1083	.0830	.0517	.0506	.0738	.0802
10	.0344	.0906	.1795	.2951	.1641	.1760	.1239	.1470	.1063	.1095
11	.0534	.1490	.1936	.3268	.1875	.2414	.1909	.2328	.1738	.1233
12	.0563	.2076	.1791	.3062	.1606	.2272	.2010	.2473	.2410	.1534
13	.0782	.3514	.2459	.3920	.1563	.2599	.2834	.3065	.3733	.2682
14	.0892	.4890	.2653	.4574	.1430	.2560	.3429	.3290	.4259	.3640
15	.1041	.7097	.2697	.5138	.1440	.2369	.4502	.3478	.5023	.4380
16	.1218	.9645	.2854	.5887	.1606	.2576	.5586	.3926	.5818	.5208
17	.0880	1.0392	.1826	.5199	.1491	.1882	.4846	.3076	.5151	.5019
18	.0778	1.2126	.1627	.5328	.1796	.1810	.5275	.2975	.5422	.6260
19	.1146	1.2481	.1484	.5930	.2889	.2171	.6494	.3094	.6678	.7550
20	.1170	2.2058	.0749	.5847	.3367	.2373	.8311	.3110	.7135	.9690
21	.2173	2.0822	.2430	.3476	.5294	.2657	1.1506	.4100	.8737	1.0967
22	.1134	1.5576	.1623	.5156	.2968	.2178	.7287	.3271	.6625	.7897
+gp	.1134	1.5576	.1623	.5156	.2968	.2178	.7287	.3271	.6625	.7897
FP6-17	.026	.1420	.1440	.2340	.1220	.1180	.1070	.0950	.1070	.0840
F10-16	.065	.3060	.2090	.3560	.1660	.2280	.2470	.2540	.2670	.1950
F5-22	.0714	.6906	.1673	.3604	.1823	.1720	.3667	.2266	.3656	.3827

Table 6. (Continued). Fishing mortality (F) at age
REDFISH, DIVISION 3M, 1968-1990, AGES 5-23

YEAR AGE	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
5	.0043	.0002	.0001	.0079	.0343	.0077	.0119	.0000	.0550	.0313
6	.0177	.0035	.0021	.0119	.0392	.0434	.0388	.0009	.0039	.0501
7	.0387	.0190	.0138	.0300	.0119	.0666	.2487	.0085	.0192	.0394
8	.0644	.0465	.0639	.0627	.0087	.0381	.5256	.0351	.0533	.0671
9	.0939	.0867	.1098	.1132	.0419	.0479	.3047	.0699	.1044	.0745
10	.1443	.1458	.2123	.1771	.1056	.1248	.1649	.0748	.2056	.1031
11	.1756	.1874	.2421	.2347	.1135	.2085	.3067	.1619	.0838	.1495
12	.1490	.1695	.2090	.2012	.2066	.3189	.2976	.2441	.2254	.2627
13	.1967	.1679	.2336	.2503	.3076	.4575	.4415	.5687	.3973	.5088
14	.2227	.1898	.2444	.3034	.3954	.5123	.5990	.6254	.3307	.6559
15	.2471	.2187	.2974	.3221	.3515	.4781	.4724	.9273	.3866	.8421
16	.2416	.2764	.3443	.4067	.5950	.7684	.7940	1.1675	.7667	1.4929
17	.2035	.2466	.2875	.2959	.3424	.4620	.5489	1.4029	.3949	1.1808
18	.2207	.2866	.2609	.2724	.4554	.6720	.4277	1.8124	.9312	1.4505
19	.3118	.4088	.3390	.2594	.2449	.5762	.4740	1.0698	.3335	.9616
20	.3733	.5966	.4061	.2886	.5418	1.0218	.5888	1.1906	.2085	1.2348
21	.5376	.7276	.7453	.3565	.7559	1.1693	.7259	2.1167	.1325	.8607
22	.3294	.4533	.4077	.2946	.4681	.7803	.5531	1.5185	.4001	1.1377
+gp	.3294	.4533	.4077	.2946	.4681	.7803	.5531	1.5185	.4001	1.1377
FP6-17	.090	.0880	.1200	.1160	.0870	.1030	.1780	.0390	.0490	.0830
F10-16	.170	.1710	.2310	.2280	.2150	.3070	.3290	.2950	.2200	.2180
F5-22	.1985	.2351	.2455	.2160	.2789	.4308	.4180	.7220	.2796	.6169

Table 7. Stock number at age (start of year) Numbers*10**-3
REDFISH, DIVISION 3M, 1968-1990, AGES 5-23

YEAR AGE	1968	1969	1970
5	95129	108751	107812
6	69407	86072	98396
7	56767	62775	77854
8	45773	51256	56698
9	38750	41243	46162
10	32726	34790	36966
11	25740	29194	30987
12	20657	22689	25894
13	15136	17950	20086
14	11341	12619	15737
15	9824	9180	10984
16	6255	7930	7966
17	4330	4930	6937
18	2190	3476	4346
19	2648	1660	3079
20	1579	2137	1456
21	151	1263	1904
22	102	42	1126
+gp	10	42	347
TOTAL	438514	497999	554738

Table 7. (Continued)&Stock number at age (start of year) Numbers*10**-3

REDFISH, DIVISION 3M, 1968-1990, AGES 5-23

YEAR AGE	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
5	90772	70327	57501	59369	74210	96354	113831	110120	100503	79008
6	97449	82112	63289	51723	53656	64622	87170	102962	98538	90352
7	88831	88125	73350	55155	45675	45951	58344	78780	92114	87147
8	70251	80286	77735	60274	45322	37845	41139	52499	70116	79954
9	50613	63309	70338	62275	46408	37269	32968	36553	46419	59960
10	40553	45199	54613	54364	44728	37681	31036	28328	31441	39012
11	32521	35454	37356	41297	36619	34348	28594	24810	22128	25580
12	27277	27895	27639	27852	26951	27470	24414	21377	17787	16828
13	22661	23331	20509	20908	18555	20767	19804	18067	15104	12648
14	17566	18961	14856	14511	12783	14361	14490	13497	12033	9409
15	13728	14538	10521	10310	8310	10025	10059	9305	8789	7112
16	9592	11194	6469	7270	5580	6511	7158	5803	5946	4812
17	6994	7684	3861	4400	3651	4300	4554	3705	3545	3007
18	6158	5795	2459	2910	2367	2846	3224	2538	2464	1917
19	3868	5155	1560	1891	1546	1790	2149	1721	1705	1297
20	2700	3121	1339	1217	946	1048	1304	1016	1143	791
21	1235	2174	311	1124	613	611	748	514	673	507
22	1586	899	245	221	718	327	424	214	308	254
+gp	1518	383	49	36	592	91	123	184	147	71
	585875	585940	524001	477109	429233	444216	481531	511993	53090	519666

Table 7.(Continued)& Stock number at age (start of year) Numbers*10**-3

REDFISH, DIVISION 3M, 1968-1990, AGES 5-23

YEAR	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
AGE										
5	78881	84485	108964	171891	372502	731011	645318	557140	119981	128869
6	71372	71069	76432	98583	154303	325704	656378	577000	504121	102749
7	80976	63445	64084	69011	88146	134254	282182	571323	521605	454359
8	76280	70490	56327	57190	60598	78816	113647	199111	512554	462994
9	68855	64713	60883	47811	48604	54358	68648	60795	173943	439718
10	50074	56719	53691	49360	38631	42175	46887	45800	51297	141794
11	31638	39220	44357	39288	37414	31451	33684	35975	38453	37790
12	20461	24017	29424	31505	28113	30221	23102	22428	27685	31997
13	13062	15951	18343	21602	23312	20690	19878	15522	15898	19995
14	8752	9708	12201	13140	15217	15508	11848	11566	7954	9669
15	5916	6338	7265	8646	8778	9272	8407	5889	5599	5170
16	4153	4181	4608	4883	5669	5589	5201	4743	2108	3442
17	2587	2951	2870	2955	2942	2829	2345	2127	1335	886
18	1647	1910	2087	1948	1989	1890	1613	1226	473	814
19	927	1195	1297	1455	1342	1141	873	951	181	169
20	551	614	719	836	1015	951	580	492	295	117
21	272	344	306	433	567	534	310	291	135	217
22	153	144	150	131	274	241	150	136	32	107
+g	52	20	16	21	140	114	34	40	95	46
	516609	517514	544024	620689	889557	1486749	1921085	2112555	1983746	1840902

Table 8. Stock biomass at age (start of year) Tonnes

REDFISH, DIVISION 3M, 1968-1990, AGES 5-23

YEAR	1968	1969	1970
AGE			
5	15316	18270	11859
6	14923	15751	19974
7	13738	14187	16349
8	11214	13327	12474
9	10850	12538	12694
10	10832	11446	12569
11	10090	10977	11310
12	9688	9756	11523
13	8098	9155	11610
14	6975	7584	10387
15	6896	6609	7875
16	4685	6384	6285
17	3429	4165	5570
18	1881	2990	3894
19	2484	1537	2943
20	1571	1988	1445
21	163	1291	2083
22	116	45	1255
+gp	12	53	392
TOTALBIO	132960	148052	162493

Table 8. (Continued). Stock biomass at age (start of year) Tonnes

REDFISH, DIVISION 3M, 1968-1990, AGES 5-23

YEAR	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980
AGE										
5	12254	10197	9488	6056	10241	12044	11952	12664	10553	10271
6	20952	15273	12405	10500	10409	12989	15952	19048	18230	17438
7	21586	19652	16577	12796	10140	10385	13594	17962	22384	20393
8	17773	19108	18579	16153	10787	10597	10285	12337	17880	20388
9	14678	16650	17725	18745	12762	11032	9956	10783	12394	19067
10	12369	13198	16438	20495	15968	12623	10304	9292	9369	12640
11	12423	12551	13299	16395	14318	13842	11667	9279	7656	10513
12	12984	11465	13875	13369	13691	12719	11206	9663	8947	7993
13	11285	12295	11895	11311	9946	10280	11130	9684	7673	6640
14	10698	11111	8899	9229	7670	8645	9375	8287	7460	5335
15	9267	9842	7365	8011	5485	7048	6810	6588	5800	4673
16	6859	8306	4561	5743	4074	4688	5147	4259	4501	3402
17	5609	5955	2876	3560	2702	3363	3442	2964	2801	2276
18	5462	4741	2140	2451	2012	2319	2740	2182	2132	1497
19	3965	5119	1449	1891	1417	1674	1998	1590	1605	1122
20	2795	3433	1368	1258	927	1039	1292	955	1259	745
21	1339	2445	328	1276	613	651	799	529	750	518
22	1901	1047	274	266	790	367	509	253	357	299
+gp	1903	478	64	46	681	119	153	239	198	89
	186101	182866	159603	159550	134633	136423	138311	138559	141949	145299

Table 8. (Continued). Stock biomass at age (start of year) Tonnes

REDFISH, DIVISION 3M, 1968-1990, AGES 5-23

YEAR AGE	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
5	7888	11152	10896	17533	37623	90645	60660	51814	6119	12758
6	14489	14214	15363	19717	27775	63838	82047	77895	63519	16645
7	18786	13514	14996	15182	18687	30610	42327	98268	102235	82693
8	18536	15860	13969	13726	14483	19546	20797	40619	126601	102322
9	18591	15790	16073	12240	14338	15220	16201	15503	51313	119164
10	16775	19284	17611	16634	13134	13875	15145	15160	17646	47501
11	12339	14707	17210	15322	15265	12077	12901	14390	14958	14587
12	9494	9967	12358	14713	12623	13902	9957	10003	12292	14591
13	6766	7704	9263	11924	12379	11090	10158	8134	8283	10557
14	5015	5776	7443	8449	9085	9491	6943	6685	5058	5859
15	3597	4424	5086	6199	6101	6416	5515	3910	3897	3557
16	3057	3061	3433	3589	4025	4141	3740	3444	1583	2530
17	2005	2314	2247	2261	2295	2224	1803	1642	1076	689
18	1286	1614	1757	1617	1748	1607	1379	1052	422	684
19	840	1085	1212	1356	1227	1074	825	823	189	160
20	550	605	704	830	1054	963	571	501	319	122
21	288	381	328	465	632	579	324	311	151	236
22	173	162	171	161	311	279	180	156	39	124
+gp	64	26	20	26	176	143	45	49	132	58
	140539	141640	150140	161943	192959	297721	291518	350358	415834	434838

Table 9. Some statistical characteristics of VPA tuning
REDFISH, DIVISION 3M, 1968-1990, AGES 5-23
LOG TRANSFORMATION
Explanatory variate EFFORT
Terminal Fs estimated by combining ln(q) after regressing with effort
Log catchability estimates

AGE	Pred. q	SE(q)	Partial F	Raised F	SLOPE	SE Slope	INTRCPT	SE Intrcpt	R
5	-16.24	3.056	.0018	.0018	-.858E-04	.158E-03	-14.472	1.679	.330
6	-14.66	1.618	.0088	.0088	-.874E-04	.836E-04	-12.861	.889	.478
7	-13.17	1.217	.0394	.0394	-.480E-04	.629E-04	-12.178	.669	.318
8	-12.64	1.076	.0671	.0671	-.526E-04	.556E-04	-11.550	.591	.282
9	-12.53	.656	.0745	.0745	-.891E-04	.339E-04	-10.695	.360	.390
10	-12.21	.407	.1031	.1031	-.104E-03	.210E-04	-10.062	.223	.470
11	-11.84	.413	.1495	.1495	-.934E-04	.213E-04	-9.909	.227	.520
12	-11.27	.203	.2627	.2627	-.553E-04	.105E-04	-10.130	.111	.804
13	-10.61	.315	.5088	.5088	-.257E-04	.163E-04	-10.080	.173	.830
14	-10.36	.369	.6559	.6559	-.140E-04	.191E-04	-10.067	.203	.848
15	-10.11	.414	.8421	.8421	-.391E-06	.214E-04	-10.099	.227	.822
16	-9.53	.472	1.4929	1.4929	.290E-04	.244E-04	-10.132	.259	.865
17	-9.77	.568	1.1808	1.1808	.285E-04	.293E-04	-10.355	.312	.743
18	-9.56	.689	1.4505	1.4505	.364E-04	.356E-04	-10.313	.378	.701
19	-9.97	.623	.9616	.9616	-.425E-06	.322E-04	-9.965	.342	.739
20	-9.72	.889	1.2348	1.2348	.825E-05	.459E-04	-9.894	.488	.618
21	-10.08	.893	.8607	.8607	-.450E-04	.461E-04	-9.155	.491	.416

Table 10. Age selectivity coefficients
Values Sa (SVPA,1972-1990, AGE=12)

AGE :	5	6	7	8	9	10	11	12	13	14
SA :	.0094	.0452	.1322	.2432	.4098	.6723	.8639	1.0000	1.4083	1.5956

AGE :	15	16	17	18	19	20
SA :	1.7306	2.1225	1.5421	1.4945	1.1868	1.0000

Table 11. Data related to catch-recruitment relationship

AGE	WEIGHT-AT-AGE	PARTIAL RECRUITMENT	NATURAL MORTALITY
5	.099	.004	.100
6	.162	.021	.100
7	.182	.062	.100
8	.221	.115	.100
9	.271	.193	.100
10	.335	.317	.100
11	.386	.407	.100
12	.456	.471	.100
13	.528	.664	.100
14	.606	.752	.100
15	.688	.815	.100
16	.735	1.000	.100
17	.778	.727	.100
18	.840	.704	.100
19	.950	.559	.100
20	1.036	.471	.100
21	1.090	.471	.100
22	1.160	.471	.100
23	1.265	.471	.100

F0.1 COMPUTED AS .2514 AT Y/R OF .1904
FMAX COMPUTED AS .4759 AT Y/R OF .2051

Tabele 12. Yield recruit analysis

	FISHING MORTALITY	CATCH (NUMBER)	YIELD (KG)	AVG. WEIGHT (KG)	YIELD PER UNIT EFFORT
	.1000	.215	.126	.586	1.665
	.2000	.332	.178	.535	1.173
F0.1---	.2514	.372	.190	.512	1.000
	.3000	.401	.198	.493	.870
	.4000	.446	.204	.458	.674
FMAX---	.4759	.470	.205	.436	.569
	.5000	.477	.205	.430	.541
	.6000	.501	.204	.407	.448
	.7000	.519	.201	.388	.380
	.8000	.535	.199	.372	.328
	.9000	.548	.197	.359	.288
	1.0000	.560	.194	.347	.257
	1.1000	.570	.192	.337	.231
	1.2000	.580	.190	.328	.209
	1.3000	.588	.188	.320	.191
	1.4000	.596	.187	.313	.176
	1.5000	.603	.185	.307	.163

Table 13. Projection; TAC = 43000 t
F = F

Age	1991 F	1991 C: 10**-6	1991 N: 10**-6	1991 B: 10**-3	1992 F	1992 C: 10**-6	1992 N: 10**-6	1992 B: 10**-3
5	0.002	0.0	128.9	12.8	0.031	0.4	128.9	12.8
6	0.009	0.2	113.0	18.3	0.050	0.9	116.4	18.9
7	0.026	0.4	88.4	16.1	0.039	0.7	101.4	18.4
8	0.049	4.0	395.2	87.3	0.067	1.1	77.9	17.2
9	0.082	8.0	391.7	106.2	0.075	6.3	340.6	92.3
10	0.135	14.9	369.3	123.7	0.103	10.2	326.6	109.4
11	0.173	6.8	115.7	44.7	0.149	14.9	292.0	112.7
12	0.200	2.3	29.4	13.4	0.263	8.9	88.1	40.2
13	0.282	2.8	22.3	11.8	0.509	4.4	21.8	11.5
14	0.320	1.7	10.9	6.6	0.656	4.2	15.2	9.2
15	0.346	0.9	4.5	3.1	0.842	2.7	7.1	4.9
16	0.425	0.5	2.0	1.5	1.493	1.6	2.9	2.1
17	0.309	0.1	0.7	0.5	1.181	0.6	1.2	0.9
18	0.299	0.1	0.2	0.2	1.451	0.3	0.5	0.4
19	0.238	0.0	0.2	0.2	0.962	0.1	0.2	0.2
20	0.200	0.0	0.1	0.1	1.235	0.1	0.1	0.1
21	0.200	0.0	0.0	0.0	0.861	0.0	0.0	0.0
22	0.200	0.0	0.1	0.1	1.138	0.0	0.0	0.0
23	0.200	0.0	0.0	0.0	1.138	0.1	0.1	0.1
TOTAL		42.5	1672.9	446.6		57.4	1521.0	451.4

Table 14. Projection, TAC = 43000 t
F = F

Age	F (1991)	C (1991) 10**-6	N (1991) 10**-6	B (1991) 10**-3	F (1992)	C (1992) 10**-6	N (1992) 10**-6	B (1992) 10**-3
5	0.002	0.0	128.9	12.8	0.001	0.0	128.9	12.8
6	0.009	0.2	113.0	18.3	0.005	0.1	116.4	18.9
7	0.026	0.4	88.4	16.1	0.016	0.3	101.4	18.4
8	0.049	4.0	395.2	87.3	0.029	0.5	77.9	17.2
9	0.082	8.0	391.7	106.2	0.049	4.2	340.6	92.3
10	0.135	14.9	369.3	123.7	0.080	8.0	326.6	109.4
11	0.173	6.8	115.7	44.7	0.102	10.4	292.0	112.7
12	0.200	2.3	29.4	13.4	0.118	4.3	88.1	40.2
13	0.282	2.8	22.3	11.8	0.167	1.7	21.8	11.5
14	0.320	1.7	10.9	6.6	0.189	1.5	15.2	9.2
15	0.346	0.9	4.5	3.1	0.205	0.9	7.1	4.9
16	0.425	0.5	2.0	1.5	0.251	0.5	2.9	2.1
17	0.309	0.1	0.7	0.5	0.183	0.1	1.2	0.9
18	0.299	0.1	0.2	0.2	0.177	0.1	0.5	0.4
19	0.238	0.0	0.2	0.2	0.141	0.0	0.2	0.2
20	0.200	0.0	0.1	0.1	0.118	0.0	0.1	0.1
21	0.200	0.0	0.0	0.0	0.118	0.0	0.0	0.0
22	0.200	0.0	0.1	0.1	0.118	0.0	0.0	0.0
23	0.200	0.0	0.0	0.0	0.118	0.0	0.1	0.1
TOTAL		42.5	1672.9	446.6		32.5	1521.0	451.4

Table 15. Projection, TAC = 43000 t
F = F

Age	F (1991)	C (1991) 10**-6	N (1991) 10**-6	B (1991) 10**-3	F (1992)	C (1992) 10**-6	N (1992) 10**-6	B (1992) 10**-3
5	0.002	0.0	128.9	12.8	0.002	0.0	128.9	12.8
6	0.009	0.2	113.0	18.3	0.010	0.2	116.4	18.9
7	0.026	0.4	88.4	16.1	0.030	0.5	101.4	18.4
8	0.049	4.0	395.2	87.3	0.055	0.9	77.9	17.2
9	0.082	8.0	391.7	106.2	0.092	7.7	340.6	92.3
10	0.135	14.9	369.3	123.7	0.151	14.6	326.6	109.4
11	0.173	6.8	115.7	44.7	0.194	18.9	292.0	112.7
12	0.200	2.3	29.4	13.4	0.224	7.7	88.1	40.2
13	0.282	2.8	22.3	11.8	0.316	3.0	21.8	11.5
14	0.320	1.7	10.9	6.6	0.358	2.6	15.2	9.2
15	0.346	0.9	4.5	3.1	0.388	1.5	7.1	4.9
16	0.425	0.5	2.0	1.5	0.476	0.8	2.9	2.1
17	0.309	0.1	0.7	0.5	0.346	0.3	1.2	0.9
18	0.299	0.1	0.2	0.2	0.335	0.1	0.5	0.4
19	0.238	0.0	0.2	0.2	0.266	0.0	0.2	0.2
20	0.200	0.0	0.1	0.1	0.224	0.0	0.1	0.1
21	0.200	0.0	0.0	0.0	0.224	0.0	0.0	0.0
22	0.200	0.0	0.1	0.1	0.224	0.0	0.0	0.0
23	0.200	0.0	0.0	0.0	0.224	0.0	0.1	0.1
Total		42.5	1672.9	446.6		58.9	1521.0	451.4

Table 16. Projection, TAC = 43000 t
F = F = (F + F)/2

Age	1991 F	1991 C: 10**-6	1991 N: 10**-6	1991 B: 10**-3	1992 F	1992 C: 10**-6	1992 N: 10**-6	1992 B: 10**-3
5	0.002	0.0	128.9	12.8	0.001	0.0	128.9	12.8
6	0.009	0.2	113.0	18.3	0.008	0.1	116.4	18.9
7	0.026	0.4	88.4	16.1	0.023	0.4	101.4	18.4
8	0.049	4.0	395.2	87.3	0.042	0.7	77.9	17.2
9	0.082	8.0	391.7	106.2	0.070	6.0	340.6	92.3
10	0.135	14.9	369.3	123.7	0.115	11.3	326.6	109.4
11	0.173	6.8	115.7	44.7	0.148	14.8	292.0	112.7
12	0.200	2.3	29.4	13.4	0.171	6.0	88.1	40.2
13	0.282	2.8	22.3	11.8	0.241	2.4	21.8	11.5
14	0.320	1.7	10.9	6.6	0.273	2.1	15.2	9.2
15	0.346	0.9	4.5	3.1	0.296	1.2	7.1	4.9
16	0.425	0.5	2.0	1.5	0.364	0.6	2.9	2.1
17	0.309	0.1	0.7	0.5	0.264	0.2	1.2	0.9
18	0.299	0.1	0.2	0.2	0.256	0.1	0.5	0.4
19	0.238	0.0	0.2	0.2	0.203	0.0	0.2	0.2
20	0.200	0.0	0.1	0.1	0.171	0.0	0.1	0.1
21	0.200	0.0	0.0	0.0	0.171	0.0	0.0	0.0
22	0.200	0.0	0.1	0.1	0.171	0.0	0.0	0.0
23	0.200	0.0	0.0	0.0	0.171	0.0	0.1	0.1
TOTAL		42.5	1672.9	446.6		46.0	1521.0	451.4

Table 17. Estimate biomass and TACs at different exploitation rates in predicted years

YEAR		1990	1991	1992	1993
		Biomass			
		435.0	447.0	451.0	
		TAC			B
F	.2514	39.5	43.0	32.5	464.0
F	.3636	39.5	43.0	46.0	449.0
F		39.5	43.0	57.4	
F	.4758	39.5	43.0	58.9	434.0

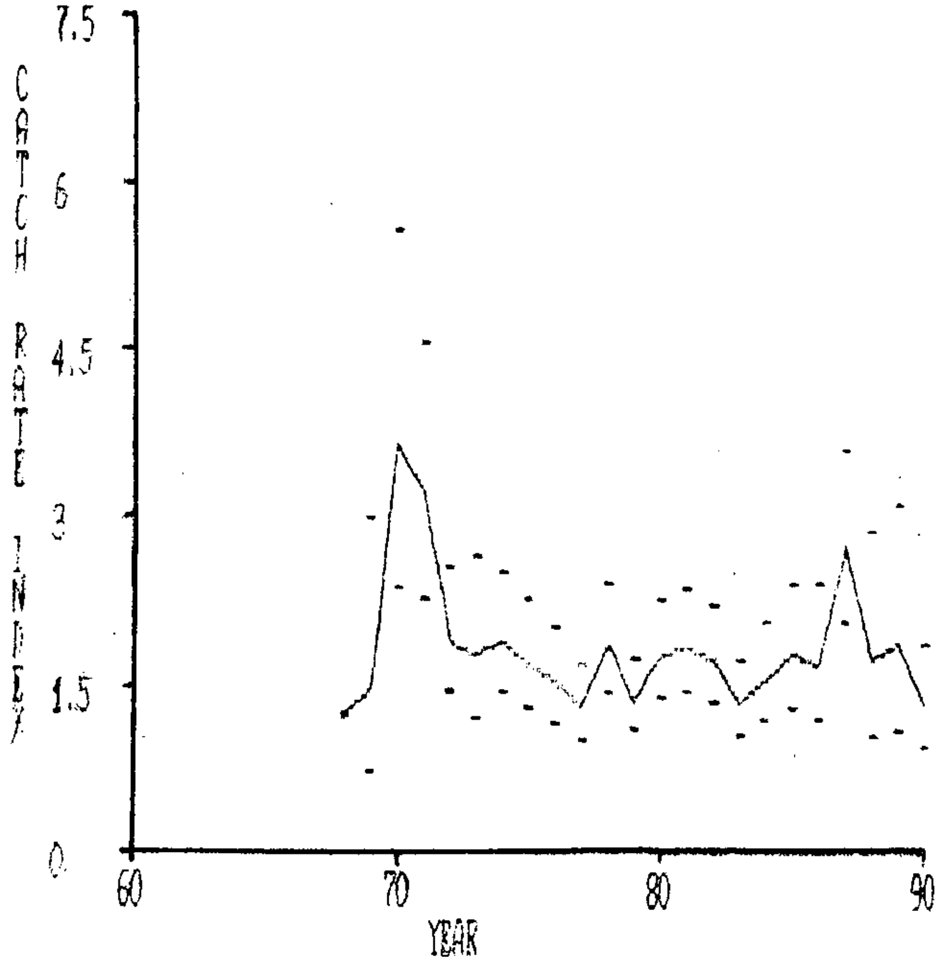

Fig. 1. Temporal dynamics of standardized catch rates of 3 M redfish.

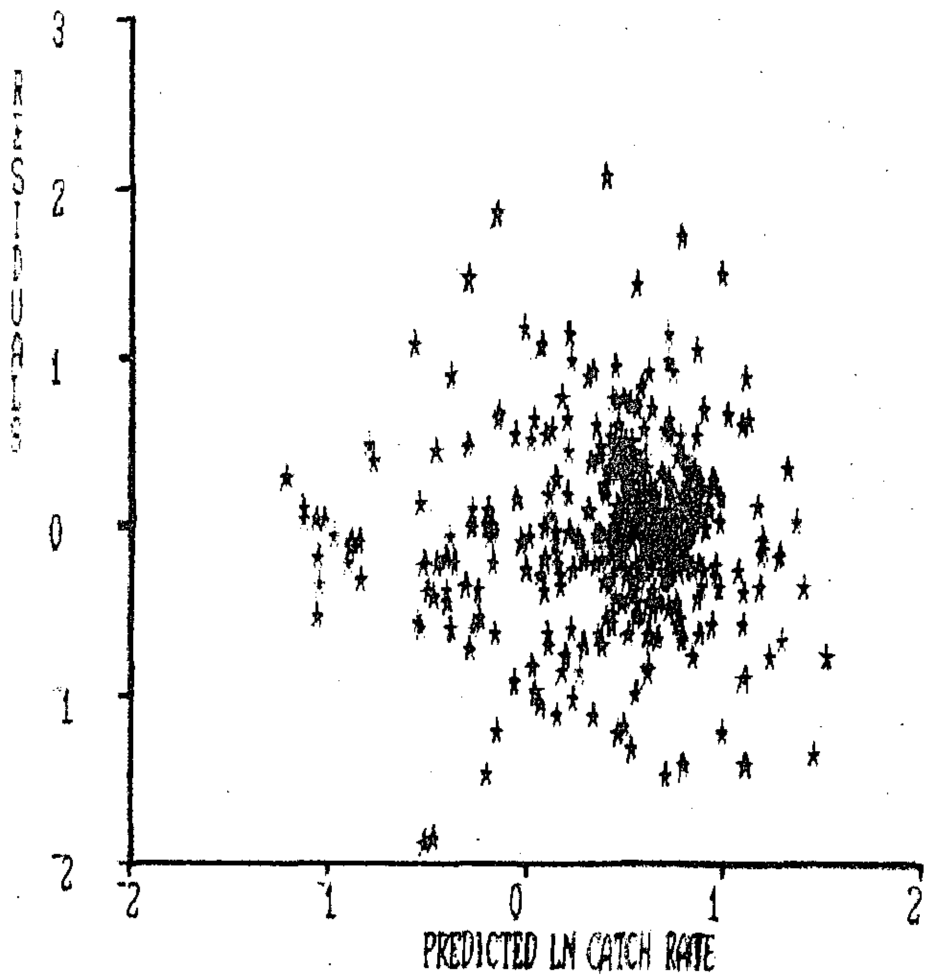

Fig. 2. Remainders in the multiplicative model.

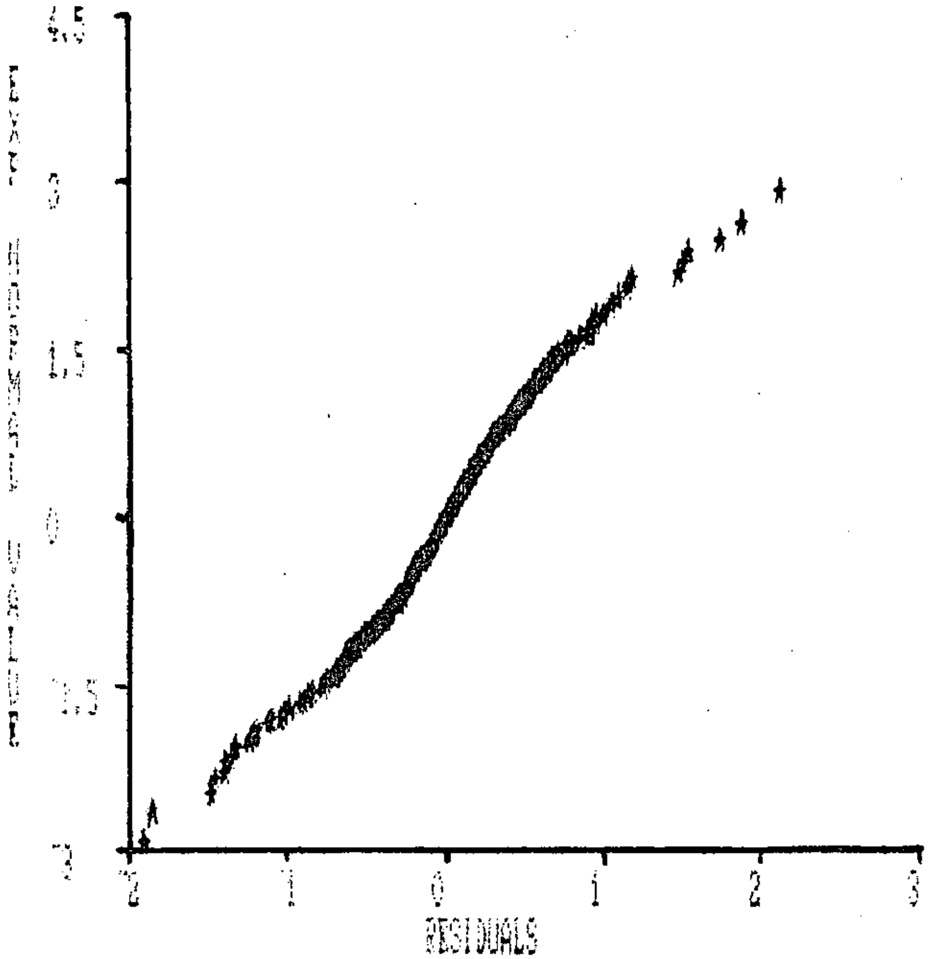

Fig. 3. Expected normal residuals in the multiplicative model

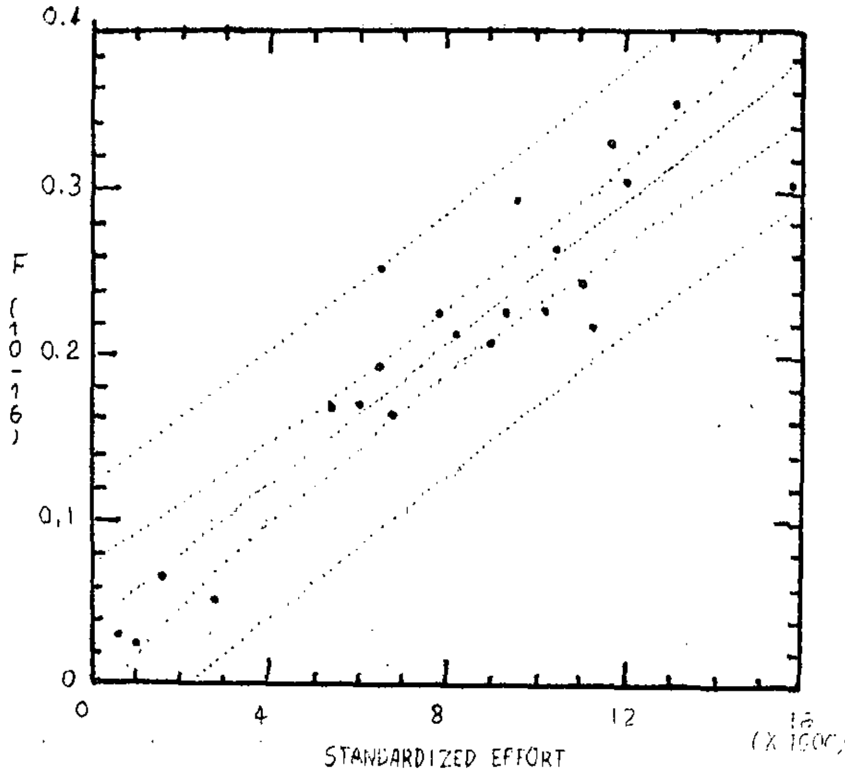

Fig. 4. Relationship between the average weighted fishing mortality rate (for age groups 10-16) and fishing effort.

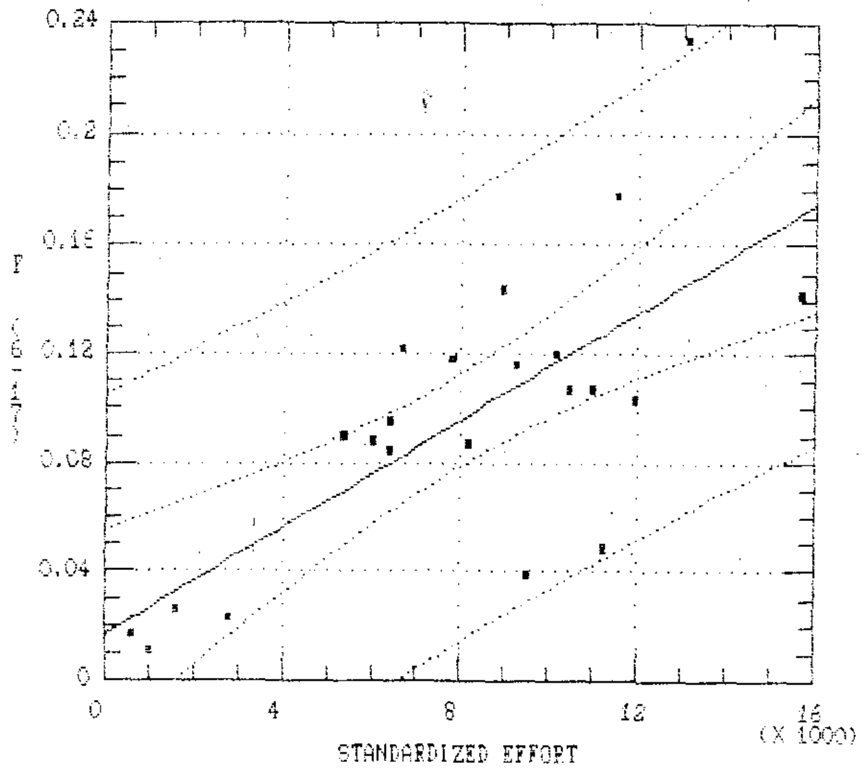

Fig. 5. Relationship between the average weighted fishing mortality rate (for age groups 6-17) and fishing effort.