

THE DYNAMICS OF TURBOT STOCK-SCHOPHTALMUS MAEOTICUS PILL ON CONTINENTAL PLATFORM OF THE BLACK SEA IN FRONT OF ROMANIAN LITTORAL

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ABSTRACT

The paper presents the results of researches effected upon the turbot stock on the continental platform of Black Sea, in front of Romanian littoral during 1964-1970 period, with the object of establishing the Scientific criteria of rational exploitation.

In the Black Sea the turbot was exploited of old time, Formerly the fishing intensity was so that it could not affect the stores, exploitation being under the level of natural productivity of this species.

Toghether with the increasing of consumption demand and development of exploitation means there appeared the risk of affecting, by fishing, the turbot stores of the Black Sea.

This situation requires the study of turbot stock of the Black Sea, of these stocks dynamics and also of the fishing influence the stock, for defining the ways of rational exploitation.

To specify those elements characterising the turbot stock on Romanian platform of the Black Sea, with the purpose of scientific organization of exploitation, we used the observations and conclusions at which Romanian research workers reached until now, the published paper about the studies effected by the research workers of other countries riparian

Black Sea and also our observations during 1960-1970 period, especially the work of 1964-1970 period.

The material and working method

Sounding fishings were carried out in 217 stations, in 1961-1970 period, from which resulted 3830 turbot samples with the purpose of collecting the elements needed to define the age and increasing of turbot on continental platform of Romanian littoral. The fishing was effected, in each season, on east-west lines: Sf. Gheorghe, Cap Midia and Mangalia at depths increasing by ten meters until 70 meters. During spring-summer period we worked also on intermediary lines. The fishing tools have been dependent on the season long lines, trawlers, but most of all nets were used.

The length measurements, effected upon the analysed turbot samples, represent the standard length - from the end of the muzzle to the bottom of the tail - summed on length classes with the frequency of 5 cm. The material analyse was made using the mathematic statistics. The otolite collected from 716 samples were used for the age study.

The collected-material processing was made using the mathematic statistics methods and mathematical analysis was used for interpretation.

The age structure of turbot stock

The first data, met in literature, about the turbot age belong to BGERMAN (1936) who affirms that, in north-western part of the Black Sea, the turbot is mature at 6 years the males and 7 years the females, and on Caucasus shore the males at 8 years and the females at 9 - 10 years.

RADUTA (1939) studying the turbot growing-up in its first year, came to the conclusion that it reaches the length of 7-11 cm until autumn and it is mature at 4 years. He used the underoperculum bone to establish the age.

CARASU (1952), quoting ILJIN, presents the following relation between age, length (without caudale) and weight:

Table A

Age (years)	1	5	8	10	12	15	20	23
Length (cm)	17,3	31,8	48,3	55,0	59,6	64,1	69,1	70,1
Weight (kg)	0,170	1,150	2,100	3,100	3,300	4,400	5,500	6,000

NICOLSKI (1954) estimates that the males are sexually mature at 7-8 years and the females at 8-10 years.

POPOVA (1957), studying the turbot growing-up, concludes that the yearly growth is 10 cm until 3 years when it becomes sexually mature; between 7 and 10 years the yearly growth is 1-2 cm and at 10-13 years, 0.4-0.8 cm. The males and the females have the same growth rate until 3-4 years, then the males grow slower. At 3 years, for both sexes, was calculated the mean length of 30-35 cm, at 4 years, 40-42 cm; at 7 years the females have a mean length of 48-49 cm and the males, 44-46 cm. Males become in a body sexually mature at 6-7 years and the females at 7-8 years.

KARAPETKOVA (1957), studying the turbot growth in first months of life, concludes that, in July, the mean length of turbot was of 4.5 cm while otolite had a dark spot formed during planktonic stage of life. At the beginning of August it had a length of 7.4 cm, and on otolite appears a narrow light ring, which coincides with the growth retardation due to the change of biotops and food, the image ending with a dark ring. At the beginning of October, the mean length was of 11.5 cm on otolite being noticed a light greater zone, a retardation in growth being visible, probably, because of the higher water temperature. In the middle of October the length was 13.4 cm, and on the otolite edge it is noticed a dark ring. In November this dark ring enlarges, what indicates a more rapid growth in autumn and winter months.

KROTOV (1958) classifies the turbot in bottom-fish class, for which the number of age groups in shoal is 14, 16, and the number of fished age groups is 8, 10.

NICULESCU, quoting ILJIN, estimates the males becoming sexually mature at 7 years and the females at 7-11 years.

AMBROZ, studying the turbot which is the object of fishing, comes to the conclusion that the fishing, contains 80% sample of 4-6 years. Males reach maturity at 3 years, and the females at 4 years.

KARAPETKOVA (1961), synthesizing the results obtained in the study of turbot growth and of composition variations on ages for captures in front of Bulgarian littoral during 1956-1959, concludes that in the first 2-3 years the growth rate is linear and most rapid. At 3-5 years, together with sexual maturity, the growth diminishes the males lagging behind the females during growth period. Exploitable agglomerations are containing samples of 2-10 years old, the most important for fishing being the 5 years old ones and then those of 4 years.

LUSCAN (1962) studying the age composition of turbot agglomerations at Romanian littoral during 1959-1961 period, obtains the following proportions on ages :

Table B

Age years	3	4	5	6	7	8	9
%	14.6-38.9	33.9-51.6	19.6-36.2	4.6-12.0	1.5-2.3	0.6-0.9	0.4

Within the same age group the sample length varied between very large limits; at the same age the females has a more rapid rate of growth.

BANARESCU (1964) appreciates the turbot growth as being a slow one : after three years it reaches the length of 17.3 cm and 170 grams weight; after five years it reaches 31.5 cm and 1.150 kg; after ten years 55 cm and 3.100 kg and, finally, at twenty three years it reaches 70.1 cm and 6 kg weight.

SVETOVIDOV (1964) affirms that males reach the sexual maturity at 7-8 years and the females at 9-11 years.

ILIESCU (1968), studying the fished turbot at Romanian littoral during 1965, comes to the conclusion that the length variation limits were 36-70 cm, the majority being of 46-55 cm, 4-5 years old.

ILIESCU and MANEA (1968) studying the growth rate of turbot whelps in 1965-1966, concluded that during July-November period, the length of turbot whelp varied between 4 and 9 cm, recording a mean monthly growth of 2-3 cm.

We have presented these data to show the diversity of research workers opinions about the age the growth of turbot species. This fact is due, to a great extent, to the subjectivism in age appreciation after otolite and also to the small number of samples analysed in every case.

To study the turbot age we use the otolite collected from 716 samples during five years of study, centralized results being presented in the following table.

Table 1

Age composition of turbot stock (in %)

Length class (in cm)	Age, in years								
	2	3	4	5	6	7	8	9	10
25 - 29	0.22								
30 - 34	1.23	3.07	0.14	0.14					
35 - 39	3.50	23.07	2.34	0.29					
40 - 44		5.89	26.90	8.83	0.42				
45 - 49			5.34	8.86	2.00	0.50			
50 - 54				0.94	0.67	1.83	1.83	0.28	
55 - 59					0.14	0.14	0.57	0.42	0.28
60 - 64							0.08		0.08
The mean value	4.95	32.03	34.72	19.06	3.23	2.47	2.48	0.70	0.36

We can affirm that the majority (66-75%) were samples of three and four years, specifying that the turbot samples less than 30 cm, which did not enter in exploitation, were not fished by sounding tools. The age of five years was about 19.06% the presence diminishing after that in

the same time as the age increases, so that at nine and ten years there are met only isolated samples.

Each length-class contains samples of different ages, generally in a four years range.

Calculating the mean length of turbot samples after ages we can conclude that generally at the same age the females have a greater length than males except the second year of life when the males are greater.

Table 2

Mean length of turbot on ages and sexes (in cm)

Age	2	3	4	5	6	7	8	9	10
♂	33.99	37.66	41.95	44.28	46.34				
♀	30.16	38.44	43.15	46.82	49.22	51.18	53.62	55.50	57.00

Analysing the dispersion indexes of turbot length on ages, we notice that the greatest standard deviation is recorded in the second year of life (3.60 cm), after that it is remaining almost constant (table 3).

This situation is reflected also in the length variation coefficient which is, at the age of two, 10.85%, then maintaining between 3.79 and 5.98%. This fact indicates us an enough homogenous growth of samples in turbot stock on our continental platform.

The characteristics of survival and mortality are the following ones, knowing at (0) and (t) moments the number of fishes N_0 and N_t of an age - class or the fishing on the unit of effort which acted upon this stock, C_0/f_0 and C_t/f_t :

$$\text{- the survival } S_{(0-t)} = \frac{N_t}{N_0} = \frac{C_t/f_t}{C_0/f_0}$$

$$\text{- the death rate } Z_{(0-t)} = \frac{N_0 - N_t}{N_0}$$

The instantaneous coefficient of total mortality (z) is obtained as follows ;

$$N_t = N_0 e^{-Z_t} \quad e^{-Z_t} = \frac{N_t}{N_0} = \frac{C_t/f_t}{C_0/f_0}$$

$$\text{- } Z_t = \text{Log}_e \frac{N_t}{N_0} = \text{Log}_e \frac{C_t/f_t}{C_0/f_0}$$

$$\text{- } Z_t = \text{Log}_e N_t - \text{Log}_e N_0 = \text{Log}_e C_t/f_t - \text{Log}_e \frac{C_0}{f_0}$$

Calculation of dispersion indexes for turbot length, on ages

Age (in years)	2	3	4	5	6	7	8	9	10
$\sum n_i u_i^2$	588	1361	1146	963	186	80	197	41	4
$\sum n_i$	45	225	238	129	22	21	24	6	6
$\frac{\sum n_i u_i^2}{\sum u_i}$	13.06	5.55	4.81	7.46	8.45	3.80	8.20	6.83	6.66
\bar{u}	0.15	0.73	0.23	0.33	0.27	0.18	0.62	1.50	0
\bar{u}^2	0.02	0.53	0.05	0.10	0.07	0.03	0.38	2.25	0
G^2	13.04	5.02	4.76	7.36	8.38	3.77	7.82	4.58	6.66
$\sqrt{G^2}$	3.60	2.24	2.18	2.71	2.89	1.94	2.79	2.14	2.58
i	1	1	1	1	1	1	1	1	1
G_x	3.60	2.24	2.18	2.71	2.89	1.94	2.79	2.14	2.58
x	33.15	37.73	42.23	45.33	48.27	51.18	53.62	55.50	57.00
$\frac{G}{x}$	0.1085	0.0593	0.0501	0.0597	0.0598	0.0379	0.0520	0.0380	0.0452
$100 \frac{G}{x}$	10.85	5.93	5.01	5.97	5.98	3.79	5.20	3.80	4.52

To apply these calculations at turbot population on continental platform in front of the Romanian littoral of the Black Sea, we use the data centralized in tables 4 and 5. The instantaneous coefficient of turbot total mortality was defined of turbot total mortality was defined transposing the calculations in table form. The ages of 3 and 4 years were excluded because these are ages at which the turbot did not enter completely in fishing.

Table 4

Distribution on age classes of turbot, fished with sounding tool (in samples number)

Age	2	3	4	5	6	7	8	9	10	Total
1966	13	82	62	27	3	3	2	-	-	192
1967	28	205	226	105	14	7	6	3	2	596
1968	30	226	334	189	31	21	20	6	3	860
1969	36	186	183	112	21	16	17	5	3	579
1970	24	132	99	14	19	19	4	2	-	376
Total	131	831	910	496	83	66	64	18	10	2603

Table 5

Distribution, on age classes, of turbot fished with sounding tools, as a function of fishing effort unit (in samples number)

Age	2	3	4	5	6	7	8	9	10	Total
1966	4.60	29.04	23.80	9.56	1.06	1.06	0.70			68
1967	4.65	34.05	37.54	17.44	2.32	1.16	0.99	0.49	0.33	99
1968	2.33	17.60	26.02	14.72	2.41	1.63	1.55	0.46	0.33	67
1969	2.92	15.09	14.85	9.09	1.70	1.29	1.37	0.40	0.24	47
1970	2.29	12.63	9.47	6.03	1.34	1.81	1.81	0.38	0.19	36
Mean value	3.01	18.05	20.97	11.43	1.91	1.52	1.47	0.41	0.23	60

To calculate the mean coefficient of total mortality we use the following data.

$$\text{from 4 to 5 years - } Z = -\text{Log}_e \frac{11.43}{20.97} = 0.606$$

Table 6

Calculation of instantaneous coefficient of total mortality of age classes which composes the turbot stock (%)

Interval	4-5 years		5-6 years		6-7 years		7-8 years		8-9 years		9-10 years	
Age	V	IV	VI	V	VII	VI	VIII	VII	IX	VIII	X	IX
Year	1967 - 1966		1967 - 1966		1967 - 1966		1967 - 1966		1967 - 1966		1967 - 1966	
p. u. e.	174,4	23,80	2,32	9,56	1,16	1,06	0,99	1,06	0,49	0,70	0,33	
Log _e	5,159	5,472	5,446	6,862	4,753	4,663	4,595	4,663	3,891	4,248	3,496	
Z _t	0,315		1,416		-0,090		0,068		0,357			
Year	1968 - 1967		1968 - 1967		1968 - 1967		1968 - 1967		1968 - 1967		1968 - 1967	
p. u. e.	147,2	375,4	24,1	174,4	1,63	2,32	1,55	1,16	0,46	0,99	0,33	0,49
Log _e	4,990	5,926	3,176	5,159	5,093	5,446	5,043	4,753	3,829	4,595	3,495	3,891
Z _t	0,930		1,981		0,353		0,290		0,766		0,396	
Year	1969 - 1968		1969 - 1968		1969 - 1968		1969 - 1968		1969 - 1968		1969 - 1968	
p. u. e.	9,09	26,04	1,70	14,72	1,29	2,41	1,37	1,63	0,40	1,55	0,24	0,46
Log _e	4,499	5,568	2,833	4,990	4,859	5,454	4,919	5,093	3,688	5,043	3,178	3,828
Z _t	0,069		2,153		0,625		0,174		1,355		0,650	
Year	1970 - 1969		1970 - 1969		1970 - 1969		1970 - 1969		1970 - 1969		1970 - 1969	
p. u. e.	6,03	14,85	1,34	9,09	1,81	1,70	1,81	1,29	0,39	1,37	0,19	0,40
Log _e	4,094	4,997	4,897	6,812	5,198	5,135	5,198	4,859	3,663	4,919	2,944	3,688
Z _t	0,903		1,915		0,063		0,339		1,259		0,744	

$$\text{from 5 to 6 years} - Z = - \text{Log}_e \frac{1,91}{11,43} = 1,789$$

$$\text{from 6 to 7 years} - Z = - \text{Log}_e \frac{1,52}{1,91} = 0,229$$

$$\text{from 7 to 8 years} - Z = - \text{Log}_e \frac{1,47}{1,52} = 0,042$$

$$\text{from 8 to 9 years} - Z = - \text{Log}_e \frac{0,41}{1,47} = 1,277$$

$$\text{from 9 to 10 years} - Z = - \text{Log}_e \frac{0,23}{0,41} = 0,578$$

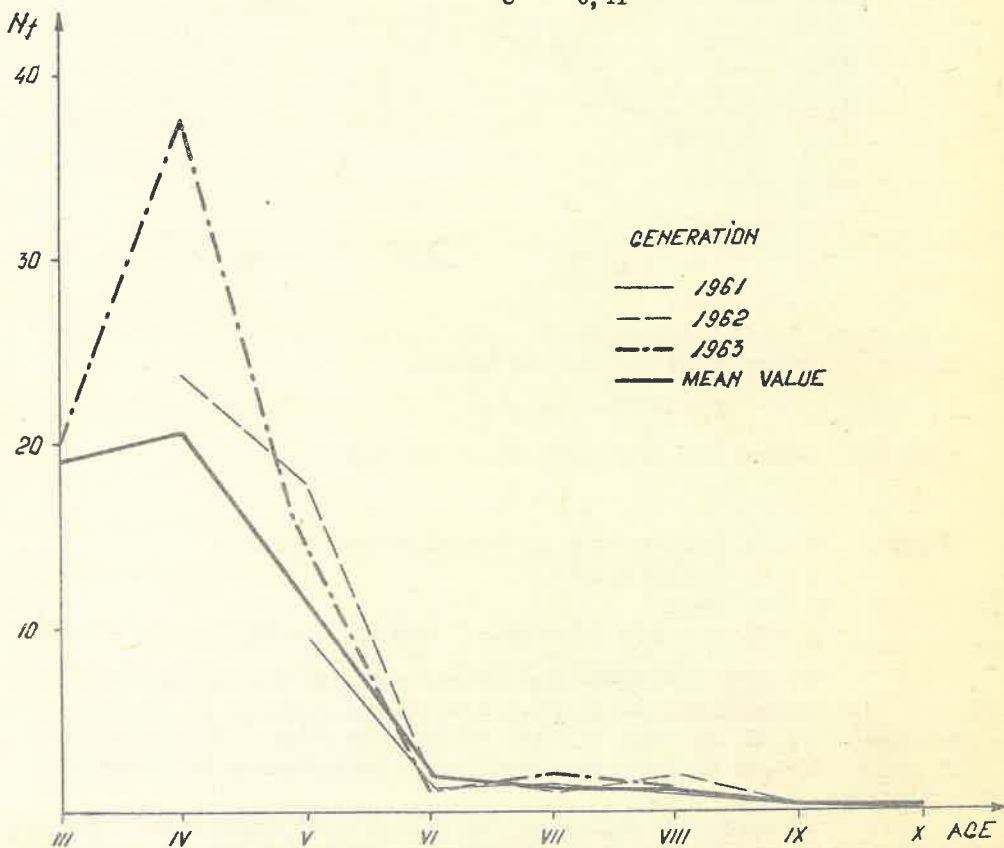


Fig. 1

To emphasize better the death rate in turbot stock we used the diagram of fig. 2 from which results that the greatest mortality is between 4 and 6 years, after which it maintains almost constant.

The total mortality contains two components: fishing mortality and natural mortality,

Of the numerous methods of calculating these two elements we appreciated that the best results are obtained taking into account the variations in fishing effort. These are reflected in the corresponding variations of fishing mortality and hence of total mortality. Thus it is possible

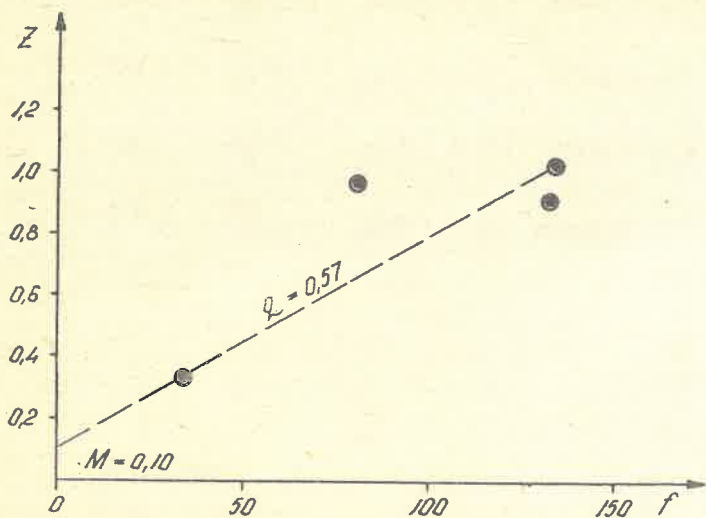


Fig. 2

to obtain the value of instantaneous coefficient of fishing mortality as a function of fishing effort applying the formula :

$$Z = F + M = 2f + M$$

which the equation of a regression line of the type :

$$Y = a x + b$$

Where $Y = Z$, instantaneous coefficient of total mortality.

$x = f$, fishing effort

$a = q$, slope

$b = M$, y = axis intersection, natural mortality.

To apply this calculation for our problem data, we use table 7.

To determine the coefficient of natural mortality we use the diagram of fig. 2, on which abscissa we have the value of fishing effort (f) and on ordinate the value corresponding to instantaneous coefficient of total mortality (Z).

We obtain the regression line $Z = qF + M$ which intersecting the Z axis gives the value of instantaneous coefficient of natural mortality (M), i.e. $M = 0,10$

Calculation of turbot growth

In quantitative study of growth we distinguish two components:

- calculation of parameters which characterize the mean growth

curve of the members of a population, an element which, in turn, characterizes the weight evolution curve of this population ;

- calculation of age or length at which the fish is caught, taking into account the selectivity of used fishing tools.

The curve of length increasing of fishes, is, nearly always, of a decreasing continuous slope, tending to become a superior asymptote, parallel to X-axis, and which has the ordinate value indicated by L symbol.

Table 7

Calculation of instantaneous coefficient of mortality for turbot of 4 - 5 years

1. Year	1966	1967	1968	1969	1970
2. Fishing effort	35	78	134	131	112
3. The fishing, on effort unit, of two age-classes, at the beginning of each year	IV 23, 80 9, 56	37, 54 17, 44	26, 04 14, 72	14, 85 9, 09	9, 09 6, 03
4. Natural logarithms corresponding to above indexes, but with a displacement of a column to the left for class figures.	5, 472 5, 159	5, 926 4, 990	5, 560 4, 500	4, 997 4, 094	4, 510
5. Z - Instantaneous coefficient of total mortality obtained from the difference of above figures.	0, 313	0, 926	1, 060	0, 903	

The curve of weight increasing tends, also, to approach to an asymptote, superior to the ordinate (W_{∞}).

To determine the length (L_{∞}) at which the increasing is zero, we use a diagram whose abscissa and ordinate represent the length in the same measurement unit. Knowing the mean length for the same time range (x), we put on diagram one series of points corresponding, on the abscissa, to the lengths (l_t), in time t - and, on the ordinate, to the lengths l_{t+x} at time (t+x) These points are, in general, in straight line and intersect the bisectrix of the axes in the point which determines the ordinate of superior asymptote of length increasing curve and which corresponds to point where $l_t = l_{t+x}$, i.e. the point in which length increasing is zero.

During the growth, the fish weight varies with its linear sizes cube. This rate is influenced by shape and density but the differences can be neglected.

VON BERTALANFFY (1938) considers the growth as a result of two opposite processes: one proportional to organism surface, then to

square length (anabolism) and the other proportional to weight, then to cubic length (catabolism).

The relation between (l_t) and (l_{t+x}) is given by the equation:

$$l_t = L \infty (1 - e^{-k(t-t_0)})$$

which can be rewritten:

$$L_t = L \infty (L - l_0) e^{-kt}$$

where :

k = catabolism coefficient

t_0 = the age at which, theoretically, $l_t = 0$

l_0 = the length at time $t = 0$.

The equation corresponding to weight increasing can be obtained by raising to cube the previous formula :

$$- W_t = W \infty (1 - e^{-k(t-t_0)})^3$$

$$- W_t = \left[W \infty^{1/3} - (W \infty^{1/3} - W_0^{1/3}) e^{-kt} \right]^3$$

where : (w_0) is the weight at time $t = 0$.

The previous formula can be written as a sum to be used for final formula of weight yield :

$$W_t = W \sum_{n=0}^3 U_n e^{-nk(t-t_0)}$$

where : for

$$n = 0 \quad U_0 = 1$$

$$n = 1 \quad U_1 = -3$$

$$n = 2 \quad U_2 = 3$$

$$n = 3 \quad U_3 = -1$$

By analysing the turbot population on continental platform of Romanian littoral we obtain the relation between mean length and age, given in table 8.

The relation weight . corresponding length is given by the formula :

$$- W = 37,40 \times 10^{-3} L^3$$

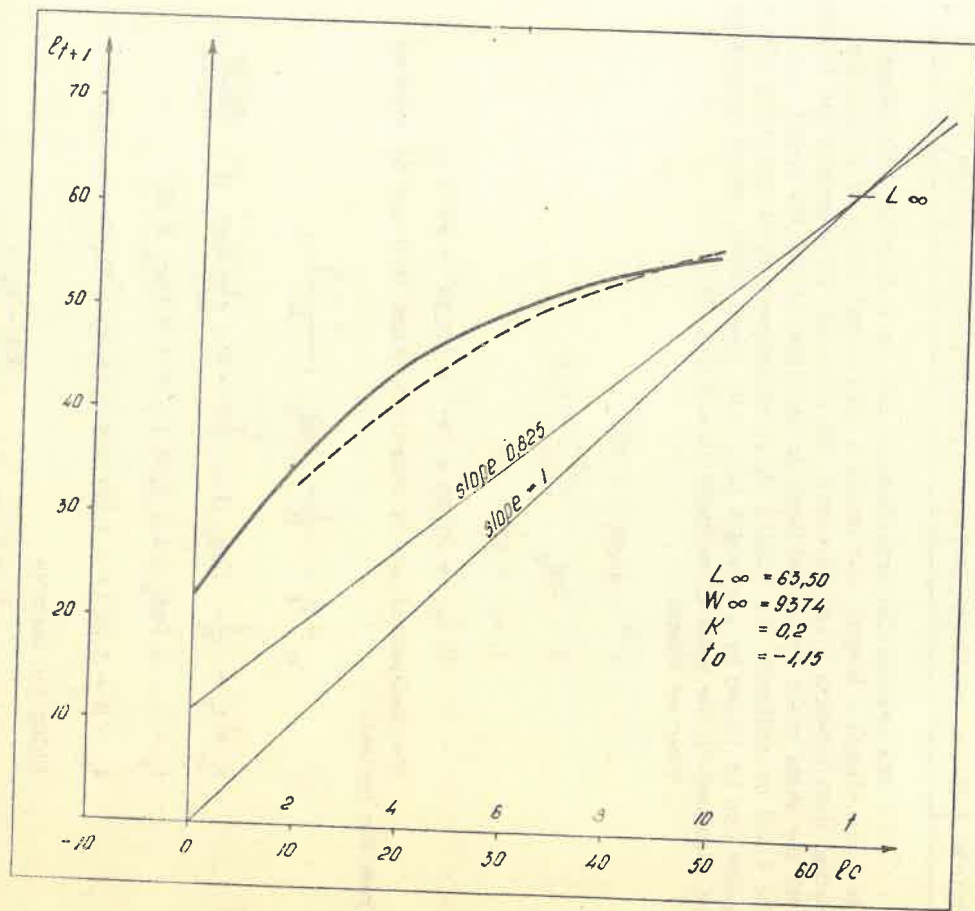


Fig. 3

Table 8

Mean length of turbot on ages

Age (years)	2	3	4	5	6	7	8	9	10	Total =54
Length in cm	33,15	37,73	42,23	45,33	48,27	51,18	53,62	55,50	57,00	.

We arrange the experimental data on a diagram with abscissa - age and ordinate - length, and obtain a provisional curve of increasing (dotted line) between 2 and 10 years. On abscissa we represent the lengths with the same scale as on ordinate; on abscissa we put the length $L(t)$ at age t and on ordinate, the lengths (l_{t+1}) corresponding to age $(t+1)$. These points can be joined by a straight line, with slope (e^{-K}), which intersects the bisectrix in the point of ordinate (L_{∞}) (fig. 3).

Thus we obtain :

$$1^{-K} - \text{slope} = 0,825$$

$$K - \text{Log}_e \frac{0,825}{1000} = 0,2$$

$$L_{\infty} = 63,3 \text{ cm}$$

$$W_{\infty} = 37,40 \times 10^{-3} \times 63,50^3 = 9374 \text{ gr.}$$

The theoretical age at which the length is 0 can be deduced from the formula :

$$t_0 = t_i + \frac{1}{K} \text{Log}_e \left(\frac{L - l_t}{L} \right)$$

$$t_0 = t_i + \frac{1}{K} \text{Log}_e \left(1 - \frac{l_t}{L} \right) = 6 + \frac{1}{0,2} \text{Log}_e \left(1 - \frac{48,27}{63,50} \right)$$

$$t_0 = 6 + 5 \text{Log}_e (1 - 0,76) = 6 + 5 \text{Log}_e 0,24$$

$$t_0 = 6 + 5(3,17 - 4,60) = 6 + 15,85 - 23,00 = -1,15$$

Using the formula :

$$l_t = L_{\infty} (1 - e^{-k(t - t_0)})$$

in which we replace the values obtained for L_{∞} , K and t_0 , we determine the curve of theoretical increase of length.

Table 9

Calculation of ordinates for theoretical curve of turbot growth

Age	$t-t_0$	$1-e^{-k(t-t_0)}$	$l_t = L (1-e^{-k(t-t_0)})$
1	2,15	0,35	22,22
2	3,15	0,47	29,84
3	4,15	0,57	36,19
4	5,15	0,65	41,27
5	6,15	0,71	45,10
6	7,15	0,76	48,26
7	8,15	0,80	50,80
8	9,15	0,84	53,34
9	10,15	0,87	55,24
10	11,15	0,87	58,88

Weight increase

The ordinates of weight-increase curve are determined in the same way from the relation :

$$W_t = W_{\infty} (1 - e^{-k(t-t_0)})^3$$

where

$$W_{\infty} = 9374 \text{ grams.}$$

Table 10

Calculation of ordinates for theoretical curve of turbot weight growth

Age	$t-t_0$	$1-e^{-k(t-t_0)}$	$(1-e^{-k(t-t_0)})^3$	$W_t=W$	$(1-e^{-k(t-t_0)})^3$
1	2,15	0,35	0,046656	431	
2	3,15	0,47	0,103823	965	
3	4,15	0,57	0,185193	1534	
4	5,15	0,65	0,274625	2568	
5	6,15	0,71	0,357911	3346	
6	7,15	0,76	0,438976	4105	
7	8,15	0,80	0,512000	4799	
8	9,15	0,84	0,592704	5549	
9	10,15	0,87	0,658503	6168	
10	11,15	0,87	0,681472	6383	

Calculation of age at which turbot enters in exploitable phase then in fishing

Two phases of fish life are important for exploitation :

t_r - mean age of fish to enter in exploitable phase, forming the completion ;

t_c - mean age of fish at which it enters in exploitation phase.

The calculation of corresponding lengths (l_t) and (l_c) is important to be used in the formula of weight yield by completion.

One of methods used for calculation of these elements is the analyse of the selectivity of fishing tools used.

Generally, the fishing tools can not retain fishes of all sizes. The selectivity of a tool is defined by the way in which the rate of capture to real size of fishes varies with the size of these fishes (Vibert, R. 1961).

We draw a dia gram in which on abscissa we note the catches fish lengths and on ordinate the fished quantity, in percents. Transposing on this diagram the obtained data of turbot population analysis, we obtain a S-curve which is characteristic for the selectivity of tools used in fishing (fig. 4).

From this diagram results that the mortality by fishing begins from the length of 275 mm, reaches 34% at 373 mm, 76% at 425 mm and is integrally fished at lengths above 575 mm.

On diagram the surface A represents the captures of fishes with the length less than (l_c) and surface (A) the captures formed by fishes with the length greater than (l_c). Inflexion point of the curve determines the 50% percentage of capture, corresponding to $L_c = 41.58$ cm.

The control of data obtained in diagram is made applying the formula :

$$l_c = \frac{\sum l_x \cdot d_x}{\sum d_x} \pm 0.5$$

$$l_c = \frac{4.218}{100} = 42.18 - 0.50 = 41.68 \text{ cm}$$

To study the biology of exploitable fishes we use the term of recruiting or completion for defining the stage in which larvar and infantile mortality is finished, young fishes becoming exploitable, having a low and constant value of natural mortality. This stage is variable from one species to other being some what arbitrarily determined, and is not possible to deduce it from a mathematical calculation. For turbot species we accepted that at a length of 25 cm it enters in exploitable phase.

Table 11

Calculation of length at which turbot enters in fishing (l_c)

l_x	n	d_x	$\frac{l}{x} \frac{d}{x}$
27,5	6	0,231	6,355
32,5	19	4,583	148,850
37,5	759	29,237	1096,125
42,5	1090	41,980	1784,150
47,5	434	16,718	793,725
52,5	144	5,546	291,165
57,5	40	1,540	88,550
62,5	4	0,154	9,625

The conversion of l_c and l_r lengths into corresponding ages

The relation "age-length" can be deduced from Von Bertalanffy formula :

$$l = L_{\infty} (1 - e^{-k(t-t_0)})$$

resulting

$$1 - \frac{l}{L_{\infty}} = e^{-k(t-t_0)}$$

or :

$$\text{Log}_e (1 - \frac{l}{L_{\infty}}) = -k(t-t_0)$$

Dividing the two terms by (K) and changing the signs, we obtain.

$$t = - \frac{1}{K} \text{Log}_e (1 - \frac{l}{L_{\infty}}) - t_0$$

We replace the terms of this formula with the data obtained in the study of turbot population and it results.

$$t_c = - \frac{1}{0,2} \text{Log}_e (1 - \frac{41,75}{63,50}) + 1,15 =$$

$$= - 5 \text{Log}_e 0,35 + 1,15 = - 5 (3,55 - 4,60) + 1,15 =$$

$$= - 17,75 + 23,00 + 1,15 = 6,40 \text{ years}$$

$$t_r = - \frac{1}{0,2} \text{Log}_e (1 - \frac{25,00}{63,50}) + 1,15$$

$$= 5 \text{Log}_e 0,61 + 1,15 = - 5 (4,11 - 4,60) + 1,15 =$$

$$= 20,55 + 23,00 + 1,15 = 3,60 \text{ years}$$

Determination of relation between exploitation
conditions and weight yield of exploitation

The mortality takes place especially in the first stages of life under the influence of environment conditions for most of marine fish species. After this stage, the mortality is determined by fishing and prey fishes. Indifferently of the level, fishing intensity provides, in these conditions, enough sires to permit the future generations development.

An age class of recruiting (t_R) contains a number of individuals (R); from (t_R) moment to (t_C) moment this age class is subjected theoretically, only to natural mortality with (M) as instantaneous coefficient.

The numerical decreasing of this age class is determined by the relation :

$$\frac{1}{N} = - \frac{dN}{dt} = - M$$

which, by integration, gives the number (N) of fishes, which have survived in ($t_R - t_0$) period, as a function of recruits number (R) in the beginning period :

$$N = R e^{-M(t_C - t_R)}$$

From t_C moment the fishing mortality is added to natural mortality, with an instantaneous coefficient (F).

The decreasing of age class in time t_C is expressed by the formula :

$$\frac{1}{N} = - \frac{dN}{dt} = - (F + M)$$

which, by integration, gives the number of fishes surviving at time (t), subsequent to (t_C), as a functions of recruits number (R) existing at time (t_C) :

$$N_t = R' e^{-(F+M)(t - t_C)}$$

The fishing number yield (c), at age (t), is equal with the product of instantaneous coefficient of capture mortality (F) with surviving fishes number of this age.

The instantaneous capture coefficient is expressed by the formula :

$$\frac{dC}{dt} = F N_t$$

Replacing (N_t) by the previously obtained value it results :

$$\frac{dC}{dt} = F R' e^{-(F+M)(t-t_C)}$$

The total number (c) of caught fishes in studied age - classes, until (t_c) age, is equal with summ of all capture coefficients, obtained at short time intervals in complete series.

Supposing that (F) and (M) are constant until age-classes no longer exist, we obtain, by integration, the following relation between ($t = t_c$) and ($t = \infty$) limits.

$$- C = FR' \int_{t_c}^{\infty} e^{-(F+M)(t-t_c)} dt$$

from where it follows

$$C = \frac{FR'}{F+M}$$

Expressing (R') as a function of (R) we obtain :

$$C = \frac{FR e^{-M(t_c - t_r)}}{F + M}$$

To use this formula in practice we must transform these numerical captures, in an age-class, into their weight correspondent. The capture value in weight (d_y/d_t) equals the product between capture numerical value and corresponding mean weight :

$$\frac{dy}{dt} = FN_t W_t = FR' W_{\infty} e^{-(F+M)(t-t_c)} \sum_{n=0}^3 U_n e^{-nk(t-t_0)}$$

Integrating this equation between ($t=t_c$) and ($t = \infty$) we shall determine the total weight yield (y) obtained from the studied age-class during all its life.

$$Y = FN_t W_t dt = FR' W_{\infty} \sum_{n=0}^3 \frac{U_n e^{-nk(t_c-t_0)}}{F + M + nK}$$

Replacing (R') with its value as function of (R) and passing (R) in the first number of equation, we obtain :

$$\frac{Y}{R} = W_{\infty} F e^{-M(t_c-t_r)} \sum_{n=0}^3 \frac{U_n e^{-nk(t_c-t_0)}}{F + M + nK}$$

Un being 1, -3, +3, -1, for (n) values of 0, 1, 2, 3 we obtain:

$$\frac{Y}{R} = W_{\infty} F e^{-M(t_c-t_r)} \times \frac{1}{F+M} - \frac{3e^{-K(t_c-t_r)}}{F + M + R} + \frac{3e^{-2K(t_c-t_0)}}{F + M + 2K} + \frac{e^{-3K(t_c-t_0)}}{F+M} \frac{1}{3K}$$

DATA	PRELIMINARY CALCULATION						
$M = 0,10$	II	III	IV				
$W_{\infty} = 9374$			n	$M+nK$	X^n	Un	$Un X^n$
$K = 0,2$	$tc - tr = 2,80$	$tc - to = 5,25$	0	0,10	1	+ 1	+ 1
$to = 1,5$	$M(tc - tr) = 0,28$	$K(tc - to) = 1,05$	1	0,30	0,339	- 3	- 1,017
$tc = 6,40$	$e^{-M(tc - tr)} = 0,75$	$e^{-K(tc - to)} = 0,55$	2	0,50	0,115	+ 3	+ 0,345
$tr = 3,60$	$W_{\infty} e^{-M(tc - tr)} = 7030$		3	0,70	0,039	- 1	- 0,039

TABEL 12
 DETERMINATION ESTIMATE
 WHEN
 $\frac{Y}{R}$
 $M = 0,10$

V

		$n = 0$		$n = 1$		$n = 2$		$n = 3$					
(A)	j	B_0	C_0	B_1	C_1	B_2	C_2	B_3	C_3	P	Q	R	S
F	j	$A + M$	$1/B_0$	$A + M + K$	$U_1 X^2 / B_2$	$A + M + 2K$	$U_2 X^2 / B_2$	$A + M + 3K$	$U_3 K^3 / B_3$	$C_0 + C_1 + C_2 + C_3$	$P \times J = P/R$	$Q \times A = Y/R$	$Y/R \times 100 / 12F - 0,5$
0	7030	0,10	10,00	0,30	- 3,39	0,50	0,69	0,70	- 0,05	7,25	50967	0	
0,1		0,20	5,00	0,40	- 2,54	0,60	0,57	0,80	- 0,04	2,99	21019	2101	82
0,2		0,30	3,33	0,50	- 20,5	0,70	0,49	0,90	- 0,03	1,76	12372	2474	96
0,3		0,40	2,50	0,60	- 1,69	0,80	0,43	1,00	0,004	1,25	8646	2593	101
0,5		0,60	1,66	0,80	- 1,27	1,00	0,34	1,20	0,005	0,72	5104	2552	100
0,7		0,80	1,25	1,00	- 1,01	1,20	0,28	1,40	0,003	0,51	3585	2509	98
1,0		1,10	0,90	1,30	- 0,78	1,50	0,23	1,70	0,002	0,34	2390	2390	93
1,5		1,60	0,62	1,80	- 0,56	2,00	0,17	2,20	0,001	0,22	1546	2319	90

DATA		PRELIMINARY CALCULATION						
$M = 0,05$		II	III	IV				
$W_{\infty} = 9374$				n	$M+nK$	X^n	Un	UnX^n
$K = 0,2$	$tc - tr = 2,80$		$tc - to = 5,25$	1	0,05	1	+1	+1
$to = -1,15$	$M(tc-tr) = 0,14$		$K(tc-to) = 1,05$	2	0,25	0,339	-3	-1,017
$tc = 6,40$	$e^{-M(tc-tr)} = 0,86$		$e^{-K(tc-to)} = 0,55$	3	0,45	0,115	+3	+0,345
$tr = 3,60$	$W_{\infty} e^{-M(tc-tr)} = 8081$			4	0,65	0,039	-1	-0,039

TABEL 13

DETERMINATION ESTIMATE
WHEN
 $\frac{Y}{R}$
 $M = 0,05$

V

		$n=0$		$n=1$		$n=2$		$n=3$					
A	J	B_0	C_0	B_0	C_1	B_2	C_2	B_3	C_3	P	Q	R	S
F	J	$A+M$	$1/B_0$	$A+M+K$	$U_1 K^1/B_1$	$A+M+2K$	$U_2 K^2/B_2$	$A+M+3K$	$U_3 K^3/B_3$	$C_0+C_1+C_2+C_3$	$P \times J = P/R$	$Q \times R = Y/R$	Y/R in % $F=0,5$
0	8081	0,05	20,00	0,25	-4,06	0,45	0,76	0,65	-0,06	16,64	90579	0	0
0,1		0,15	6,66	0,35	-2,09	0,55	0,62	0,75	-0,05	4,33	50439	3045	109
0,2		0,25	4,00	0,45	-2,26	0,65	0,55	0,85	-0,04	2,25	15676	3153	112
0,3		0,35	2,85	0,55	-1,84	0,75	0,46	0,95	-0,04	1,45	10052	3015	108
0,5		0,55	1,81	0,75	-1,34	0,95	0,36	1,15	-0,05	0,79	5553	2776	100
0,7		0,75	1,33	0,95	-1,06	1,15	0,30	1,35	-0,02	0,55	3866	2706	97
1,0		1,05	0,95	1,25	-0,80	1,45	0,23	1,65	-0,02	0,36	2530	2530	91
1,5		1,55	0,64	1,75	-0,58	1,95	0,17	2,15	-0,01	0,22	1546	2319	83

DATA		PRELIMINARY CALCULATION					
$M = 0,15$	II	III	IV				
$W_{\infty} = 9374$			n	$M+nK$	X^n	U_n	$U_n X^n$
$K = 0,2$	$t_c - t_r = 280$	$t_c - t_0 = 5,25$	1	0,15	1	+1	+1
$t_0 = -1,15$	$M(t_c - t_r) = 0,42$	$K(t_c - t_0) = 1,05$	2	0,35	0,339	-3	-1,017
$t_c = 6,40$	$e^{-M(t_c - t_r)} = 0,65$	$e^{-K(t_c - t_0)} = 0,35$	3	0,55	0,115	+3	+0,345
$t_r = 3,60$	$W e^{-K(t_c - t_r)} = 6093$		4	0,75	0,039	-1	-0,039

TABEL 14
 DETERMINATION ESTIMATE
 WHEN
 Y/R
 $M = 0,15$

V

		$n=0$		$n=1$		$n=2$		$n=3$					
(A)	(j)	B_0	C_0	B_1	C_1	B_2	C_2	B_3	C_3	P	Q	R	S
F	j	$A+M$	$1/B_0$	$A+M+K$	$U_1 K^1/B_1$	$A+M+2K$	$U_2 X^2/B_2$	$A+M+3K$	$U_3 X^3/B_3$	C_0+C_1	$P \times j = P/R$	$Q \times A = X/R$	$Y/R \text{ in } \% F=0,5$
0	6093	0,15	6,66	0,35	2,90	0,55	0,69	0,75	0,05	4,40	26809	0	
0,1		0,25	4,00	0,45	2,26	0,65	0,53	0,85	0,04	2,23	13587	1358	70
0,2		0,35	2,85	0,55	1,84	0,75	0,46	0,95	0,04	1,43	8712	1742	90
0,3		0,45	2,22	0,65	1,56	0,85	0,40	1,05	0,03	1,03	6273	1882	98
0,5		0,65	1,53	0,85	1,19	1,05	0,32	1,25	0,03	0,63	3838	1919	100
0,7		0,85	1,17	1,05	0,96	1,25	0,27	1,45	0,02	0,46	2802	1964	102
1,0		1,15	0,86	1,35	0,74	1,55	0,22	1,75	0,01	0,33	2010	2010	104
1,5		1,65	0,60	1,95	0,54	2,05	0,16	2,25	0,01	0,21	1264	1896	98

Therefore, the equation of weight yield of recruits fishing takes into consideration the exploited species growth and mortality characteristics, the selectivity of fishing tools and also the fishing mortality.

This recruit weight yield (Y/R) during time interval (t_c to t_r) equals the weight productivity by recruits (P'/R), which actually exists in exploitation during the same time period, multiplied by instantaneous coefficient of fishing mortality.

$$\frac{F'}{R} = W_{\infty} e^{-M(t_c - t_r)} \times \frac{1}{F+M} - \frac{3e^{-K(t_c - t_0)}}{F + M + R} +$$

$$+ \frac{3e^{-2K(t_c - t_0)}}{F + M + 2K} - \frac{e^{-3K(t_c - t_0)}}{F + M + 3K}$$

To apply this formula to our data we use table 12 basing upon the following elements previously determined :

$$M = 0,10 \quad W = 9374 \text{ gr} \quad K = 0,2 \quad t_0 = -1,15$$

$$t_c = 6,40 \quad t_r = 3,60$$

In section II of table is determined the value $W_{\infty} e^{-M(t_c - t_r)} = 7030$ which is the first factor in weight yield formula and which will be put in (Y) column of section V. In section VII is determined $X = e^{-K(t_c - t_r)} = 0,35$, which in section IV permits the calculation of (X^n) for (n) value of 0, 1, 2, 3. In section IV we calculate the corresponding values of $(Un X^n)$ for these values of (n) ; in section V it will serve for the calculation of corresponding values of $Un X^n/B_n$, columns C_0, C_1, C_2, C_3 .

The values of (F) written in column (A) of section V, lead us to the determination of corresponding values (Y/R) in column (R); in column (S) these values are rewritten in percents, one of them being chosen as reference.

In our case, for $S = 0,5$, we find $Y/R = 2552$ grams. We calculate in the same way, for (M) values of 0.05 and 0.15 (tables 13, 14).

On the diagram of figure 5, we put on abscissa the values of (F) and on ordinate the values of (Y/R) in percents ; we obtain the (A) curve for an instantaneous coefficient of natural mortality $M = 0,10$; for the values $M = 0,05$ and $M = 0,15$, rewriting the table values, we obtain the (B) and (C) curves.

The analyse of the three curves results in the idea that, for a low fishing intensity, the weight fishing yield will increase, because the fish will be permitted to develop, while, for a high fishing intensity, the weight yield will decrease.

These elements, characterising the turbot stock dynamics on continental platform, correlated with the conclusions of previous studied (PARCALABOIU, 1971) permitted to elaborate some principles of turbot exploitation organization.

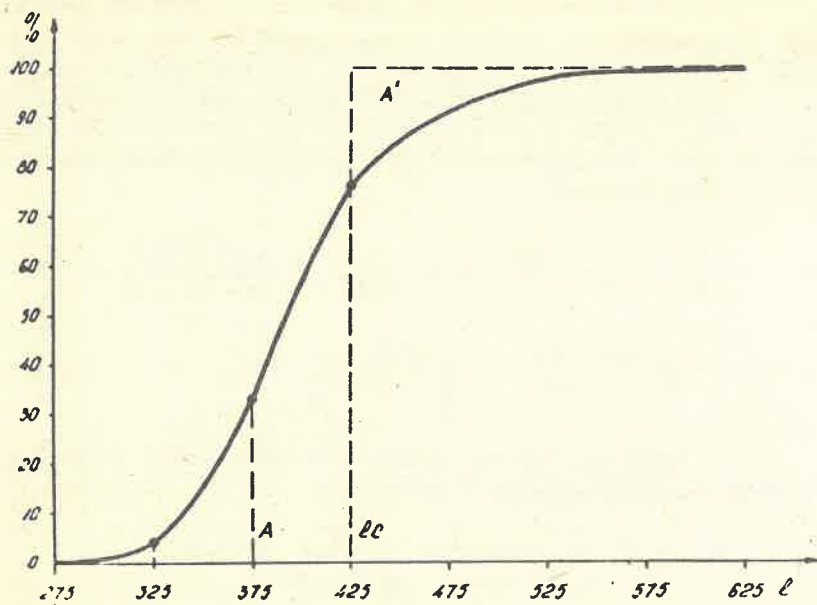


Fig. 4

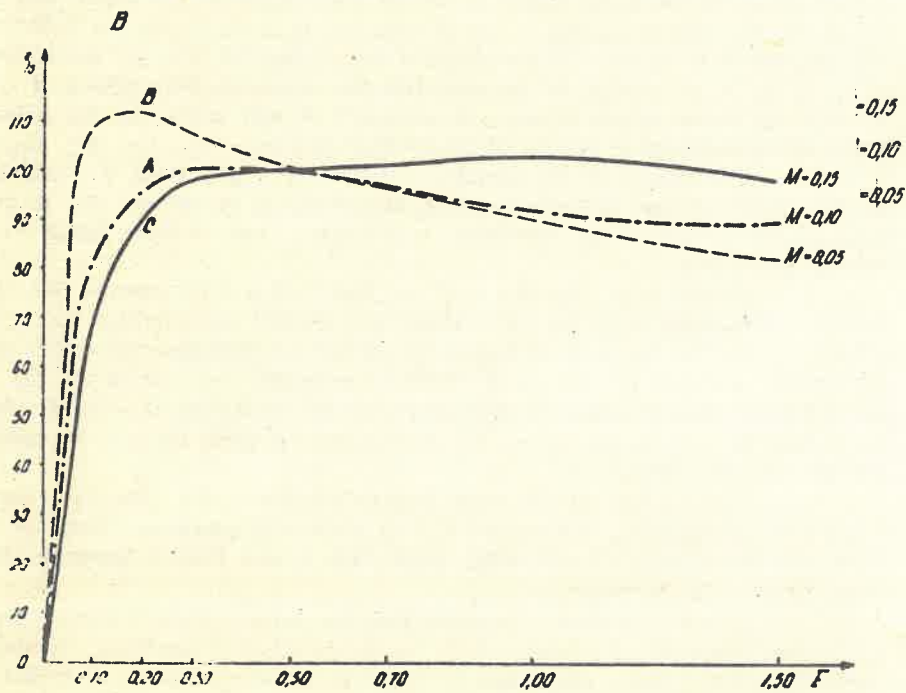


Fig. 5

Thus it is appreciated that turbot stock on continental platform of Romanian littoral, of 1200-1500 tons, permits an yearly exploitation of 200 tons without affecting the sire stock. To assure an additional safety coefficient, we appreciate that it is necessary and opportune that the zone of continental platform in front of Danube mounth should be forbidden for fishing, being kept as a natural reservation for reproduction and growth of young fishes. Also the turbot fishing at depths less than 15 meters must be forbidden together with the total removing from use of the paragate for young turbot. The minimum permissible length of fished turbot must be of 35 cm.

The turbot exploitation must be organized during April-June period only with nets.

x

x x

The paper represents the results of researches effected upon the turbot on continental platform of the Black Sea in front of Romanian littoral, with the view to determine the criteria of rational exploitation of stocks. The analyse effected upon 3830 turbot samples, which were the study material collected in 217 stations, during 1961-1970, period, on the whole continental platform, resulted in the following conclusions ;

- most of fished samples (66-75%) were of three and four years, those of five years were 19%; after that the presence decreases with age so at nine and ten years only isolated species were meat ;
- at the same age, generally, the females have a greater length than males, excepting the second year of life when males are longer than females ;
- a turbot homogenous growth resulted from the analyse of length dispersion indexes on ages ;
- the highest total mortality takes place between 4 and 6 years, after that being almost constant ;
- the natural mortality coefficient is $M = 1,10$;
- the fishing mortality begins at the length of 27.5 cm, reaches 34% at 37.5 cm, is 76% at the length of 42.5 cm; and the turbot is integrally fished at the length of 57.5 cm ;
- the length growth is decreasing with the age so that if from 2 to 3 years it grows with 6.35 cm, from 9 to 10 years it grows by 3.64 cm ;
- the weight growth is also decreasing with age, so that, if from 2 to 3 years it is 569 grams, from 9 to 10 years the weight growth is of 215 grams ;
- the mean length at which the turbot enters in exploitable phase is $l_T = 25.00$ cm and the age $t_T = 3.60$ years ;

- the mean length, at which it enters in exploitation, is $l_c = 41.68$ cm at the age of $t_c = 6.4$ years.

The conclusions resulted in the elaboration of principles for turbot exploitation organisation. So the yearly exploitable quantity is of 200 tons; its fishing must be effected only with nets during April-June period; the minimum permissible length must be 35 cm; the fishing, in front of Danube mouths and on lengths less than 15 meters, must be forbidden.

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