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Estimation of the Stock Abundance and TAC for Capelin in Div. 2J+3K and 3LNO for 1985-1986

by

V. S. Bakanev, L. S. Lugovaya and V. L. Tretyak
Polar Research Institute of Marine Fisheries and Oceanography (PINRO)
6 Knipovich Street, 183763, Murmansk, USSR

ABSTRACT

The abundance and biomass of the capelin commercial stock were assessed by VPA throughout the area for the 1973 - 1984 period. Natural mortality rates at different ages were estimated and applied for realization of the method. It is advised to limit the fishing regime by F = 0.10 level of exploitation. In this case the TAC will be some 200 thou. tons.

INTRODUCTION

The Newfoundland capelin are known as an important food item for many predatory fish, mammals and sea birds, and since 1971 - as an object of intensive fishery.

With the start of intensive fishery the necessity in scientifically grounded catch limitation arose which provides that in the first place the actual relationship between the stock size and fishing intensity should be determined.

Two methods are mainly used for capelin stock assessment: a hydroacoustic method and mathematical one of a sequential capelin abundance model (SCAM). An attempt to use VPA is made in the paper. For this purpose the yearly catch data from the whole area are pooled by ages for the biological-fishing year.

MATERIAL AND METHODS

In order to estimate the abundance and biomass of any commercial stock by VPA the total number of fish caught at different ages in each considered year of fishery, natural mortality rates set constant in the interval of one year of fish life and terminal rates of fishing mortality are assumed to be known.

Table 1 shows the yearly number of fish at different ages caught by all fleets for the 1973-1984 period. In contrast to conventional methods the data of the total yield by ages are pooled not for the calendar year but for the biological-fishing one. The autumn catch from Divs. 2J3K for each year is pooled with spring and summer catches of the next year from Divs. 3L and 3NO.

Natural mortality rates of capelin are determined after V.L.Tretyak (Tretyak, 1983). Their variation with age is represented by $M(t)$ function having one (positive) minimum and turning into infinity with t tending to maximally possible age τ_e which under real ecological conditions corresponds to maximally possible hypothetical life span of fish. $M(t)$ function is expressed analytically in the following way:

$$M(t) = a\left[-t-(\tau_e-\overline{\tau}_s)\ln(\tau_e-t)\right]+b.$$

In the interval $[\tau_l, \tau_e)$ where τ_l - age of fish entering the fishery it is determined, continuous and has the only stationary point $\overline{\tau}_s$. With $a>0$ $\min M(t)=M(\overline{\tau}_s)$. In virtue of hypothesis of the minimum $M(t)$ to correspond to the mean age of mature fish (Nikolsky, 1974), the parameter $\overline{\tau}_s$, like τ_e, has a concrete biological content. Parameters a and b have no biological content. Basing on the fishery-biological statistics for the 1973-1984 period the mean age of mature capelin ($\overline{\tau}_s$) equals 4 years. Under intensive fishing the effect of different factors depending on the density and limiting the fish abundance will get weaker, that is why the mortality of fish resulting from natural reasons will decline (Pianka, 1981). This will lead to a certain growth of τ_e which as a first approximation is set equal for capelin to 10 years.

To estimate a and b parameters it is necessary to have two different meanings of age in the interval $[\tau_r, \tau_e)$ in which $M(t)$ is known. But this requirement may be fulfilled in exceptionally rare cases, and capelin have no such age groups. In order to determine a and b parameters the average number of fish at each age caught during the considered period of fishery, von Bertalanffy parameters l_∞ = 19.1 cm, K = 0.356 and t_0 =-0.667, those of allometric growth a_1 = 0.300, b_1 = 3.284 and the natural mortality rate of capelin set constant and equal to 0.30 in the interval from 3 to 4 years. Von Bertalanffy parameters are obtained after Hohendorf (Hohendorf, 1966), a_1 and b_1 - by the least-squares method. a and b parameters turned out to equal 2.4002 and 35.6421, respectively. Natural mortality rates of capelin at each age and mean integral values in the interval of one year of fish life are given in Table 2, the $M(t)$ function is shown in Fig. 1.

The applied methods consider in the integral form the phenomenon of post-spawning mortality of capelin, but to separate out this component quantitatively seems not possible as yet. This is a weak point of the methods. Nevertheless, we found it possible to apply them because we believe that for a first approximation within all conventions and limitations we managed to estimate natural mortality rates at each fishing age.

Terminal values of fishing mortality rates $F_{\tilde{\tau}_{st}}$ needed for VPA relating the year classes having undergone fishery are determined from the catch data. The main relation of VPA:

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

where C_τ - catch at age τ, and F_τ and Z_τ - fishing and total mortality rates at this age, represented in the form of the transcendental equation

$$Z_{\tau+1} - a_{\tau+1}(Z_{\tau+1} - \bar{M}_{\tau+1})(1-exp(-Z_{\tau+1})) = 0$$

with the unknown $Z_{\tau+1}$ and $a_{\tau+1} = \frac{N_{\tau+1}}{C_{\tau+1}}$ (N stands for abundance at age $\tau+1$), shows that under the straight-forward calculation there is a requirement which must be fulfilled for all τ from the interval $[\tau_r, \tau_\lambda - 1]$, namely, $a_{\tau+1} > 1$. Among all possible test values of the fishing mortality rate of capelin at the age of τ_r = 2 the lowest $\hat{F}_{\tau_r}$ will always be found under which the requirement $a_{\tau+1} > 1$ cannot be realized for any age τ and the lowest ($\hat{F}_{\tau_r} + \Delta F_{\tau_r}$) under which this requirement still may be fulfilled. The highest biased estimator of F_{τ_λ} is the fishing mortality rate at age τ_λ corresponding to this sum. In order to determine it for the 1971 to 1978 year classes having undergone fishery the search for the highest numerical values at each position of F_{τ_r} is performed sequentially beginning with the class of units under which $a_{\tau+1} > 1$ for all τ. The search is performed under the initial test $F_{\tau_r} = 9$ with the step $h = -1 \cdot 10^{-j}$ (j = 0, 1,...8). which is constant within each position of the rate and varies from position to position. The abundance at age τ_λ converges with the number of fish caught at this age. This phenomenon is taken as a principle of the criterion for cessation of the calculating procedure. Specification of F_{τ_r} and, correspondingly, F_{τ_λ}, is ceased immediately after

$$\frac{|C_{\tau_\lambda} - N_{\tau_\lambda}|}{C_{\tau_\lambda}} \leq 0.05$$

The growth of age τ_λ by 1-2 age groups and the repeated calculating procedure permitted to reduce the bias of estimators at the age of 6 for each year class undergone fishery. To re-run VPA directly the catch was extrapolated 1-2 age groups towards older ages. This is made in agreement with the straight line passing through the two last known points and expressing the relationship between $\lg\left(\frac{C_\tau}{N_2} \cdot 100\right)$ and age τ, N_2 is the abundance obtained after the first straight-forward calculation.

The terminal F_{τ_λ} values for the 1967 to 1970 year classes for which the catches at the age of $\tau > 2$ are only known are estimated as the arithmetic mean for a number of estimates obtained as the result of a very close linear relationship between the abundance and virtual population of year classes at different ages(correlation coefficients vary from 0.90 to 1). This fact makes it possible to extrapolate by the corresponding abundance regression equations for the considered year class at age τ we are interested in. For the 1979 to 1982 year classes having undergone fishery partially the terminal F_τ values are determined as roots of the equations

$$C_\tau = N_\tau \frac{F_\tau}{F_\tau + M_\tau}\left(1 - exp\left(-\left(F_\tau + M_\tau\right)\right)\right),$$

in which N_τ stands for the abundance of capelin at age τ obtained from the data of the 1984 echo survey in Divs. 3LNO. The results of the echo survey in Divs. 2J3K are not taken into account because of incomplete survey coverage. All terminal $F_{\tau_{st}}$ values are listed in Table 3.

RESULTS

No statistically significant relationship between the fishing mortality rates of capelin from different age groups and their combinations and the fishing effort was found. However, there exists a rather close linear relationship between the mean yearly production of the Soviet large refrigerator trawler ($\frac{Y}{f}$) and the mean annual biomass ($\bar{P}_{2-5}$) of capelin at the age of 2 - 5 years (Fig. 2). The correlation coefficient equals 0.86. The regression equation is as follows:

$$\frac{Y}{f} = 0.900 \cdot \bar{P}_{2-5} + 1.915$$

While obtaining this equation 4 latest years were excluded because there were few ships in the fishing area and the fishing effort in these years was much lower compared to other years of fishery. Fig. 3 shows the linear relationship between the biomass of capelin in Divs. 2J3K obtained from the echo survey results and the biomass estimated by VPA. The correlation coefficient between these values is equal to 0.97. The regression equation is as follows:

$$P_{ac} = 0.348 \cdot P_{VPA} - 0.100$$

It should be noted that the regression line which passes through the origin of coordinates was drawn, the years 1982, 1983 and 1984 being excluded. The correlation coefficient will somewhat decline (till 0.88) if the values for 1982 and 1983 are added to random ones. The existence of these two rather close relations proves the validity of the VPA input parameter determination.

The abundance at the beginning of each considered biological-fishing year is shown in Table 4. from which it follows that in the 1975-1980 period the total abundance of the commercial stock was on the steady decline from 188 to 7 bill. fish. Beginning with 1973 the abundance of the year classes at the age of 2 was also on the decrease till 1977 inclusively. The 1971 and 1973 year classes are the richest for the period under consideration. Their abundance amounted to 153 and 99 bill. fish, respectively. The poorest 1977 year class totalled 2 bill. fish. We believe that the 1979 year class may be attributed to average while those of 1980 to 1982 to rich ones. In the calendar year 1985 fish from these year classes will attain the age of 3 - 6 years and will comprise the bulk of catches. The comparison of the data on the commercial stock biomass (Table 5) also testifies to its steady growth in the latest years starting with 1981. Bearing in mind the results of the echo surveys made in 1982 to 1984 the total abundance and biomass of the commercial stock in 1985 will be above the 1984 level and will come up to 129 bill. fish and 2.3 mill. tons, respectively. The TAC for 1985 and 1986 at the $F = 0.10$ level of exploitation will be 200 thou. tons.

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Table 1. Number of fish caught at different ages (thou. spec.) by biological-fishing years in Divs. 2J3K and 3LNO.

Age, yrs	Biological-fishing year				
	I972-I973	I973-I974	I974-I975	I975-I976	I976-I977
2	I93I20	I2I340	767500	4079I0	99I50
3	684550	33I7450	30I9930	I0028I40	I654380
4	5020250	3354440	4700300	3907590	92454I0
5	II28350	37I69I0	I454050	969720	8798I0
6	880I0	363900	I079090	224730	I50020
	7II2280	I0874040	II020870	I5538090	I2028770

Table 1 (contd)

	I977-I978	I978-I979	I979-I980	I980-I98I	I98I-I982
	48507	I030	7420	I4I7I0	I6740
	242770	520080	I90920	600740	I345740
	2085575	8I5070	375670	5II400	385540
	3680977	I050980	236490	298I40	6IIIO
	348233	I538I0	6I780	26250	II340
	6406062	2540970	872280	I578240	I820470

Table 1 (contd)

	I982-I983	I983-I984
	I07840	5I590
	882920	7457I0
	683040	608770
	42020	992300
	2I30	2000
	I7I7950	2400370

Table 2. Natural mortality rates (M_{τ}) at age τ and mean ($\overline{M}_{\tau}$) in the interval of one year of life

yrs	M_{τ}	$\overline{M}_{\tau}$
2	0.896	0.636
3	0.419	0.300
4	0.238	0.311
5	0.464	0.811
6	1.277	2.049
7	3.020	4.543

Table 3. Fishing mortality rates of capelin at different ages for biological-fishing years in Divs. 2J3K and 3LNO.

Age, yrs	Biological-fishing year				
	I972-I973	I973-I974	I974-I975	I975-I976	I976-77
2	0,002	0,005	0,0II	0,034	0,0I4
3	0,044	0,049	0,246	0,253	0,257
4	0,I47	0,352	0,I0I	0,665	0,443
5	0,202	0,222	0,369	0,038	0,445
6	0,2I0	0,292	0,292	0,28I	0,022

Table 3 (contd)

I977-I978	I978-I979	I979-I980	I980-I98I	I98I-82
0,0I6	0,000	0,003	0,0I8	0,000
0,060	0,322	0,206	0,64I	0,3I7
0,684	0,328	0,463	I,634	I,45I
0,467	I,532	0,2I3	I,353	I,590
I,I87	0,096	I,234	0,I00	0,508

Table 3 (contd)

I982-I983	I983-I984
0,002	0,00I
0,046	0,0I7
0,297	0,045
0,905	I,550
0,675	0,297

Table 4. Abundance of capelin (thou. spec.) in Divs. 2J3K and 3LNO at the beginning of a biological year

Age	I972-I973	I973-I974	I974-I975	I975-I976	I976-I977
2	I53075344	30I96064	98601648	I640584I	9244025
3	I8389632	80890720	I589840I	5I648848	8394528
4	42490784	I3032883	57076544	9205I09	29708000
5	8887686	2688I456	67I6365	37786528	3469762
6	I057I6I	322807I	9572356	2064262	I6I59376
	223900592	I54229I84	I87865296	II7II0576	66975680

Table 4 (contd)

	I977-I978	I978-I979	I979-I980	I980-I98I	I98I-I982
	4I73338	2225620	2745720	I0923I99	42933200
	4824443	2I7487I	II77825	I4488I7	5679963
	48I08I3	3366937	II67740	709988	565663
	I3970320	I777873	I777565	538776	I0I478
	988209	3892363	I70769	638570	6I877
	28767I20	I3437664	70396I9	I4259350	49342I44

Table 4 (contd)

	I982-I983	I983-I984
	968604I6	69754I60
	22720768	5II84656
	3065383	I60788I9
	97I67	I6689I8
	9I99	I7470
	I22752896	I38704000

Table 5. Biomass of capelin in Divs. 2J3K and 3LNO at the beginning of a biological year (tons)

Age, yrs	1972-1973	1973-1974	1974-1975	1975-1976	1976-1977
2	1377678	301960	986016	131246	83196
3	331013	1860486	349764	981327	125917
4	1104760	377953	1712296	257743	742699
5	248855	806443	214923	1209168	107562
6	32772	100070	306315	70184	646375
	3095077	3446912	3569315	2649669	1705751

Table 5 (contd)

Age, yrs	1977-1978	1978-1979	1979-1980	1980-1981	1981-1982
2	29213	22256	24711	76462	386398
3	101313	39147	21200	20283	95559
4	125081	84173	29193	15619	14141
5	419109	51558	49771	17240	2942
6	32610	120663	5464	19157	1980
	707328	317798	130342	148763	502022

Table 5 (contd)

Age, yrs	1982-1983	1983-1984
2	1259185	558033
3	363532	972508
4	73569	401970
5	3206	63418
6	276	559
	1699767	1996488

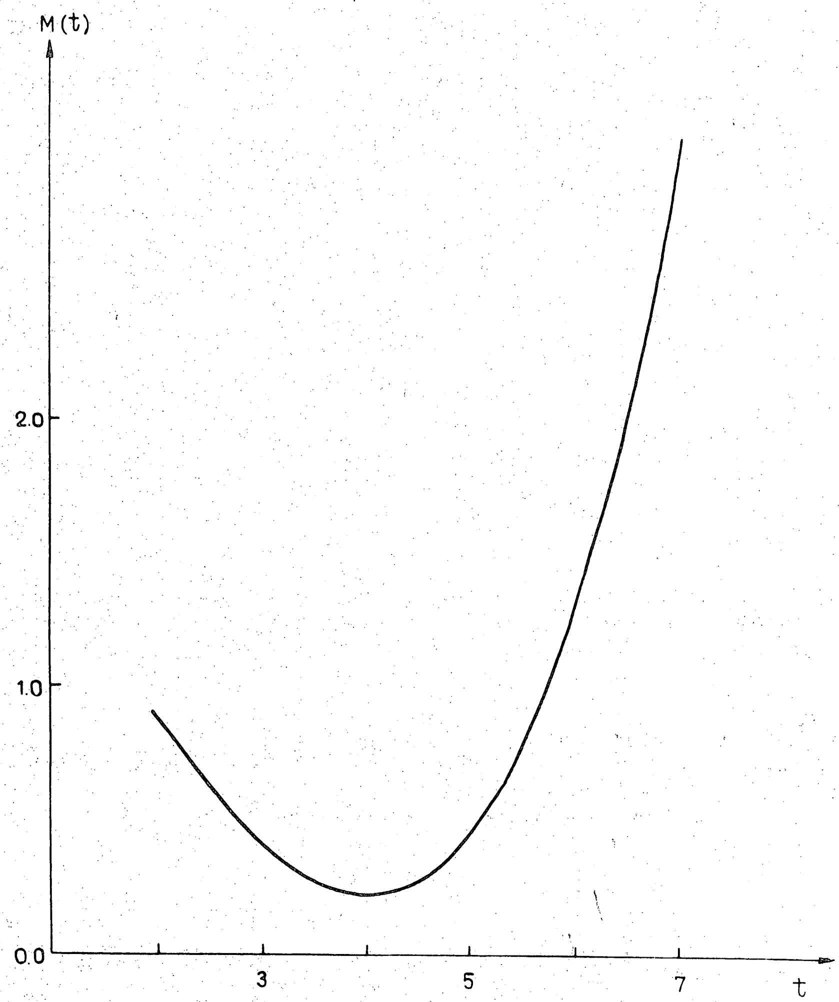

Fig. 1. M(t) function.

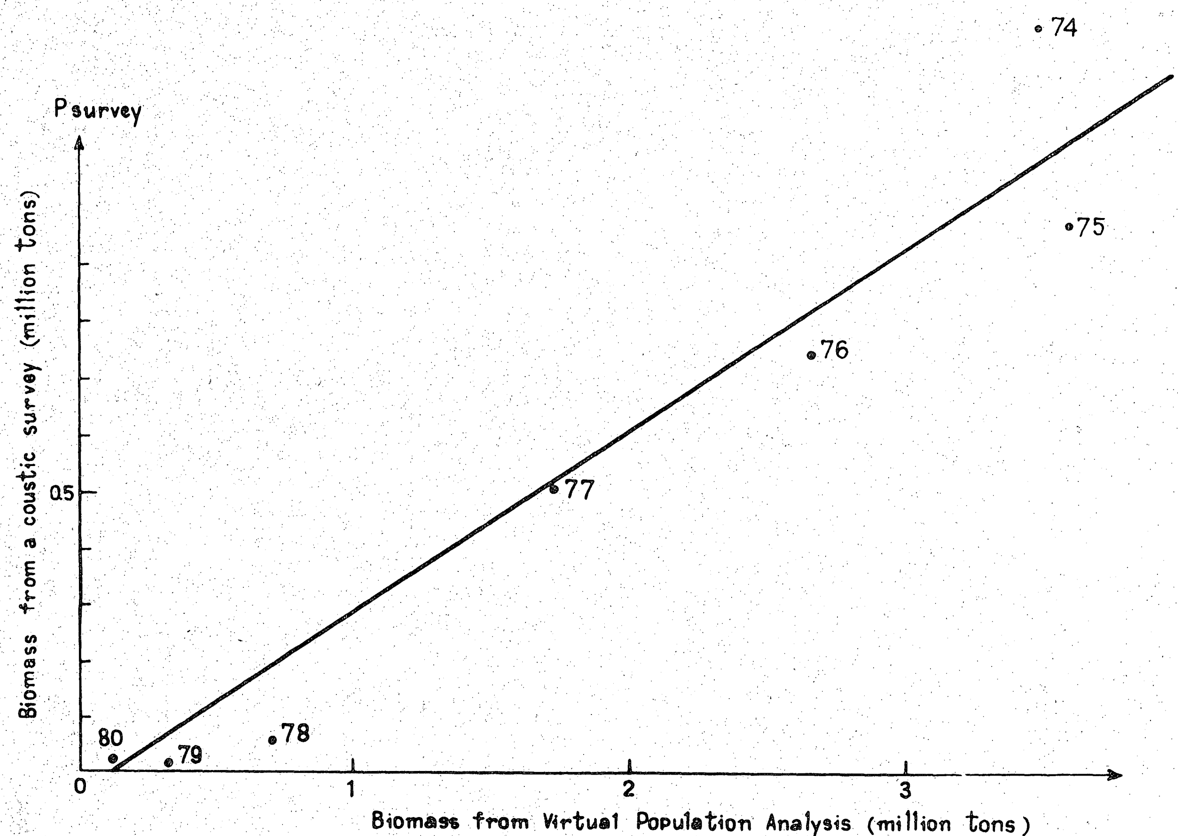

Fig. 2. Relationship between the mean yearly catch per trawling hour taken by the Soviet large refrigerator trawler ($\frac{Y}{f}$) and the mean yearly biomass of capelin at an age of 2 - 5 years in all fishing areas.

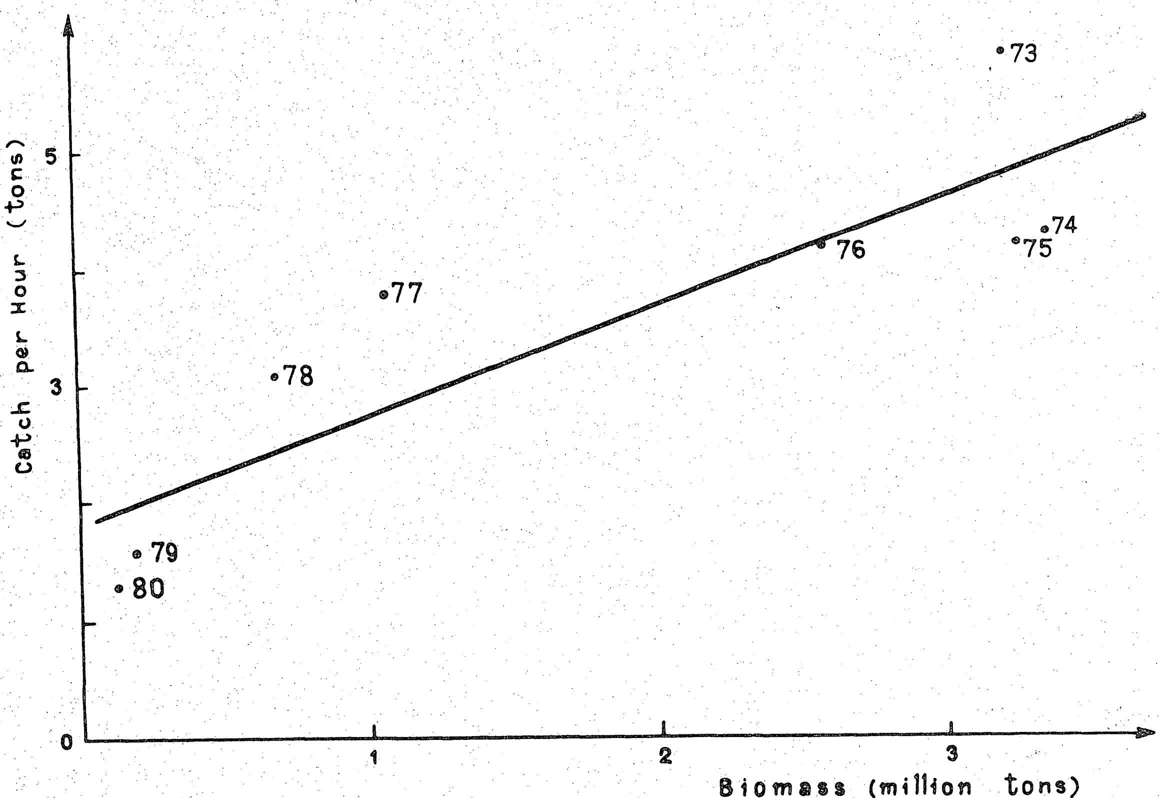

Fig. 3. Relation between the biomass of capelin in Divs. 2J3K estimated by the echo survey results and the biomass calculated by VPA.