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Estimation of the Stock Abundance and TAC for Beaked Redfish in Div. 3LN and 3M for 1985

by

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ABSTRACT

The abundance and biomass of the beaked redfish commercial stock in Divs. 3LN and 3M were assessed by VPA for the period 1968 to 1984. Natural mortality rates at different fishing ages were estimated and applied in order to realize the method. Statistically significant Ricker's relations between the parent stock biomass and the abundance of daughter year classes at the age of 5 were obtained. They served as a biological substantiation for the management of the redfish fishery in these divisions. It is advisable to limit the fishing regime by F_{max} level.

INTRODUCTION

The total allowable catch (TAC) is the most important index determining the efficiency of fishery management. Estimation of the yield per unit of recruitment ($\frac{Y}{R}$) in relation to fishing intensity (F) is the first stage in TAC calculation. F.I.Baranov constructed a mathematical model for such relationship (Baranov, 1918) which was modified later by Beverton and Holt (Beverton and Holt, 1957). This relationship has a clearly pronounced maximum for many species including beaked redfish in Divs. 3LN and 3M (Fig. 1). The fishing intensity at which the maximum catch may be taken is called optimal and the yield itself - the maximum sustainable yield (MSY).

This model, however, is based on the prerequisites which leave out of account the most important peculiarities of most commercial fishes, namely, a considerable variation of natural and fishing mortality rates with age (Tretyak, 1983), variability of the year class abundance and parameters of growth functions. That is why optimal, in the above sense, level of fishery is always constant. It does not depend on variations of age composition and of other parameters relating the commercial stock. Besides, fish with a low value of metabolism parameter (K) in the von Bertalanffy equation and (or) with high natural mortality rates give the curves of the catch per unit of recruitment either without a maximum or with a slightly pronounced one. It produces an effect as if the fishing intensity for these fishes may be increased to a very high level without the least reduction of the yield. In reality the exploitation of commercial stocks of such fishes with a high intensity or with that close to F_{max} leads to undesirable consequences - to depletion of commercial and spawning stock biomass, possibly to a sharp decline of daughter year class abundance.

The sparing fishing regime at the $F_{0.1}$ level also does not take into account the current state of the stock and, consequently, does not have any biologically substantiated notable advantages over the conception of F.I.Baranov and Beverton and Holt. Its consistent utilization will provide only a certain stabilization of the fish supply in the years with a poor recruitment at the expense of biomass reserve which is formed in the years prior to fishery when recruitment was numerous.

The abstract character of some prerequisites for these models and the absence of a biological criterion providing the needed level of stock reproduction which should be assumed as a basis while estimating the optimal values of F and MSY notably limit the possibility of applying the results of the theoretical fishery analysis directly to real fishery management.

In this paper the biological criterion - the optimal biomass of the parent stock - is obtained which may be taken as a principle in the redfish fishery management in Divs. 3LN and 3M. TAC for 1985 was estimated with allowance for peculiarities of beaked redfish - variation of natural and fishing mortality rates with age and variability of the year class abundance.

MATERIAL AND METHODS

Natural mortality of commercial fishes results from the interaction of fish from a commercial stock with numerous interdependent and independent ecological factors. Mortality varies with age and under the influence of these factors. But, as a rule, it is set invariable in time and independent of age. In some fishes the relative error in the abundance estimates of some age groups which is introduced by the second assumption may be higher than 100% (Blinov, 1979). That is why the method of estimating the natural mortality rates at different fishing age was applied to the redfish in Divs. 3LN and 3M (Tretyak, 1983). Variation of the redfish natural mortality rate with age is represented by the convex downward one-(positive) minimum function

$$M(t) = a\,[-t-(\tau_e-\bar{\tau}_s)\ \ln\,(\tau_e-t)] + b,$$

which turns into infinity with the age tending to maximally possible hypothetical age τ_e, which may be reached by fish under real ecological conditions, fishing being intensive, if they were not caught. In the interval from τ_r to τ_e where τ_r - age of recruitment this function is determined, continuous and has the only stationary point $\bar{\tau}_s$. With $a>0$ $\min M(t) = M(\bar{\tau}_s)$. In virtue of the hypothesis of the minimum M(t) to correspond to the mean age of mature fish (Nikolsky, 1974), the parameter $\bar{\tau}_s$ has a concrete biological content. Parameters a and b have no biological content. For the period 1968 to 1984 the mean age of mature redfish in Divs. 3LN is equal to 11 and in Div. 3M - to 12 years. Parameters τ_e are set equal to 50 and 51 years, respectively. To estimate parameters a and b it is sufficient to know the average number of fish caught at each age, von Bertalanffy parameters (l_∞, K and t_0), those of allometric growth (a_1 and b_1) and the natural mortality rate for redfish set constant at some section of the interval $[\tau_r, \tau_e]$. Von Bertalanffy parameters are determined by Hohendorf's method (Hohendorf, 1966), a_1 and b_1 - by the least-squares method (Table 1). The intervals in the life span of fish in which natural mortality rates are obtained and set constant include age groups making up the bulk of catches. It turned out possible to calculate the total mortality rates for them. In Table 2 the total mortality rates for beaked redfish in Divs. 3LN and 3M in the intervals 12 to 16 and 11 to 15 years, respectively, are given, They are obtained as the difference of natural logarithms of the total catch to the total effort ratios in two adjacent age groups. In this case the age composition is pooled for the whole survey period and smoothed by three adjacent age groups. Fishing effort is reduced to a standard type of the ship - the Soviet large refrigerator trawler and set average for 1968 to 1984. In Divs. 3LN it is equal to 9 847, in Div. 3M - to 7 813 trawling hours. Taking into account the main relationship of the VPA

$$\frac{C_{\tau+1}}{C_\tau} = \frac{F_{\tau+1}}{F_\tau} \cdot \frac{Z_\tau \cdot (1 - \exp(-Z_{\tau+1}))}{Z_{\tau+1} \cdot \exp(Z_\tau) \cdot (1 - \exp(-Z_\tau))},$$

where C_τ - the catch at age τ, and F_τ and Z_τ - fishing and natural mortality rates at this age, it is obvious that the ratios $\frac{F_{\tau+1}}{F_\tau}$ for certain age groups are about 1 (Table 2). This means that fishing mortality rates are approximately equal in the intervals considered (in this case accurate to 0.01). Natural mortality rates in these intervals are obtained as the difference between mean rates of the total and fishing mortalities. The latters are conventionally set equal to the least values of Z_τ. Natural mortality rates in the considered intervals and a and b parameters of M(t) functions are given in Table 1. Variation of natural mortality rates for beaked redfish in both areas in relation to age is shown in Fig. 2.

Abundance and biomass of the beaked redfish commercial stocks under consideration are calculated for the period 1968 to 1984 by VPA. To realize the method it is sufficient to know the number of fish caught at different ages in different years of fishery (Tables 3 and 4), natural mortality rates at the age from τ_r to τ_λ (τ_λ - the latest age of fish in the commercial stock) set constant during one year of fish life and, the so-called final values of fishing mortality rates $F\tau_{st}$. The age of redfish entering the fishery in both areas is set equal to 5, τ_λ - to 23 years.

Beginning with age τ_c the final values of fishing mortality rates in the latest passed year of fishery were determined by the formula

$$F\tau_{st} = \bar{Z} - M_\tau$$

where $\bar{Z}$ - arithmetic mean of the total mortality rates obtained from the pooled sample in the interval from τ_c to $\tau_\lambda - 2$, $M_\tau = \int_\tau^{\tau+1} M(t)dt$. For fish from Divs. 3LN and 3M τ_c is set equal to 10 and 11 years, respectively, $\bar{Z}$ - to 0.200 and 0.304. M_τ values are given in Tables 5 and 6. For the year classes having undergone fishery the final rates of fishing mortality at the age τ_λ are assumed constant and equal to F_{τ_λ} in 1984. $F\tau_{st}$ values at the age from τ_r to $\tau_c - 1$ inclusively are determined in this year as arithmetic means of the corresponding F_τ obtained by back VPA calculation. All final values of $F\tau_{st}$ are given in Tables 5 and 6.

RESULTS

Beaked redfish in Divs. 3LN

Bearing in mind that 90% of the catch include fish aged 5 to 15, arithmetic means of the fishing mortality rates ($\bar{F}_{5-15}$) of redfish from these age groups for the latest 10 years of fishery are obtained. Fig. 3 represents the linear stochastic relationship between the total international fishing effort for these years (f) and $\bar{F}_{5-15}$. The regression equation looks like follows:

$$\bar{F}_{5-15} = 0.044 \cdot f - 0.181$$

The availability of a rather close and stable correlation between random values f and $\bar{F}_{5-15}$ (correlation coefficient is equal to 0.75) and correspondence of the free term in the regression equation to its physical meaning (it is close to 0) show the validity of input parameter determination in VPA.

The fish abundance at the beginning of each considered year of fishery is given in Table 7. It is obvious that during the survey period the abundance of year classes aged 5 is subject to low fluctuations. The 1973-1978 year classes were the richest. Their abundance at that age averaged 115 mill. specimens. The 1968-1970 year classes were poor, their abundance averaging 44 mill. specimens which is lower than the average abundance of rich year classes by a factor of 2.6. In length frequencies of the catches taken by a small meshed trawl in Divs. 3LN (South Newfoundland) in 1980-1984 length groups corresponding to fish from abundant year classes of 1973 to 1978 dominate (Fig. 4). This phenomenon confirms indirectly the abundance estimates obtained by VPA. In 1985 fish from these year classes will reach the age of 7-12 years and will compose the bulk of catches. The commercial stock biomass has not almost changed since 1975 and averaged 150 thou. tons. In 1984, by our calculations, it amounted to 140 thou. tons being somewhat lower than the estimate obtained from the trawl survey results.

If we assume that redfish in Divs. 3LN are immature till the age of 11 and that beginning with this age the portion of mature fish at each age amounts to 100%, than in the first approximation we obtain the biomass of the parent stock of 12 year classes. The comparison of the parent stock biomass and the abundance of produced offspring aged 5 shows that this relation may be described by the Ricker curve of recruitment:

$$R_5 = \alpha \bar{P} e^{-\beta \bar{P}} ,$$

where $\bar{P}$ - mean annual biomass of the parent stock, R_5 - recruitment, α and β - parameters equal to 3.161 and $0.960 \cdot 10^{-2}$, respectively. We have no reasons to consider the stock-recruitment regression line (Fig. 5) not adequate to the data available. It is confirmed indirectly by a rather close back linear relationship between $\bar{P}$ and $\ln \frac{R_5}{\bar{P}}$. The correlation coefficient between these values differs significantly from 0, being stable and equal to 0.99.

Relating to the fact that in the 1985 commercial stock there will be 6 abundant year classes, its total abundance and biomass will come up to 520 mill. specimens and 166 thou. tons, respectively. The biomass of mature fish will also increase and reach 60 thou. tons. At the level of exploitation $F_{max} = 0.15$ the total allowable catch will be 25 thou. tons.

Beaked redfish in Div. 3M

Fish aged 8 to 15 years make up the bulk of catches (about 80%). Mean rates of fishing mortality are calculated for these age groups ($\bar{F}_{8-15}$) for all considered years of fishery. The linear stochastic relationship between the total international fishing effort and $\bar{F}_{8-15}$ is shown in Fig. 6. The regression equation looks like follows:

$$\bar{F}_{8-15} = 0.024 \cdot f + 0.006$$

A rather close and stable relation between these random values (correlation coefficient equals 0.92) and correspondence of the free term in the regression equation to its physical meaning also show the validity of input parameter determination needed for VPA.

Table 8 shows the fish abundance at the beginning of each considered year of fishery. Thus, it may be concluded that the abundance of the year classes aged 5 is not subject to great fluctuations except the 1979 year class. Its abundance, by our calculations, amounts to 153 mill. spec. thus being higher than that of poor year classes by a factor of 3. The 1971 to 1975 year classes may be attributed to rich while those of 1976 to 1978 - to poor ones. Length frequencies of the catches taken by a small meshed trawl in Div. 3M (the Flemish Cap Bank) in 1980 to 1984 (Fig. 7) confirm indirectly the abundance estimates obtained by VPA. In 1985 fish from the 1971 to 1975 year classes will attain the age of 10-14 years and will make up the bulk of catches. Since 1975 the commercial stock biomass has remained at the level of 120 thou. tons. In 1984 it amounted to 134 thou. tons, which is in a good correlation with the biomass estimate obtained from the trawl survey results.

If we assume that redfish in Div. 3M are immature till the age of 12 and that beginning with 12 years the portion of mature fish at each age is 100%, than in the first approximation we also obtain the biomass of the parent stock of 12 year classes. The comparison of the parent stock biomass and the abundance of produced offspring aged 5 shows that the back relationship exists between these random values. Fig. 8 demonstrates the Ricker's stock-recruitment regression equation. Notwithstanding a low correlation coefficient between $\bar{P}$ and ln $\frac{R_5}{\bar{P}}$ (it equals 0.65), we have no grounds to consider the regression line inadequate to the data available.

In 1985 the total abundance will remain at the 1984 level and amount to 500 mill. specimens, the biomass will be somewhat higher than the average level for the period 1975 to 1984 and come up to 145 thou. tons. The biomass of mature fish will grow and total about 62 thou. tons. At the level of exploitation F_{max} = 0.15 the total allowable catch in 1985 will be 22 thou. tons.

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Table 1. Parameters of the von Bertalanffy equation, allometric growth, natural mortality rates and a and b parameters of M(t) functions for beaked redfish in Divs. 3LN and 3M.

Divs.	l_∞,cm	K	t_0 years	a_1	b_1	M	a	b
3LN	56,3	0,061	-2.09	$0{,}177 \cdot 10^{-4}$	2,96	0,08	0,0227	3.5645
3M	53,4	0,066	-2,57	$0{,}750 \cdot 10^{-5}$	3,16	0,07	0,0227	3,5858

Table 2. Running mean of catches based on pooled age composition and mean rates of total mortality for beaked redfish at different age in Divs. 3LN and 3M.

Age	Divs. 3LN				Div. 3M			
	C_τ, thou.sp.	Z_τ	$\frac{F_{\tau+1}}{F_\tau}$	F_τ	C_τ, thou. sp.	Z_τ	$\frac{F_{\tau+1}}{F_\tau}$	F_τ
11					4430	0.131	1.029	0.130
12	3222	0.202	1.026	0.150	3883	0.192	0.982	0.130
13	2634	0.254	1.010	0.150	3207	0.152	1.032	0.130
14	2042	0.276	0.943	0.150	2754	0.217	1.041	0.130
15	1551	0.152	1.045	0.150	2214	0.303	0.917	0.140
16	1319	0.264	0.946	0.150	1637	0.122		
17	1022	0.131			1449			
18	888							

Table 3. **Total number of beaked redfish taken by international fishery in Divs. 3LN (thou. spec.).**

Age	Year of fishery								Year of fishery								
	I968	I969	I970	I97I	I972	I973	I974	I975	I976	I977	I978	I979	I980	I98I	I982	I983	I984
5	446	397	2489	3272	977	942	3I6	77I6	2I7	26	2243	4786	2773	76I8	9346	52I3	273I
6	784	95I	3220	482I	I942	2466	579	759I	533	I09	2939	4294	2803	877I	I36I6	I0933	4570
7	I605	I823	2720	3554	2070	3565	4II	5I9I	953	24I	2442	3633	2486	69II	II328	I0743	48I2
8	2692	2745	3420	34I9	2500	4680	I226	65I9	I672	449	3I59	5397	3572	8252	II949	II646	602I
9	3I49	3099	3574	2562	2548	5387	980	5545	2434	749	2609	40I4	3430	7972	I0964	94II	5222
I0	504I	4I29	4324	2702	4505	758I	2290	3972	6223	2095	2674	344I	4297	753I	9042	9270	59I3
II	3358	4035	352I	2708	3897	5085	3508	I900	77II	3255	I6I7	2238	30I9	4I23	3I59	3593	3I47
I2	3550	4556	4I00	384I	3589	4727	2039	I498	79I2	3872	I867	I998	3539	4086	2I75	2493	25I5
I3	2885	3545	3470	2560	292I	3290	334I	I322	5295	3I98	I5I8	I396	2924	2639	I0I6	II02	I255
I4	I832	2479	22I4	I847	2432	2792	3I87	I223	2982	2467	II93	908	I9I5	I493	534	587	662
I5	I389	2049	I359	4402	2857	289I	2936	873	I8I0	248I	II20	796	I453	I305	385	344	46I
I6	923	I329	628	2699	2I89	2I6I	228I	850	972	I409	6I3	6I4	783	797	227	2I3	282
I7	548	803	I5I	996	I398	I662	I223	526	497	788	264	42I	462	5I7	94	86	I29
I8	708	II08	20I	I703	I826	2029	I302	475	558	I208	342	535	496	548	I02	58	I4I
I9	733	I202	I5I	24I8	I824	I928	895	299	642	908	324	395	370	495	48	I5	68
20	2069	3282	275	7I07	523I	4923	3342	I498	I65	I682	I255	962	II44	I406	79	28	95
2I	633	835	I00	2844	I2I6	II97	895	207	484	7I9	300	2I4	2I7	3I0	I6	20	I5
22	534	895	000	II38	I400	II64	I222	495	332	344	386	247	323	4I7	25	20	3
23	275	444	26	428	730	732	8I6	500	I94	I64	I84	I27	I53	220	25	20	3

Table 4. Total number of beaked redfish taken by international fishery in Div. 3M (thou. spec.).

Age	I968	I969	I970	I97I	I972	I973	I974	I975	I976	I977	I978	I979	I980	I98I	I982	I983	I984
5	4	6	I08	23	363	322	67	2658	I6	39	II60	6I8	I23	32I	I4	I3	I027
6	29	29	2I2	54	997	222I	II84	2735	I35	99	II04	2II8	8I8	II94	233	I55	875
7	II4	I08	204	96	2I07	64I7	4825	3667	462	308	I228	357I	2708	2925	II37	837	I536
8	I83	228	725	270	2428	8488	8562	3937	I342	706	II40	3665	3672	4533	3050	3320	262I
9	287	370	II79	629	28II	9773	I2245	4537	2827	I58I	I7I8	3I46	4399	5877	5II9	603I	3857
I0	440	5I7	976	I305	3728	855I	I3254	6449	5794	3445	3690	3020	3855	64I2	7334	9792	6044
II	633	549	80I	I6II	4676	6266	I0985	5967	7025	4736	49I3	3364	2827	4855	6387	9095	6204
I2	779	467	809	I42I	4985	43I9	7008	38II	5323	4238	4467	3632	2280	2699	3569	529I	4335
I3	II33	53I	640	I624	6597	4264	6474	2558	4533	4662	4550	4492	2838	2223	2350	3643	36I2
I4	II39	457	538	I428	7007	3302	5088	I623	3093	40I4	36II	3985	2740	I666	I600	2523	2599
I5	I009	358	364	I293	7072	2372	3959	I062	20I6	3483	2609	33I6	2409	I235	II87	I783	I799
I6	769	25I	225	I048	6644	I532	3093	789	I4I0	2929	I799	2508	I867	850	963	I28I	I233
I7	465	I20	I25	56I	4766	6I4	I705	482	703	I67I	936	I364	II34	454	6I5	684	573
I8	339	70	68	439	39I3	352	II49	37I	449	I263	623	986	853	3II	454	457	35I
I9	272	48	90	399	3533	205	809	370	333	982	437	795	658	237	383	356	250
20	I74	3I	87	284	2688	92	5I5	258	2II	705	259	558	47I	I64	264	229	I58
2I	I0I	I8	I44	230	I840	64	3I5	24I	I36	49I	I65	376	324	I08	I70	I54	99
22	32	5	I33	I62	684	35	85	I76	6I	2I0	57	I43	I33	4I	50	48	25
23	3	5	4I	I55	29I	7	I4	I45	I7	6I	49	68	37	I4	7	5	4

Table 5. Mean rates of natural (M_τ) and fishing mortalities in the interval of one year of life for beaked redfish in Divs. 3LN.

Age	M_τ	Fishing mortality rates by years of fishery							
		I968	I969	I970	I97I	I972	I973	I974	I975
5	0.085	0.008	0.006	0.044	0.064	0.026	0.025	0.007	0.I72
6	0.082	0.0I6	0.0I9	0.059	0.090	0.044	0.076	0.0I7	0.2II
7	0.080	0.030	0.042	0.060	0.075	0.049	0.093	0.0I4	0.I85
8	0.079	0.055	0.059	0.09I	0.088	0.06I	0.I32	0.037	0.28I
9	0.077	0.063	0.072	0.089	0.080	0.077	0.I58	0.033	0.203
I0	0.077	0.068	0.097	0.I20	0.079	0.I73	0.293	0.082	0.I56
II	0.077	0.060	0.063	0.099	0.090	0.I36	0.263	0.I87	0.079
I2	0.078	0.079	0.094	0.074	0.I30	0.I45	0.2I2	0.I40	0.I00
I3	0.079	0.059	0.093	0.085	0.054	0.I2I	0.I67	0.200	0.III
I4	0.08I	0.038	0.058	0.068	0.052	0.059	0.I43	0.2I2	0.092
I5	0.083	0.025	0.048	0.036	0.I65	0.094	0.082	0.I94	0.073
I6	0.087	0.0I2	0.026	0.026	0.0I6	0.083	0.I02	0.076	0.070
I7	0.09I	0.005	0.0II	0.003	0.030	0.050	0.093	0.056	0.020
I8	0.096	0.0I6	0.0I9	0.005	0.066	0.093	0.I29	0.I32	0.037
I9	0.I02	0.030	0.049	0.005	0.I05	0.I40	0.202	0.II4	0.060
20	0.I08	0.I76	0.I67	0.0I3	0.286	0.3I0	0.594	0.56I	0.255
2I	0.II6	0.345	0.09I	0.006	0.I59	0.066	0.098	0.I8I	0.054
22	0.I25	0.064	I.059	0.000	0.082	0.I0I	0.076	0.I26	0.I32
23	0.I35	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065

Age	Fishing mortality rates by years of fishery								
	I976	I977	I978	I979	I980	I98I	I982	I983	I984
5	0.003	0.000	0.025	0.04I	0.027	0.068	0.079	0.052	0.035
6	0.0I4	0.002	0.04I	0.053	0.027	0.099	0.I47	0.I09	0.052
7	0.033	0.007	0.053	0.057	0.035	0.075	0.I56	0.I45	0.057
8	0.074	0.0I7	0.I04	0.I40	0.065	0.I35	0.I58	0.208	0.I00
9	0.I40	0.038	0.II5	0.I64	0.I09	0.I75	0.233	0.I57	0.II9
I0	0.3I8	0.I5I	0.I60	0.I92	0.232	0.3I7	0.267	0.274	0.I23
II	0.436	0.237	0.I45	0.I7I	0.223	0.3I5	0.I85	0.I4I	0.I23
I2	0.463	0.353	0.I8I	0.234	0.383	0.454	0.238	0.I90	0.I22
I3	0.5I5	0.298	0.I98	0.I75	0.538	0.473	0.I68	0.I59	0.I2I
I4	0.557	0.4I6	0.I5I	0.I53	0.335	0.50I	0.I42	0.I22	0.II9
I5	0.I68	0.449	0.293	0.I26	0.340	0.348	0.202	0.II3	0.II7
I6	0.096	0.I69	0.I66	0.227	0.I54	0.277	0.082	0.I45	0.II3
I7	0.047	0.094	0.038	0.I45	0.235	0.I29	0.042	0.036	0.I09
I8	0.036	0.2II	0.072	0.I38	0.347	0.668	0.045	0.044	0.I04
I9	0.095	0.III	0.I20	0.I66	0.202	I.355	0.I68	0.0I2	0.098
20	0.038	0.340	0.I99	0.54I	0.862	2.592	0.7I9	0.I26	0.092
2I	0.III	0.2I3	0.085	0.043	0.200	0.536	0.I75	0.355	0.084
22	0.I06	0.099	0.I55	0.085	0.078	0.65I	0.067	0.3I3	0.075
23	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065

Table 6. Rates of natural (M_{τ}) and fishing mortalities of beaked redfish in Div. 3M in the interval of one year of life.

Age	M_{τ}	Fishing mortality rates by years of fishery							
		I968	I969	I970	I97I	I972	I973	I974	I975
5	0.080	0.000	0.000	0.000	0.000	0.006	0.007	0.002	0.046
6	0.077	0.000	0.000	0.003	0.000	0.0I5	0.044	0.027	0.068
7	0.075	0.003	0.002	0.003	0.00I	0.029	0.II0	0.II2	0.096
8	0.073	0.005	0.005	0.0I6	0.005	0.036	0.I37	0.I83	0.I09
9	0.07I	0.009	0.0II	0.032	0.0I5	0.053	0.I75	0.258	0.I22
I0	0.070	0.0I7	0.0I8	0.033	0.039	0.I0I	0.I96	0.325	0.I82
II	0.069	0.030	0.023	0.03I	0.060	0.I65	0.2I2	0.353	0.205
I2	0.069	0.044	0.024	0.037	0.062	0.227	0.I95	0.332	0.I72
I3	0.070	0.088	0.033	0.036	0.084	0.379	0.266	0.425	0.I67
I4	0.07I	0.II9	0.04I	0.038	0.093	0.5I7	0.285	0.492	0.I54
I5	0.073	0.I34	0.044	0.036	0.I04	0.726	0.284	0.550	0.I54
I6	0.076	0.II5	0.039	0.030	0.I23	0.9I8	0.287	0.6I7	0.I72
I7	0.079	0.I3I	0.02I	0.022	0.087	I.0I2	0.I64	0.5I2	0.I56
I8	0.083	0.204	0.023	0.0I3	0.088	I.I39	0.I52	0.447	0.I72
I9	0.088	0.087	0.036	0.033	0.087	I.620	0.I30	0.528	0.22I
20	0.094	0.II7	0.0II	0.074	0.I24	I.092	0.I24	0.48I	0.279
2I	0.I0I	0.290	0.0I4	0.060	0.254	2.624	0.054	0.685	0.383
22	0.I09	0.676	0.0I9	0.I23	0.08I	2.74I	0.32I	0.085	0.939
23	0.II8	0.I86	0.I86	0.I86	0.I86	0.I86	0.I86	0.I86	0.I86

Age	Fishing mortality rates by years of fishery								
	I976	I977	I978	I979	I980	I98I	I982	I983	I984
5	0.000	0.000	0.0I5	0.008	0.002	0.005	0.000	0.000	0.007
6	0.003	0.002	0.0I6	0.030	0.0II	0.0I9	0.004	0.003	0.0I7
7	0.0I3	0.006	0.020	0.057	0.043	0.043	0.0I9	0.0I6	0.038
8	0.04I	0.02I	0.026	0.068	0.067	0.082	0.050	0.064	0.057
9	0.093	0.054	0.056	0.082	0.096	0.I26	0.I09	0.II6	0.086
I0	0.I96	0.I37	0.I50	0.II5	0.I20	0.I72	0.I98	0.268	0.I42
II	0.266	0.2I0	0.255	0.I72	0.I3I	0.I89	0.223	0.343	0.235
I2	0.244	0.2I9	0.268	0.260	0.I46	0.I54	0.I78	0.25I	0.235
I3	0.273	0.30I	0.330	0.402	0.287	0.I80	0.I69	0.240	0.234
I4	0.270	0.354	0.345	0.458	0.392	0.235	0.I65	0.238	0.233
I5	0.252	0.468	0.352	0.520	0.474	0.265	0.226	0.242	0.23I
I6	0.272	0.593	0.404	0.573	0.534	0.262	0.294	0.348	0.228
I7	0.I99	0.5II	0.328	0.523	0.476	0.205	0.266	0.304	0.225
I8	0.I86	0.557	0.3I5	0.585	0.625	0.200	0.284	0.282	0.22I
I9	0.203	0.665	0.33I	0.7I9	0.858	0.306	0.353	0.329	0.2I6
20	0.I67	0.728	0.320	0.79I	I.I4I	0.465	0.574	0.326	0.2I0
2I	0.207	0.627	0.325	0.9I6	I.462	0.775	I.II6	0.682	0.203
22	0.I4I	0.499	0.I20	0.460	0.888	0.633	0.9I9	I.032	0.I95
23	0.I86	0.I86	0.I86	0.I86	0.I86	0.I86	0.I86	0.I86	0.I86

Table 7. Abundance of beaked redfish at different age in Divs. 3LN by years of fishery (thou. spec.).

Age	Year								
	I968	I969	I970	I97I	I972	I973	I974	I975	I976
5	5928I	63228	60752	546I5	39872	39388	45028	5I2I8	58658
6	50779	54033	577I5	53422	4705I	35683	35275	4I072	3959I
7	55407	460I7	48858	50I27	44599	4I498	30473	3I944	3063I
8	52850	496I6	40727	42488	42926	39I84	34892	27732	24509
9	53055	46242	43222	34353	3597I	373I3	3I724	3I07I	I9350
I0	77II8	46I08	39835	366II	29356	3085I	29503	2843I	23494
II	60938	66676	38742	32720	3I33I	22857	2I302	25I74	225I3
I2	48385	53I52	57945	32506	27695	25324	I6276	I6357	2I528
I3	52669	4I294	44703	49707	26375	22I45	I8929	I308I	I3677
I4	50609	45882	34756	37957	43524	2I589	I7309	I4327	I08I8
I5	56333	44944	399I9	29930	332I8	37840	I7253	I29I2	I2052
I6	8I057	50589	39427	3543I	23352	27826	32095	I3082	II049
I7	98237	734I0	45I84	3555I	29888	I9327	23438	27273	III82
I8	7I379	8920I	66268	4III8	3I5I0	25953	I6073	20233	24404
I9	25903	26903	33498	25253	I4734	I0997	8738	5392	7466
20	I3455	2269I	23I39	30I06	20529	II572	8II6	704I	4587
2I	2286	I0I27	I7229	20506	20302	I35I3	5733	4I55	4900
22	9I05	I44I	8232	I5247	I557I	I693I	I09I2	4258	3506
23	4667	7536	44I	7265	I239I	I2425	I385I	8487	3293

Age	Year							
	I977	I978	I979	I980	I98I	I982	I983	I984
5	83807	97074	I25393	I09278	I2066I	I28865	I07652	82803
6	53700	76950	87003	II0587	97726	I03569	I09402	93904
7	35957	49382	68068	76008	99I93	8I586	82383	90335
8	27370	32962	43228	59324	67765	84944	644II	65759
9	2I040	24859	27439	34742	5I377	54703	6703I	48323
I0	I557I	I8759	20509	2I554	28852	399I6	40II0	53040
II	I5835	I2402	I4800	I5679	I5827	I946I	28298	28229
I2	I3476	II568	9929	II549	II6I5	I069I	I4976	22755
I3	I2526	8752	89I7	726I	7273	68I8	7789	II443
I4	7555	8594	6633	69I4	39I8	4I89	5325	6I37
I5	7I20	4597	68I3	5247	456I	2I88	3350	4347
I6	9375	4I8I	3I55	5530	3436	2963	I646	2753
I7	9I98	7259	3247	2304	4345	2387	250I	I305
I8	9738	7644	6378	2563	I662	3488	2090	2202
I9	90I8	3020	2723	2I27	693	326	I277	765
20	6I32	7288	2420	2083	I569	I6I	249	II39
2I	3962	39I6	5362	I264	789	I05	70	I97
22	3905	2852	3205	4574	92I	4II	78	44
23	2783	3I23	2I55	2597	3734	424	339	50

Table 8. Abundance of beaked redfish at different age in Div. 3M by years of fishery (thou. spec.).

Age	Year								
	I968	I969	I970	I97I	I972	I973	I974	I975	I976
5	76554	89422	89448	75704	58555	50094	49034	60553	738I8
6	56099	70642	825I7	8254I	69858	537I7	45922	45I8I	53396
7	45902	5I922	65383	76206	76396	637I7	4758I	4I367	39092
8	37577	42476	48082	60459	70622	68854	52943	39477	34854
9	32I54	34740	39270	43999	55936	633I3	55794	40966	32892
I0	27772	29678	3I994	3543I	40372	49408	4952I	40I44	33777
II	22438	25452	27I79	28874	3I766	34037	3787I	33367	3I202
I2	I8852	20330	232I3	24589	25387	25I34	25698	24823	25377
I3	I3767	I6844	I8528	20879	2I573	I8889	I9299	I7206	I95I2
I4	I0600	II752	I5I9I	I6660	I790I	I3768	I3505	II762	I3570
I5	8246	8765	I05II	I3626	I4I45	9938	9649	7692	9390
I6	7363	6706	780I	9423	II420	636I	6956	5I73	6I29
I7	3942	608I	5976	70I3	7725	4226	4422	3478	4037
I8	I9I9	3I96	5503	5404	5942	2595	33I5	2450	2750
I9	34II	I440	2874	5000	4554	I75I	205I	I95I	I899
20	I688	2864	I273	2546	4I98	825	I408	II08	I432
2I	429	I367	2578	I075	2047	I28I	663	792	763
22	68	290	I2I8	2I93	754	I34	I098	302	488
23	I8	3I	255	966	I8I4	43	87	904	I06

Age	Year							
	I977	I978	I979	I980	I98I	I982	I983	I984
5	8028I	8259I	8636I	72950	63422	50I98	58440	I53I88
6	68II8	7408I	75I05	79II0	672I8	58268	4632I	53927
7	493I2	62954	67520	67506	72474	6I085	53733	42747
8	35806	45465	5724I	59I84	60002	644I7	5558I	49036
9	3III0	32597	4II80	49689	5I45I	5I403	56952	4846I
I0	27906	27459	28709	35323	42033	42237	42946	47234
II	25890	2268I	2204I	2385I	292I8	33007	32303	306I5
I2	2233I	I9590	I64I2	I7325	I9533	22583	24648	2I392
I3	I8552	I6749	I3979	II806	I397I	I5626	I7634	I7900
I4	I3849	I2806	II227	87I5	8263	I0883	I2306	I2935
I5	9650	9053	845I	66I4	5484	6087	8594	903I
I6	6787	56I6	59I9	4672	3829	39I2	45I4	627I
I7	4327	3477	3475	3092	2539	273I	2702	2953
I8	3058	2399	23I3	I904	I776	I9II	I934	I84I
I9	2I0I	I6I2	I6I2	II86	938	I337	I324	I342
20	I420	989	I060	7I9	460	632	860	872
2I	II03	624	654	437	209	263	325	565
22	56I	532	407	236	9I	87	78	I48
23	380	305	424	230	87	43	3I	24

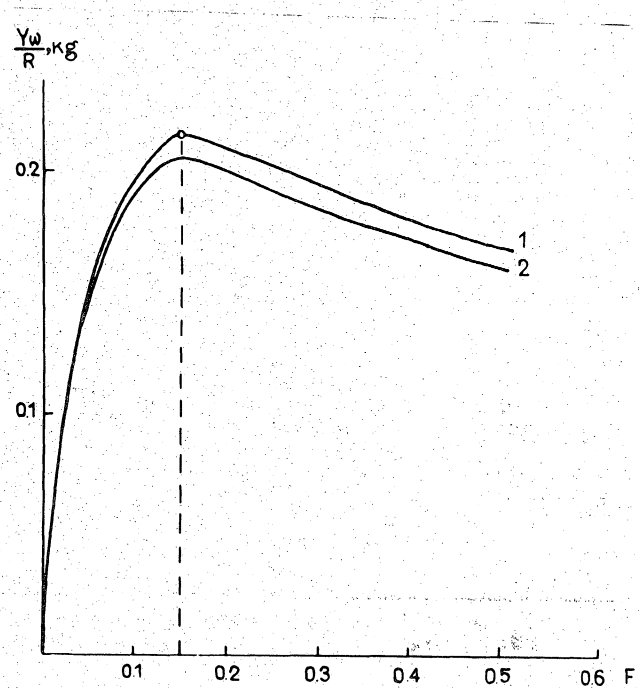

Fig. 1. Possible yield per recruit of beaked redfish in Divs. 3LN (Curve 1) and in Div. 3M (Curve 2).

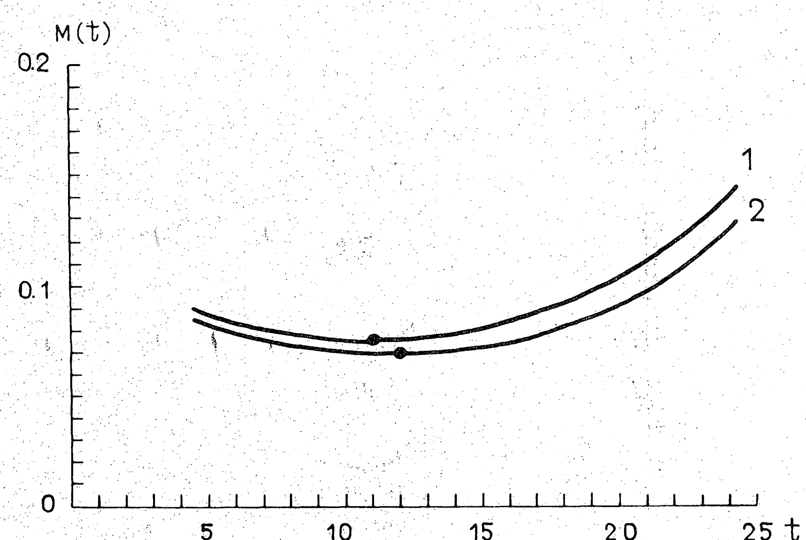

Fig. 2. Variation of beaked redfish natural mortality rates with age in Divs. 3LN (Curve 1) and in Div. 3M (Curve 2).

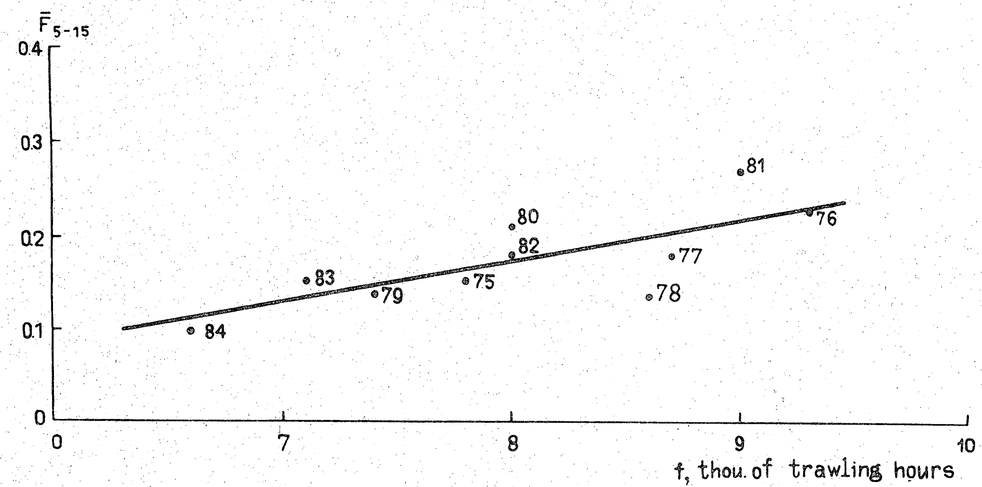

Fig. 3. Relationship between the mean rate of fishing mortality for beaked redfish aged 5 to 15 in Divs. 3LN and the total international fishing effort.

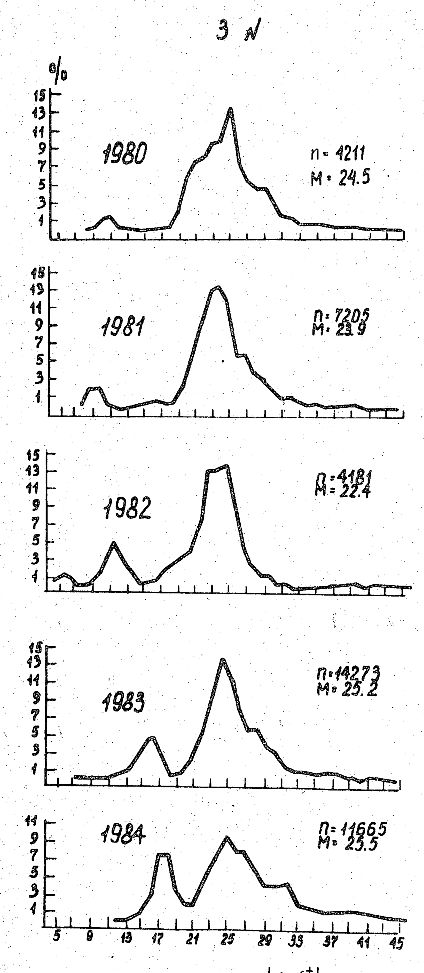

Fig. 4. Length composition of beaked redfish from trawl catches taken in the South Newfoundland in spring-summer 1980 to 1984.

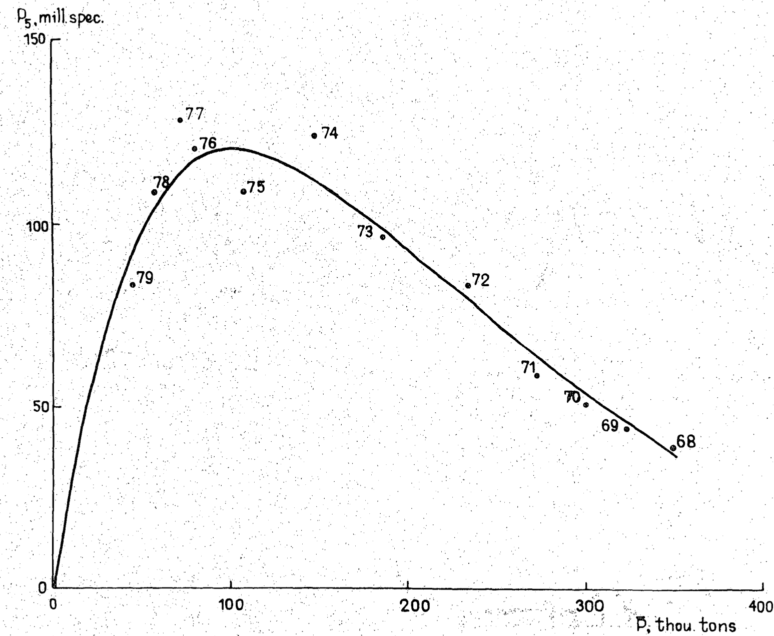

Fig. 5. Relationship between the abundance of beaked redfish year classes aged 5 in Divs. 3LN and the mean annual biomass of mature fish.

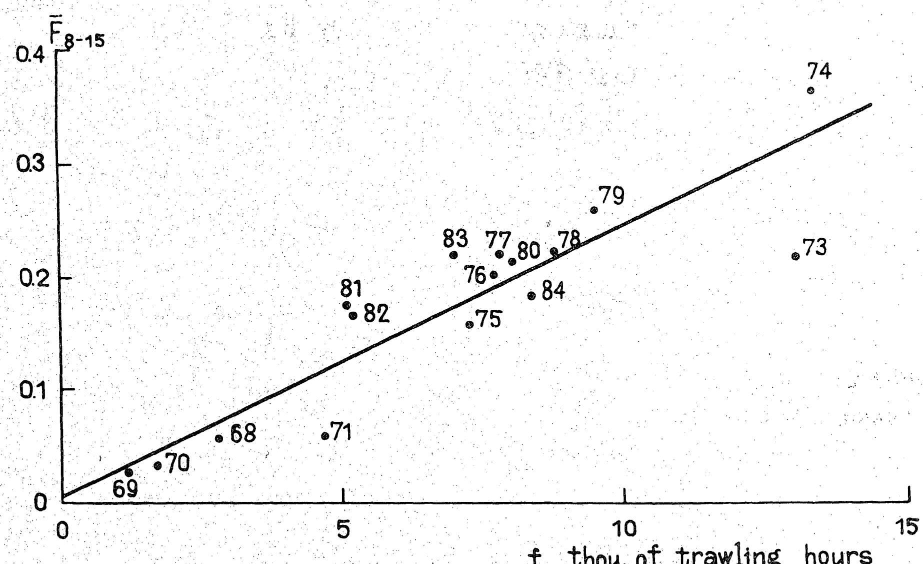

Fig. 6. Relationship between the mean rate of fishing mortality for beaked redfish aged 8 to 15 in Div. 3M and the total international fishing effort.

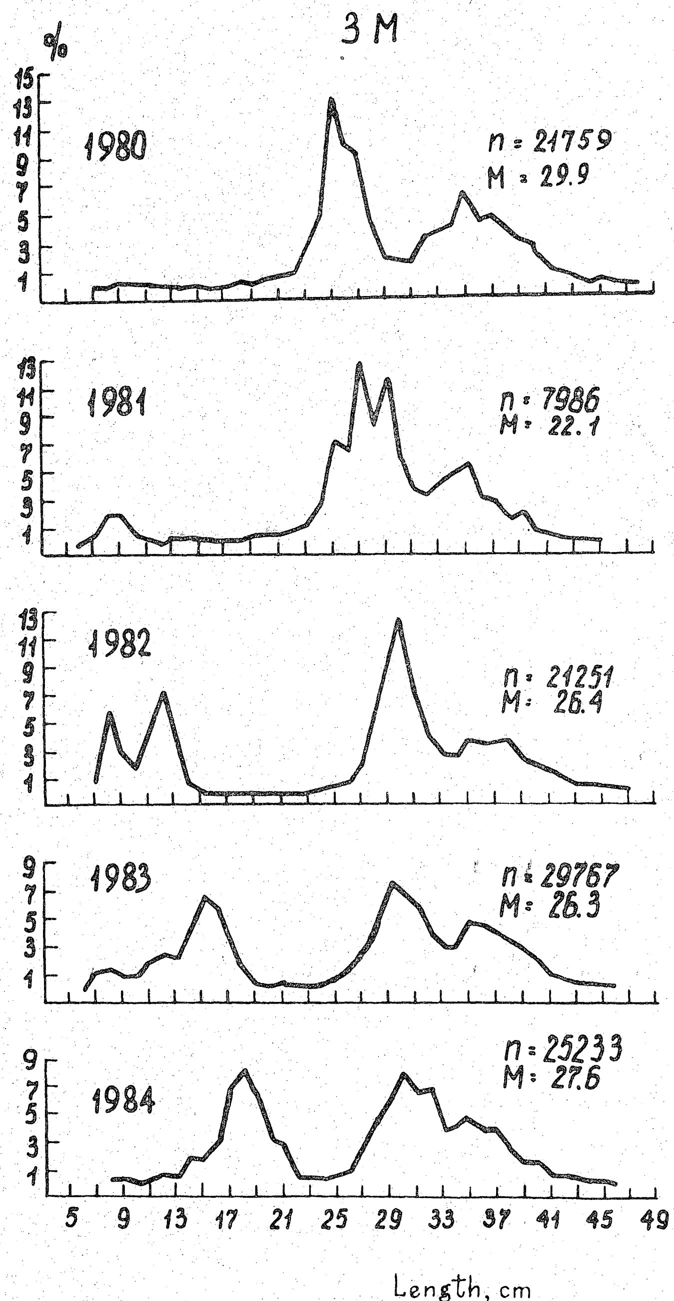

Fig. 7. Length composition of beaked redfish from trawl catches taken in the Flemish Cap area in spring-summer 1980 to 1984.

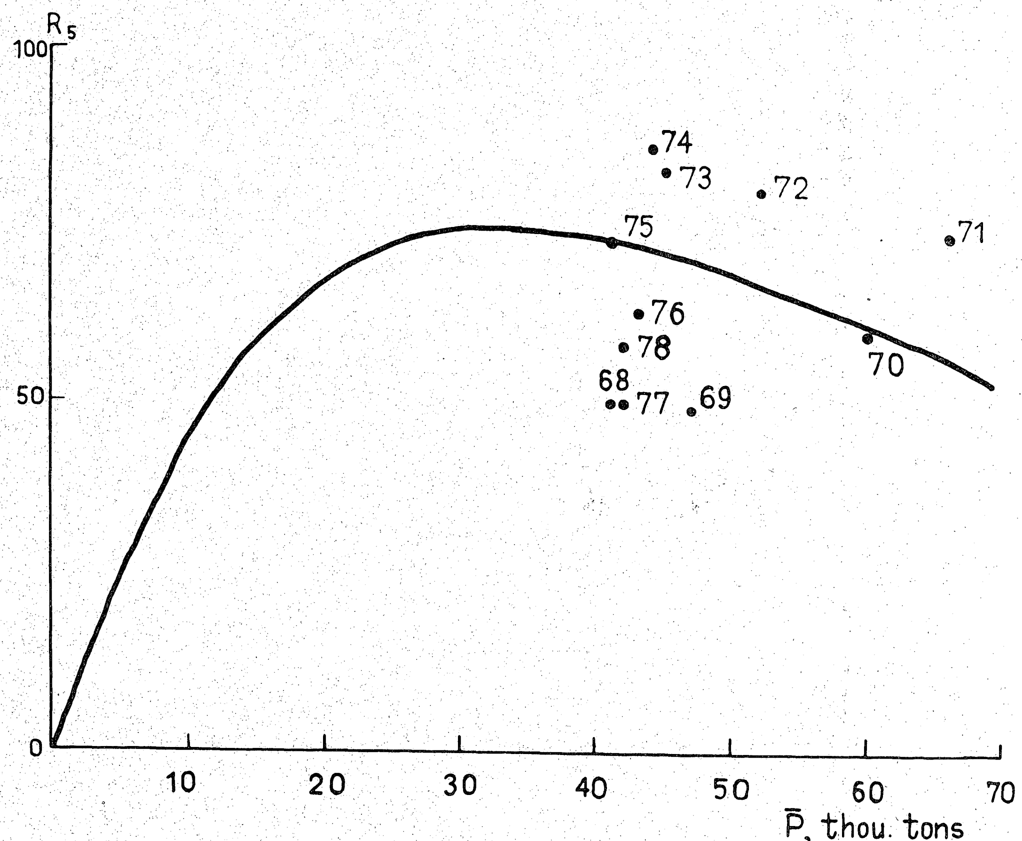

Fig. 8. Relationship between the abundance of beaked redfish year classes aged 5 in Div. 3M and the mean annual biomass of mature fish.