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On Natural Mortality of Azov Pike Perch

by

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Determination of optimum intensity of fishing of commercial species represents one of the main problems of modern theoretical and applied ichthyology. However, the solution of this problem is impeded by lack of reliable information on natural mortality rates of fish. Attempts for determining natural mortality rates of fish were made continuously (R.J.H. Beverton and S.J. Holt, 1957, 1959; W.E. Ricker, 1945, 1958; E.S. Russel, 1942; H. Thompson, 1929, 1930; P.V. Tyurin, 1962) and though sufficiently successful on the whole, they do not solve the problem completely.

A judgement regarding the amount of natural mortality can be most reliable if it is based on the data representing the mean age composition of an unfished or poorly fished population during many years. In this case, the decrease in abundance beginning from a younger age to an elder one may be due to natural mortality. However, in relation to the main commercial species this condition cannot be observed, because exactly those species are fished intensively from the old times and consequently the natural correlation between the ages in the stocks is disordered by the fishery. In a number of cases age determinations made on the basis of remnants of fish (bones, scales), found during the archaeological excavations, could be successfully used in the judgment regarding the age composition of the unfished populations. But the attention of the scientists was however drawn insufficiently to such materials.

In order to carry out such kind of analysis it is quite necessary to ensure that the remains of fossil fishes were referred to the period when fishing did not affect the natural correlation of ages in the stock ("unfished" population), and when the climatic conditions were similar to contemporary conditions. It is desirable also that the age data should cover as long a period of time as possible in order to remove the effect of sharp variations in abundance of separate year-classes. The author has tried to use materials of such kind with a view to determine the rate of natural mortality of Azov pike Perch. In his work on age composition of unfished populations of pike perch the author used age determinations made on the basis of bones and scales which were found during excavations carried out in the basins of the Don and Kuban rivers as well as on some other rivers of the European part of the USSR (Desna, Volhov, Oka, Neman, Kama). Such data were taken from a comprising summary by V.D. Lebedev (1960) and from some other sources (E.A. Tsepkin, 1961; L.D. Voronenkova, 1962).

Age determinations apply to pike perch which lived in the above-mentioned rivers in the period when fishing could not exert any considerable influence on age structure of pike perch stocks (periods, preceeding XIII-XIV centuries) or when it was not conducted at all (several thousand years ago). The effect of fishing on species inhabiting these rivers started to appear only from the end of XVII - beginning of XVIII centuries (V.D. Lebedev, 1960). Correlation of ages of pike perch which in the past inhabited the Azov Sea basin (the Don and the Kuban rivers) is the same in general as that in the stocks of pike perch which dwelled in other said rivers (E.G. Boiko, 1963). That is why the character of age composition of "unfished" stock of pike perch is given (assuming a certain relativeness of such grouping) according to the summary curve plotted on the basis of all age determinations (about 600) independently of habitats of ancient pike perch. It could be supposed that in the past like at present a pike perch was mainly fished within the period of spawning migrations. To catch it at the time of spawning is much easier than under other conditions. That is why the data obtained, most probably, relate to a spawning population. Six year-olds prevailed in the said population which corresponds to the age at which the bulk of this species reaches maturity. More young specimens (5, 4, 3 year-olds) observed in a few number because only a smaller portion of pike perch matured at this age (Figure 1).

Successive diminishing of elder ages (the number of seven year-olds is less than that of six year olds, and so on), is connected undoubtedly with increasing natural mortality of pike perch "because of old age". Pike perch of nowadays, having begun spawning once, continue to spawn every year till the old age is reached. There is no reason to believe that the spawning pattern of ancient pike perch was different. Therefore, it can hardly be supposed that the decrease in percentage of elder ages in a spawning population of ancient pike perch is due to the fact that it did not spawn annually being at a mature age. During the period of the current investigations carried out for several years more than 100.000 determinations of age of pike perch[x] were performed and not a single pike perch older than 17 years had been observed. This fact indicates that the age mentioned is the highest a pike perch can reach. This observation has been confirmed by age determinations of fossil pike perch. The oldest pike perches found in excavations were 14 (V.D. Lebedev, 1960) and 15 years old (L.D. Voronenkova, 1962) respectively. At present, in the spawning populations of pike perch (depending on abundance of a stock) four or three year olds prevail. When fishery was less intensive, but abundance of a stock was high and the growth rate was low (1940 - 1951), the four year olds prevailed; on the other hand, when fishery was more intensive, but abundance was low and rates of growth were high (1952 - 1959), the three year olds prevailed. (Figure 1).

More retarded maturing of ancient pike perch (at the age of six years) is undoubtedly connected with low growth rates, which may be attributed to the greatest abundance of stocks of pike perch, and consequently by poorer feeding conditions. The length of the body of six year olds which inhabited the Don and the Kuban rivers in ancient times was 45 - 48 cm, which corresponds to the average length of contemporary four-year-olds (46.9 cm) and 12 cm less than the average length of six year old Azov pike perch (59.8 cm) which enter those rivers nowadays. The difference between the abundance of the said and a preceeding year-class of ancient pike perch (beginning from seven year-olds) can be considered as a value characterizing a natural diminution at this age. Six year-olds, for instance, numbered 117, while seven year-olds - 103 only. Hence, a number of pike perch in their seventh year of life decreased by 14 or, in relation to abundance of six year-olds, by 12%. Similarly, a percentage of decrease of all elder ages were calculated. (Table 1).

Table 1. Natural mortality rates of ancient pike perch

Age	Age composition		Rates of decrease	
	Number	%	According to age composition	According to curve
3	4	0.7	-	-
4	20	3.7	-	-
5	75	13.8	-	-
6	117	21.5	-	-
7	103	18.9	12	12
8	79	14.5	23	23
9	58	9.8	33	28
10	36	6.6	32	32
11	25	4.6	31	36
12	15	2.8	39	39
13	11	2.0	27	42
14	6	1.1	45	45
15	-	-	-	50
16	-	-	-	65
17	-	-	-	100

[x] From 1939 the age of the Azov pike perch is being determined by examining of cross-cut of hard and soft rays of abdominal fin, and due to it an exact calculation of annual rings of the fish of all extreme old ages can be ensured (E.G. Boiko, 1951).

A mortality curve was plotted on the base of those data (Figure 2, black dots). A certain scattering of mortality indices is explained by the lack of information. However, in spite of small deviations, a general character of the curve is distinct:- natural mortality of pike perch increases with age. Missing indices of natural mortality for 15, 16 and 17th years of life were calculated by means of extrapolation (the age of 17 years was taken as a limit). Mortality indices of intermediate ages - for 9, 11 and 13th years of life were corrected also by means of an interpolation method (both are shown on Figure 2 by light dots).

Natural mortality coefficients obtained with the described method can be considered as long-term average rates, because they are calculated on the basis of age composition data relating to unfished stock of pike perch for several centuries. It is believed that the data obtained on natural mortality of pike perch, which inhabited several thousands years ago, could be relatively objective for and characteristic of the mentioned period and the environmental conditions. It is quite natural that it would not be right to transfer those rates to contemporary populations of pike perch. However, having received natural mortality rates of an unfished population, which inhabited several thousands years ago, the author considered it interesting to try to make a rather approximate calculation of the optimum intensity of fishing of the contemporary population of the Azov pike perch. Further with due regard to changes in weight and mortality rate of pike perch at different ages we calculated with the use of a model the absolute values (in number and by weight) of feasible catches and losses caused by natural mortality for the cases of different fishing intensity (from 10 to 100%) when pike perch from three up to ten years inclusive is taken by fishery. It is assumed in the calculations that the abundance of a year-class before the beginning of fishing amounts to thousand specimens (at the age of three years), which complies with the actual average catch taken on 1952 - 1961 year-classes. In order to simplify calculations it is assumed that a total catch is taken in spring (in fact a little number of pike perch is also taken in autumn). Table 2 shows as an example the calculation (in number of specimens) of a catch and losses (caused by natural mortality) for the case when pike perch is fished from the age of three years with a fishing intensity of 50%.

The difference between stock and catch is a remainder, a part of which dies by natural death (losses) by the next spring. Mortality is estimated only from the age of six, seven years and more but at younger ages it is not taken into account, but considered as negligible. In general, in the case of three-five-year-olds it can hardly be more than 10%. The difference between the remainder and the losses is the stock for the next spring, when pike perch becomes one year older.

The bottom line of Table 2 shows the yield and the losses (caused by natural mortality) for the whole period of life of a year-class. In the case of a stable (from year to year) abundance of year-classes these total figures can be regarded as a catch and losses of the whole population of pike perch (here it is caught from the age of three years with fishing intensity as 50%).

Table 2. Catch and natural mortality of pike perch (in thousand specimens) when fished from the age of 3 years with a fishing intensity of 50%

Age	Stock	Catch	Remainder	Losses due to natural mortality	Natural mortality after the mentioned age
3	10000	5000	5000	-	-
4	5000	2500	2500	-	-
5	2500	1250	1250	-	-
6	1250	625	625	75	12
7	550	275	275	63	23
8	212	106	106	30	28
9	76	38	38	12	32
10	26	13	13	5	36
11	8	4	4	2	39
12	2	1	1	1	42
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The same method was applied when calculating the yield and the losses, (in numbers and by weight), caused by natural mortality for other values of fishing intensity (from 1o to 1oo%) in cases when pike perch is fished not only from the age of three years but from four, five years and older up to ten years inclusive. The increase in weight of pike perch is not uniform from year to year; up to the age of three years the annual increments in weight are not great, they reach a maximum in 4th - 8th years of life and decrease again noticeably in the subsequent years. Therefore, under certain conditions - i.e., when catching is conducted for not very young pike perch and the fishing intensity is not great - the losses caused by natural mortality can be partly or completely compensated by annual increments in weight. Hence, it is very important to know the ratio between the yield and the losses from natural mortality not only in numbers but also by weight. The Figures 3 and 4 show this ratio when pike perch is caught starting from different ages with different fishing intensity. As it could be expected the maximum losses are observed everywhere, when the fishing intensity is lowest (1o%). When the fishing intensity is increasing the losses decrease, and in cases when relatively young pike perch (from three to five years) is caught with high fishing intensity (6o - 8o%), the losses caused by natural mortality are practically reduced to nothing (Figure 3).

However, when pike perch is fished from the age of 7 to 1o years (even if the fishing intensity is rather high) the losses caused by natural mortality are so large that sometimes they prevail the yield. Hence, fishing for pike perch from the age as such is inadmissible because of very heavy concomitant losses (Figure 4). The possible largest catch would be taken if pike perch is fished from six years when the fishing intensity is comparatively low (from 4o to 6o%). The losses are not great in this case. However, it is not done in practice yet, because a bulk of pike perch is taken at a younger age, mostly from three years. The latter is explained by the fact that there has not so far been invented a method of selective fishing of pike perch of different lengths and ages. This is partly due to the necessity of catching pike perch simultaneously with other smaller fishes, for the catching of which small-meshed fishing gears are used. In case of catching pike perch from the age of three years the biggest yield can be obtained, if the fishing intensity is about 3o - 2o%. Such fishing intensity should be considered here as "optimum". The yield of three-year-old pike perch will decrease if fishing intensity is higher or lower than the one mentioned (Figure 3). When catching four or five-year-old pike perch the "optimum" fishing intensity increases to 4o and 5o%. Thus the older the pike perch is caught the higher would be the optimum fishing intensity. The optimum fishing intensity is also governed by many other factors, in particular, by the necessity of a rational utilization of feeding resources of a given water-body.

If food is plenty and the stock of pike perch is not great, then care should be taken of obtaining the possible largest catch without taking into account the losses caused by natural mortality. But when the food stock is scanty which may result in a decrease in the growth rate of pike perch, the natural mortality must be reduced to a minimum, even if it will require a certain lowering of catches. In years when the rate of weight increment is slow, the fishing intensity must be higher than that under the conditions of fast growing rate. Otherwise annual weight increments (when growing rate is slow) will not compensate the losses caused by natural mortality. The richest year-classes of pike perch must be fished more intensively in comparison with poor year-classes in order to avoid large (absolute) losses caused by natural mortality.

These are a few estimations and considerations as to the optimum intensity of fishing of Azov pike perch. These observations were made on the basis of the data on natural mortality rate obtained from the analysis of fossil remains of pike perch which inhabited the basin of the Azov Sea in general thousand years ago. It has to be stressed again that such estimates are rather conditional, but it is hoped that they are of some interest even as they stand. Because of numerous factors determining an "optimum" catch, it appears difficult to find a correct and timely solution for each specific case by means of model manually. But with the use of electronic computers the solution of this problem is quite feasible.

Summary

Determination of optimum intensity of the fishery represents one of the main problems of modern ichthyology. However, due to lack of reliable information on the natural mortality of fish, the problem has not yet been solved.

In order to make a judgement on the natural mortality of the Azov pike perch more than 600 age determinations were used of pike perch which had lived mainly about two thousand years ago in the European part of the USSR (and in some cases even much earlier). At that time as now the pike perch was mainly fished in the period of spawning migrations.

Judging by the age composition of a very old and poorly fished spawning population of pike perch, death caused by natural mortality begins to increase in the seventh year of its life and amounts to 12%. During a period of eight-sixteen years the mortality gradually increases from 23 to 65%. Seventeen is the age-limit for a pike perch.

On the basis of the natural mortality ratio the absolute values of losses and assumed catches of pike perch were counted (in numbers and by weight), the intensity of fishery (10 - 90%) being different. It turned out that a low intensity of fishing (10 - 20% of the stock) cannot be passed since in this case losses caused by natural mortality amount to 70 to 40%.

The "optimum" intensity of fishing (when losses caused by natural mortality are exceeded in weight by an annual increment) first of all depends on the age of pike perch at which the fishery for it starts; the optimum intensity of the fishery for a pike perch at the age of three is 30%, at the age of four 30 - 40%, and at the age of five 40-60%. If the intensity is above the optimum then an actual catch is less than that assumed owing to the under-exploitation of an annual increment in weight, and on the other hand, if the intensity is less than the "optimum" then an actual catch is less due to the large losses caused by the natural mortality.

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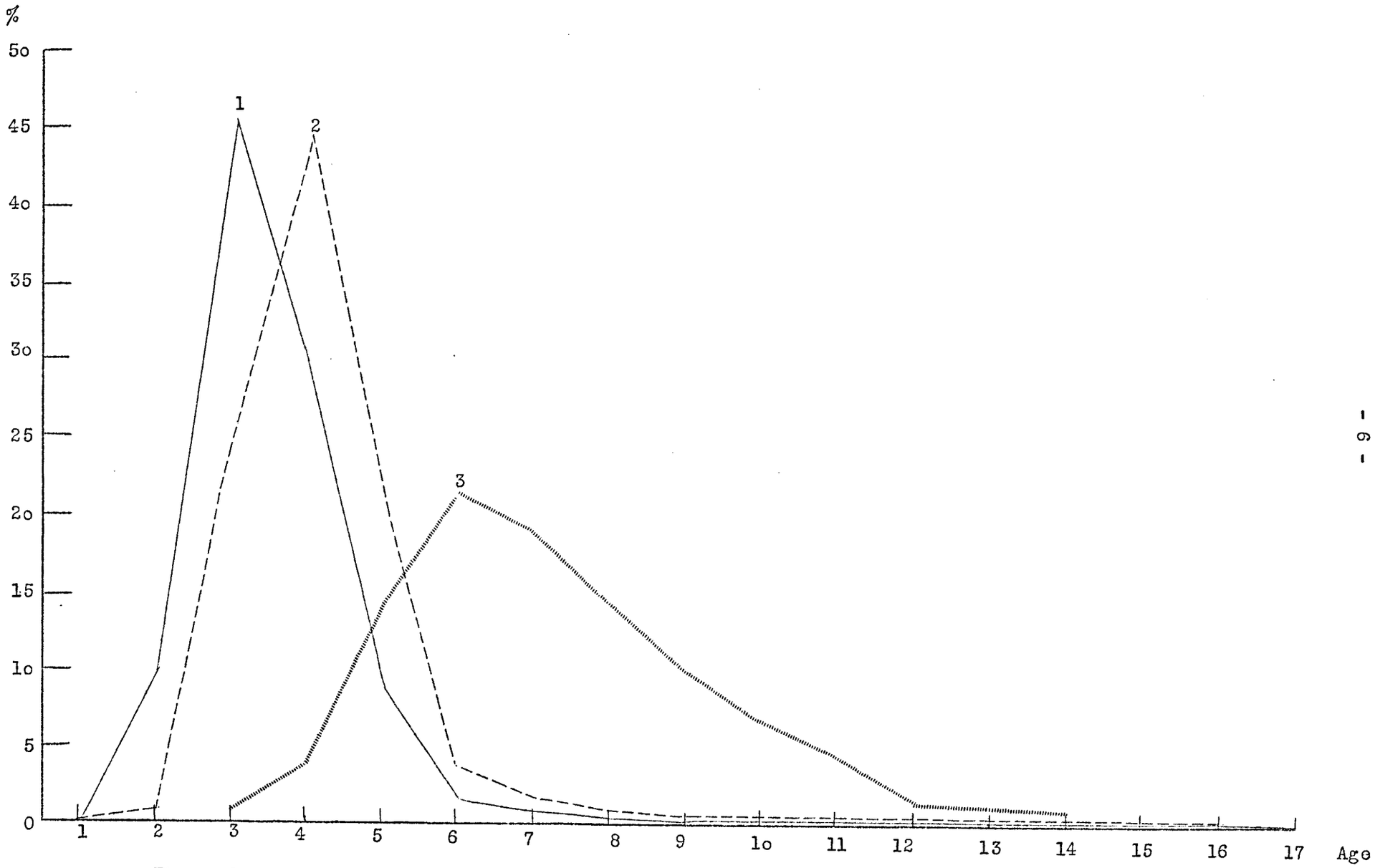

Figure 1. Age composition of pike perch.

1. Commercial catches of Azov pike perch in 1952-61.
2. Commercial catches of Azov pike perch in 1940-51.
3. Unfished population - pike perch obtained from excavations.

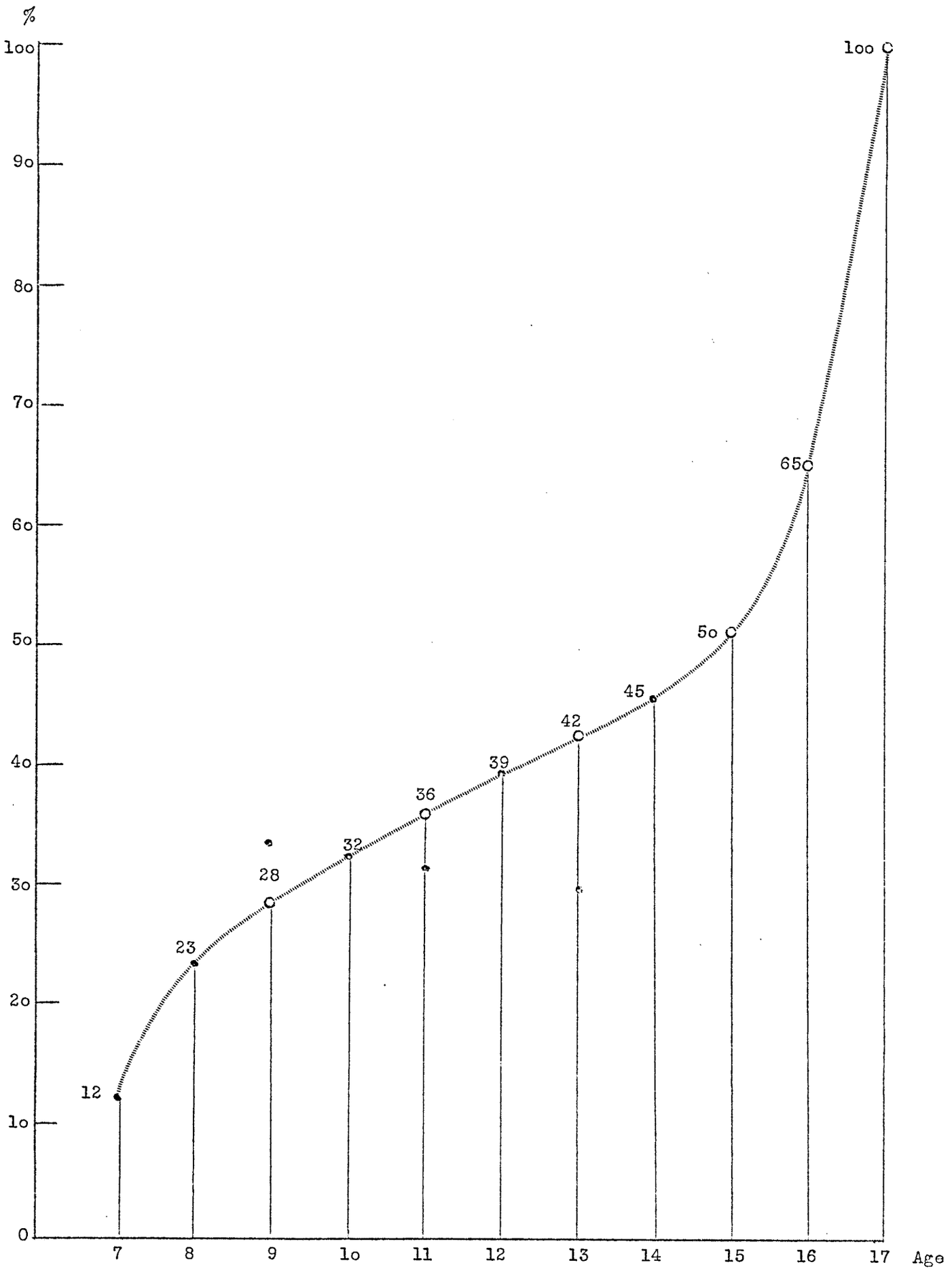

Figure 2. Natural mortality of pike perch at the age of 7-17 by age composition.

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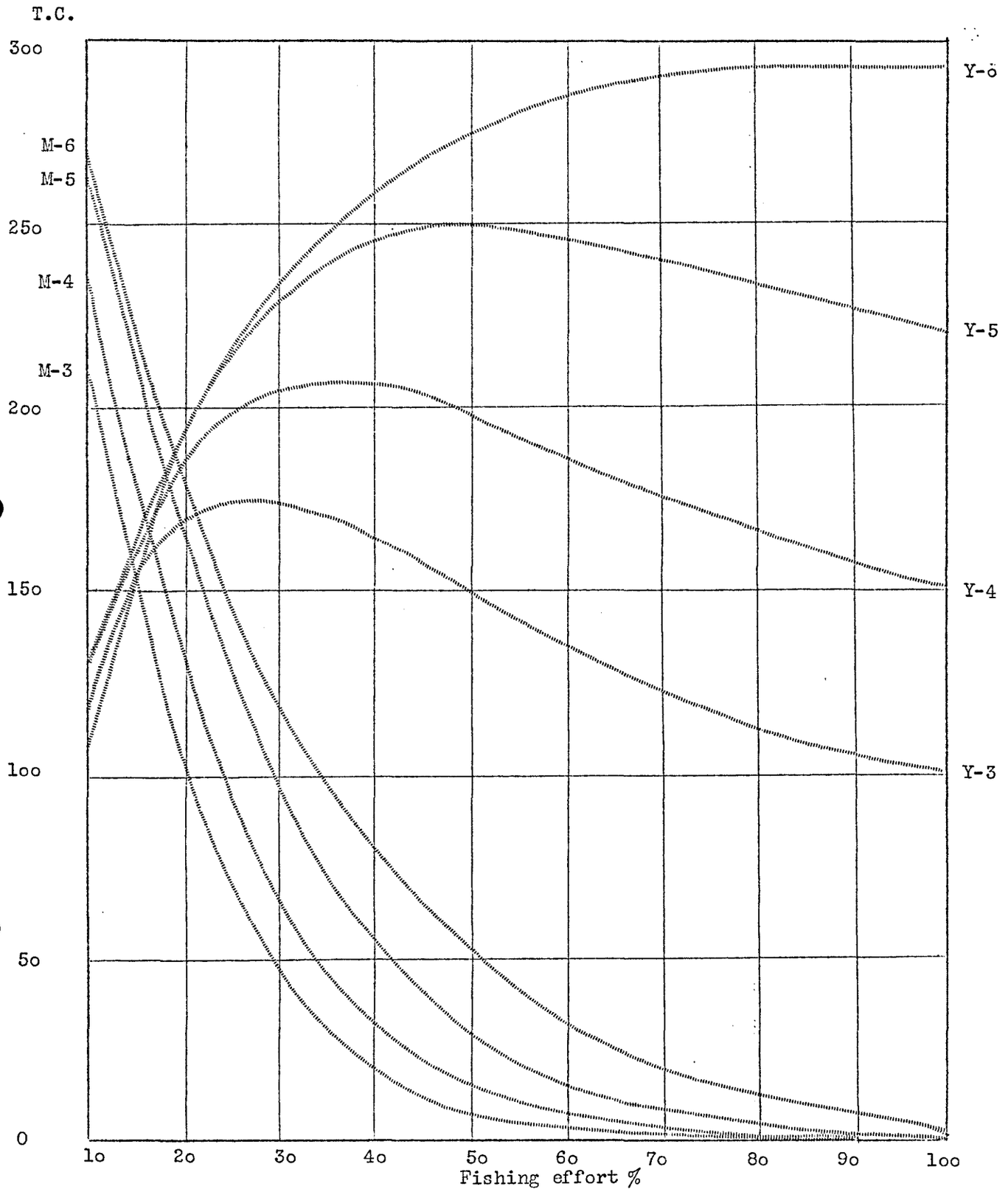

Figure 3. Possible catch and losses (in 1000 centners) caused by natural mortality in fishing of Azov pike perch from the age of 3, 4, 5 and 6 years.

Y = catch

M = losses

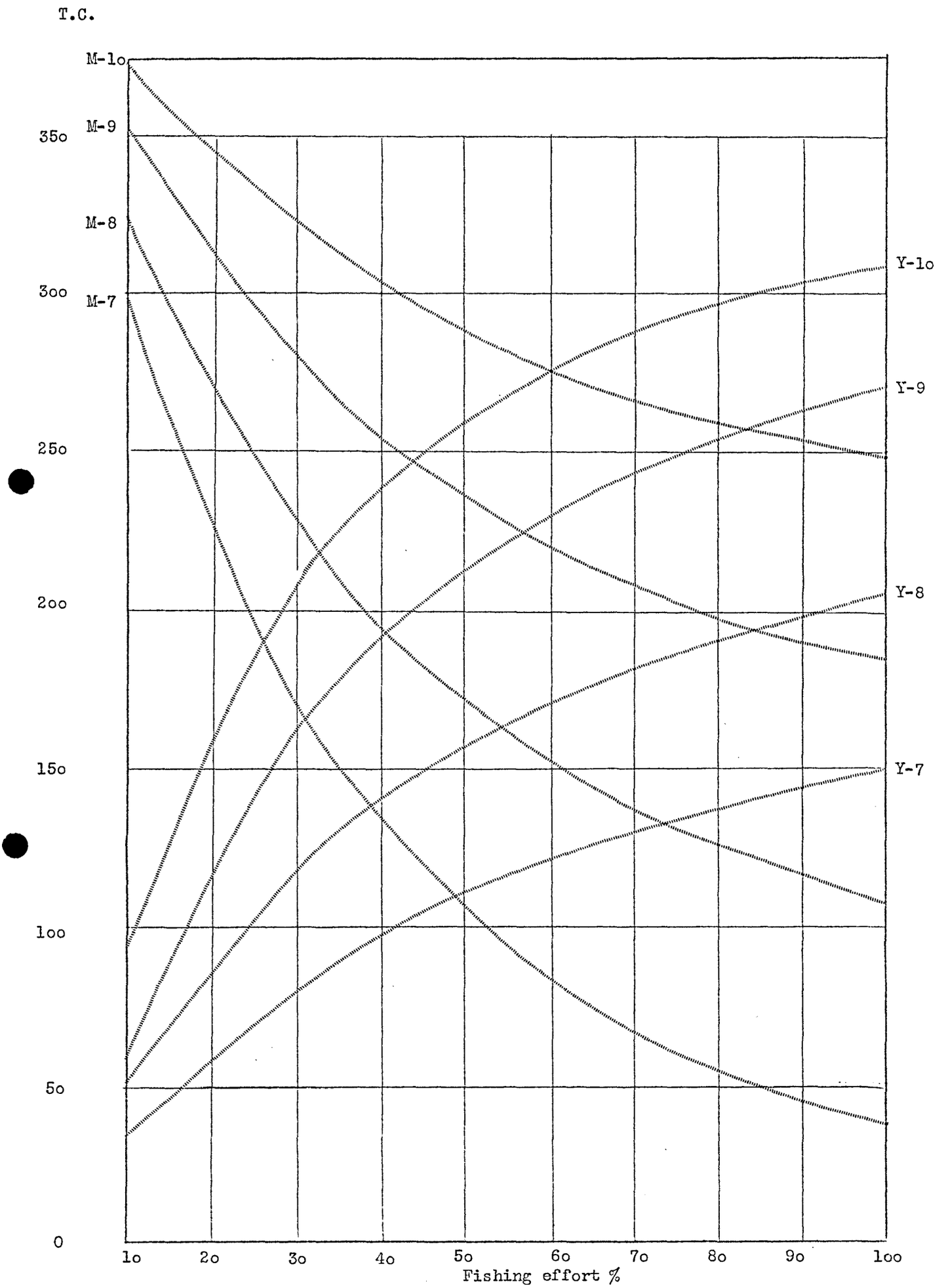

Figure 4. Possible catch and losses (in looo centners) caused by natural mortality in fishing Azov pike perch from the age of 7, 8, 9 and lo years.

Y = catch
M = losses.