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Evaluating natural mortality in the Azov zander [*Stizostedion lucioperca*]

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Evaluating natural mortality in the Azov zander [Stizostedion lucioperca]

By E. G. Boiko

One of the basic objectives facing investigators in applied ichthyology is that of determining the optimum intensity of fishing. However, finding an answer for this important question is made extremely difficult by the absence of necessary data concerning what rates of natural mortality are usual among fishes.

Unless we know the magnitude of natural mortality rate, and the weight increase at different ages, as well as the upper limit of age, it is impossible to come to a decision on what fishing intensity should be used to catch the fish in question, and at what age it should begin, in order that the weight of the catch (not the number) should be as large as possible.

But whereas obtaining information on the annual increase in weight of fishes does not present any great difficulties, evaluation of the magnitude of the natural mortality is incomparably more complex; and the numerous experiments which have been attempted along these lines [10, 11, 12, etc.] cannot be considered wholly successful.

P. V. Tiurin [7] is one of those who did not achieve this goal. The coefficients of natural mortality which are given in his work are quite provisional, because they were obtained not from factual data concerning the maximum age of the fish, but from calculations based on the theory of probability which did not take into consideration the biological characteristics of the fish. The maximum age of zander, according to Tiurin, is 21 years. However, zander of this age have never been found in catches anywhere. And to judge by paleoichthyological data [5, 8], there weren't even any some thousands of years ago, when the intensity of the fishing was quite low.

In addition, Tiurin adopts the same coefficients for all ages, whereas in fact the rate of natural mortality at different ages is far from uniform.

The principal obstacle to determining average values for natural mortality of commercial fishes, including zander, is the intensity of the fishery, which changes the natural numerical ratios between the age groups in the stock. If we do not know these ratios, it is impossible to estimate the size of the natural mortality at a given age or, in particular, the numbers of mature zander that die "from old age".

All information on the age composition of the zander stock which has been collected up to the present time pertains to the period when it has been intensively fished. During their 3rd and 4th years of life, that is, in two years, the abundance of zanders decreases on the average by 80%. Under such circumstances it is impossible to estimate the magnitude of such loss from natural mortality.

[Page 144]. The high level of intensity of the fishery has also made it difficult to estimate the maximum age of zander. The absence of very old zanders in the catches has been explained as exclusively the result of the fishery [9]. As a matter of fact this is not the complete answer. During the last 20 years the age of these fish has been determined from the cross-sections of the fins, which eliminates errors in counting the annual rings. Although during this time hundreds of thousands of age determinations have been made for zander, fish older than 17 years have never once been encountered. From this we may conclude that this is the upper limit of age for zander. This is confirmed also by determinations of age of zanders in ancient times.

To get an idea of what the age composition of the zander stock might have been in the absence of fishing, I have used determinations of age made from the remains of zanders from archeological excavations.

The principal source of this information is the interesting work by V. D. Lebedev [5].

Inasmuch as the age of ancient zanders was determined from remains whose antiquity spans many hundreds or thousands of years, and in a few cases even hundreds of thousands of years, we are justified in considering that these remains characterize the age composition of unfished populations of zander: the fishery practically did not exist at that time.

The capture of fish at that time [the period prior to the 14th-15th century] was undoubtedly so limited that it could not exert a noticeable effect on the abundance of the zander, consequently on its age composition. In Lebedev's [5] opinion, the influence of fishing began to be apparent in the age composition of fishes of the European part of the USSR beginning in the 17th or early 18th centuries, while the Azov fishery began to become intensive starting at the end of the 18th and beginning of the 19th centuries.

Materials

The natural mortality rate of the zander has been estimated from 544 age determinations of ancient zanders. To determine their rate of growth we have used data from 736 computations of body length.

The material is distributed as follows: 407 determinations of age and 165 of length are from remains found in excavations on the Desna, Volkhov, Oka, Kama, and Neman Rivers, these belonging to zanders of the central portion of the USSR. These remains are dated between the 3rd and 2nd centuries B.C. to the 10th-14th centuries A.D.

Information on the zanders that lived in the Don and Kuban Rivers in ancient times is somewhat more limited [137 determinations of age and 571 of length].

Remains of these zanders are found on the Don River in strata that lie on the boundary between the Tertiary and Quaternary periods [3 determinations of age], in the Khozarskie strata of the lower Don whose age of deposition has been calculated as hundreds of thousands of years [65 determinations], in the delta of the Don in excavations of the ancient city of Tanais which belongs to the 2nd to 1st century B.C. [6 age determinations], in the Gulf of Kerch in the excavations of Pantikapeà belonging to the period between the 4th century B.C. and the 4th century A.D. [2 age determinations]; in the Kuban River delta in excavations of the Chumian "redant", in the Primorsko-Akhtara region in the village of Nekrasovka [61 age determinations], these being remains which belong to the 2nd or 3rd century A.D. (Table 1).

The last age determinations pertain to zander which inhabited the delta of the Kuban River, which is the principal site of the zander fishery at the present time. Remains of zander from the lower Quaternary Khozarskie strata are found between the stations of Mariinsk and Romanovsk and upstream, in places which today are flooded by the Tsimlian reservoir, that is in the [page 147] part of the lower Don to which the semi-migratory zander come to spawn even now.

Inasmuch as natural mortality rates are determined by the biological characteristics of a particular species, and depend on its conditions of life, we may form conclusions about natural mortality of the zander which exist today on the basis of the age of the ancient stock which was untouched by a fishery.

According to Lebedev [5] conditions of existence for the ancient zander differed little from those at present,

hence we are justified in considering that the rate of natural mortality of zander at the present time will not have changed either. Even in those distant times when the Khozarskie strata were laid down, climatic conditions in the Don River lowlands and Azov coastal region were close to the present conditions.

Rates of natural mortality of zander from waters of the central portion of the USSR obviously must be a little different from those prevailing further south in the lower reaches of the Don and Kuban. But judging by the material at hand, these differences among the ancient zander were not large.

Figure 1 shows that the differences in age composition, for example between zander of the Khozarskie strata of the lower Don and those inhabiting the central regions of the river, are insignificant, and apparently may be explained on the basis of the unequal reliability of the data obtained [65 age determinations in the first case and 407 in the second].

Therefore to characterize the natural mortality rate of an unfished stock of zander I will use the combined curve of age composition from all the age determinations available [544], without reference to their place of origin.

[Page 148] Age composition of the ancient zander stock

Three-year-old fish were the least abundant age group in the ancient zander stock, amounting to 0.7%. Age 4 fish were somewhat more numerous -- 3.7%. Age 5 was still commoner -- 13.8%, while the predominant age group was 6, amounting to 21.5% (Table 1, Fig. 1). The remaining groups were distributed as follows: age 7 was less common than age 6, age 8 less than age 7, and so on. On the average 1% were 14 years old. This indicates that age 14 was not the upper age limit for the ancient zanders. The absence of zanders older than 14 years in paleoichthyological collections is to be explained, apparently, by the errors which arise in identifying annual rings on very old fish; this is quite usual, especially when age is determined from the scales. As mentioned above, the Azov zander in our times lives to 17 years.

We must notice that the people of long ago, like those living today, caught zanders mainly during the period of their spawning migrations. For to catch the fish at their spawning places or on their approach to them -- in the delta or in the river -- is much easier than to catch them at other times in

places where they feed -- in the sea or in a lake far from shore.

It is obvious that these remains of ancient zanders pertain to the spawning population, and that the percentages of the younger ages in them reflects the age of sexual maturity; at age 3 only an unstable fraction of zanders have become mature, there is a larger number at ages 4 and 5, but the principal time of first maturation is among the 6-year-olds, hence they predominate in the stock.

[page 149] At the present time the Azov zander attains sexual maturity mainly by 4 or 3 years of age. With a greater intensity of fishing (1951/52-1958/59), when the stock was not very large and its rate of growth had increased, 3-year-olds predominated in the spawning population. With a somewhat lesser intensity of fishing, a larger stock and slower rate of growth (1939/40-1950/51) 4-year-olds predominated in the spawning stock and consequently in the catches (Fig. 2).

The lateness of sexual maturity among the ancient zanders is undoubtedly also associated with their slower rate of growth, which in turn is caused by the great abundance of their stocks and consequently also the poor feeding conditions (Table 2).

V. D. Lebedev [5] has also remarked on the slowness of the growth of certain ancient fishes, due to these causes.

The extreme slowness of the rate of growth of the zanders of ancient times can also be judged from the fact that among the zanders living in the Don and Kuban Rivers the most frequent length class was 45-48 cm (Fig. 3, Table 3).

[page 152] From this we may conclude that the 6-year-olds, which were definitely predominant in the stock of ancient zanders, were also about 45-48 cm long. But this length corresponds to the average length of 4-year-olds today (46.9 cm), and is approximately 12 cm less than the average for 6-year-olds (Table 2).

A connection between growth rate and stock size of zanders can be recognized at the present time also. Thus at the time of their largest stock in 1936-1938 and 1942-1947 (average catch 570,000 centners) the increase in weight of [Azov] zanders in their 4th and 5th years of life was on the average 13% less than in 1948-1959 when the level of stock was considerably lower, [as shown by a] catch of 186,000 centners [2].

The regular decrease among all ages beyond age 6, in the unfished spawning populations of zanders, must evidently

be a result either of increase in mortality rate with age, or of failure to spawn every year on the part of fish older than age 6.

However, in our times zanders of the older ages (from age 4 onward) spawn every year; and there is no reason to imagine that the ancient zanders would have behaved differently in this respect. Though some older zanders do turn up in the catches with undeveloped sex products, these are as a rule fish older than 10 years. Therefore we must presume that the decrease in abundance of zanders of older ages in the ancient unfished spawning populations is caused mainly by their natural mortality.

Rate of natural mortality of Azov zanders

The difference between the abundance of a given age group and that of the previous age (beginning with age 7) can be considered as representing the rate of natural mortality at this age.

For example the 6-year-olds numbered 117, and 7-year-olds 103 (Table 4). Consequently the abundance of zanders during the 7th year had decreased by 14 or by 12%.

A certain scattering of the estimates of mortality of adjacent ages (Table 4) is obviously caused by insufficient material. However, in spite of small deviations, the general character of the mortality curve is quite clear: mortality increases with age.

From the curves obtained by this method I have calculated by extrapolation the missing estimates of mortality rate for the 15th, 16th and 17th years (assuming that age 17 is the maximum age), and I have also smoothed the estimates of mortality for three of the intervening ages -- 9, 11 and 13 years (Fig. 4).

This adjusted and extended curve is taken to be characteristic [page 153] of the natural mortality of Azov zanders from their 7th to 17th years. These values are given in figures in Table 4.

The estimates of zander mortality calculated using data from archeological excavations may be considered as average long-term values, since they are based on data of the age composition of zanders over many thousands of years. The effects of year-classes of differing strengths on the corresponding age-groups is of course smoothed out under these conditions.

The classical example of Thompson [12], pertaining to the little-fished population of haddock near the Island of Rockall, could not supply the hoped-for criterion for estimating natural mortality of haddock at different ages, because the age composition of the haddock living near this island showed quite unmistakable evidence of the effects of good and poor year-classes.

Natural mortality at an early age

Natural mortality among young fish -- age 3+ to 5+ -- is not large; and hence in estimating a rational intensity of fishing it need not be taken into consideration.

It is impossible to estimate natural mortality rates for the young zanders from the ratios of their ages in the spawning population. However, there are no data available on the age composition of the unfished zander stock in the places where they feed in the sea. The long-term age composition of the Azov zander stock, obtained from studies of the catches in the sea, (Fig. 5) are not suitable for this purpose. The decrease in numbers of the older ages, in comparison with the younger ones, is in this case the result of the intensive removal by the fishery, and is not due to natural losses. At the present time zanders are fished practically from the time they are one or two years old.

However, in determining the optimum intensity of fishing, the magnitude of the natural mortality of zanders 2 years old and younger has no special interest, since it is clear that we know it is undesirable to fish zanders of these ages even without having this information. Zanders of age 3+ are already of commercial size, and therefore it would be desirable to know their natural mortality in the 4th year of life, but unfortunately this has not been possible as yet. [page 154] Age 3+ fish are, in part sexually mature, and therefore their natural mortality in comparison with the younger ages must be somewhat larger. Among zanders, as among all other anadromous and semi-anadromous fishes, natural mortality must increase somewhat with the onset of sexual maturity.

The spawning migrations are accompanied by increased risk of death (during the time of their spawning migration the fish are frequently attacked by predators, sometimes the approaches to the spawning grounds dry up and the fish cannot get away in time, etc.).

The ancient zanders matured mainly at 6 years, while among the present-day fish it happens considerably earlier:

at age 3 or 4. Consequently the mortality of fish of ages 3 and 4 must today be somewhat greater than in antiquity.

However, bearing in mind that young zanders are better able to withstand diseases and all sorts of unfavourable conditions than are the 6-year-olds which have already begun to age, and considering that even in their 7th year of life the natural mortality of zanders amounts only to 12%, we will be right in concluding that natural mortality between ages 3 and 5 is not great and in all probability does not exceed 10%.

Losses from natural mortality and optimal fishing intensity

Thus in an unfished population of zanders natural mortality from old age begins to appear after 6 years, and increases with age.

Let us attempt to determine the absolute magnitude of these losses at different intensities of fishing (Table 5).

In these calculations I assume that the abundance of a year-class (of 3 years of age) at the beginning of fishing is 10,000,000 individuals, which is the actual commercial return of the 1952-1961 year-classes (over a longer period of time -- the year-classes of 1922-1961 -- the average commercial return was somewhat larger -- 14,600,000 individuals).

To simplify the calculations I have assumed that the whole catch is taken at the beginning of the year, in the spring; actually some part of the zander catch is taken in autumn.

The difference between the stock and the catch is the carry-over [ostatok], part of which perishes from natural mortality during all seasons except the spring. [page 155] Mortality of the zanders is computed only from the 6th year of life. Natural mortality of the age 3 to age 5 zanders is considered to be insignificant and is not taken into consideration.

The rate of natural mortality at each age is shifted to the year ahead: in the figure the age 6 fish, for example, are assigned the mortality for the 7th year, and so on.

The difference between the carry-over and the natural loss is the stock present in the spring of the following year, when the zanders have become a year older.

In a similar way the stock and loss from natural mortality, in numbers, is computed for the situations where zanders are caught starting in their 4th and 5th years.

Table 5 shows the total catch and the total natural mortality for the whole period of existence of a year-class (if the size of the year-classes were stable from year to year, these totals could be considered as the catch and natural mortality of the whole population of zanders in a single year).

Table 5 shows that with increase in intensity of fishing natural mortality decreases, while the catch rises steadily. When the intensity of the fishery reaches 50%, the zanders practically never suffer natural death, the natural loss in that case being less than 2% by number; and when the fishing intensity is 70% natural losses are less than 0.2%.

Such are the relationships between natural mortality and catch at different fishing intensities, in numbers. In terms of weight these relationships are somewhat different. In this case with increasing intensity of the fishery the loss from natural mortality also decreases, but the catch at first increases fairly rapidly, reaches a maximum, and with further intensification of the fishery it gradually falls off (Table 6, Fig. 6).

Table 7 shows (in weight units) the catch and natural mortality at different fishing intensities for 3 situations: when zanders are caught starting in their 3rd, 4th and 5th years (the data for fish of ages 7-10 and 11-17 are combined to save space).

The greatest loss from natural mortality in all 3 variants is at a low intensity of fishing. With a fishing intensity of 10% natural losses are at a maximum and considerably exceed the catch, while with a fishing intensity of 30% they already amount to no more than 1/5 to 1/3 of the total production of the year-classes (see Fig. 6).

With further intensification of the fishery the natural loss becomes still smaller and when intensity reaches 60% it is so small it need no longer be taken into consideration, being no more than 2-6% of the total production (increase of biomass) of the year-class. However, insignificant losses, amounting to fractions of a per cent, occur even when fishing is intensified almost to the limit -- 80-90% (Table 8).

Having determined the magnitude of the loss ascribable to natural mortality we may now turn to the question of optimum fishing intensity.

From the computations presented it follows that a very light fishery, which uses about 10% of the stock, should not be considered because natural mortality of the zander in that

case is very large and exceeds the catch. With increase in fishing intensity the natural mortality declines and the catch increases. However, an extreme intensification of the fishery also leads to decrease in catch. This occurs because the zander puts on most of its weight increase in its 5th to 8th years, and with an intensive fishery it does not reach these ages. The later the fishery begins to catch the zanders, the larger the fraction of them which will live to an age which permits optimal catch. When they are captured beginning at age 3+ the greatest catch can be taken if the intensity of the fishing does not exceed 30%, whereas if fishing begins at age 4 or 5 its intensity must be raised correspondingly, to 40-50% (Fig. 6).

[page 158] Thus it is more rational to catch zanders beginning at age 5. Under these conditions the catch will be larger than if they are caught beginning at age 4 or 3. Although the theoretical calculations lead to this conclusion, in practice there exists a selective fishery which as yet is not able to protect the younger age groups from fishing, even including those of age 3. Theoretically the zander can be subjected to capture beginning at age 3 but as a matter of fact with existing methods of fishing age 2 and age 1 fish are also taken in the nets. Mass capture of small sized zanders may be avoided by prohibiting the use of gillnets.

It would be a very complicated matter to keep age 3 and age 4 fish out of the catch. At this age zanders have become sexually mature and at the time of the spawning migration they are captured along with the fish of older ages. In addition, they would unavoidably be taken in the seine fishery for other similar fishes (taran, shad, chekhon and others).

In the past the zander stock has sometimes been exploited to excess. For example, the year-classes of 1934-1939 and 1948-1956 were captured at age 3 to the extent of more than 30%, that is, at an intensity greater than optimal. In some cases (1950 and 1952 year-classes) up to 75% of a year-class of 3-year-olds has been captured (Fig. 7).

The data of Fig. 6 indicate that the natural mortality of zanders, as well as the catch, is the greater, the later it begins to be fished; when the fishery begins at age 4 the loss is greater than when it begins at age 3, and when it begins at age 5, it is still greater and so on. Computations show that when zanders begin to be taken at age 3, as now happens, then at age 9 and subsequently losses from natural mortality have already begun to exceed the catch even [page 159] with a rather high rate of fishing. This position, however, should be avoided because it would lead to an unrational utilization of the food supply.

Consequently in determining the age of commercial utilization of zanders we must also take into consideration the necessity for rational utilization of the food resources of the body of water, and if these are limited, the fishery should be intensified.

In this paper I do not propose to dwell on the theory of optimal intensity of fishing for zanders, because this has already been done in a special article [1]. It is true that in that article it was provisionally estimated that natural mortality of zanders up to 10 years of age was not large, and that only after that age did it increase abruptly. Hence zanders older than age 10 were excluded from the calculations in determining the probable catch.

However, in spite of the arbitrariness of this method of estimation, the final conclusions relative to optimal intensity of fishing given in the above work remain true. The reason for this is that a certain degree of underestimation of natural mortality of zanders less than 10 years old, which was involved in the computations, is compensated by overestimation of the mortality among zanders older than 10 years (it was arbitrarily assumed that they all died). At that time I came to the conclusion that the optimal intensity of fishing for Azov zanders might vary within the range 30-40% (depending on circumstances), and that it is determined by many factors: the strength of the year-class, the rate of growth, the food and taste qualities of zanders of different ages, the necessity of fishing other species that are commercially valuable at the same time as the zander, the objectives of a rational utilization of food resources in the sea, and so on.

Strong year-classes of zanders must be fished with greater intensity than less numerous ones, in order to avoid great losses from natural mortality.

In years when rate of increase in weight of zanders is slow, the rate of fishing should be greater than when the rate of growth is rapid. If this is not done the yearly increases in weight (when growth is slow) will not compensate for the loss from natural mortality.

If we have as our objective that of increasing the quality of zanders caught, they should be fished starting in their 3rd or 4th year. Food value and taste qualities of young zanders are better than for old ones. However, this may be achieved only [page 160] by increasing the intensity of fishing and consequently at the cost of some decrease in size of the possible catch.

Sometimes it is necessary to catch zanders with a somewhat greater intensity than would be desirable, in the interests of improving the conditions of fisheries for other fishes (chekhon, shad, taran and others), which are caught at the same time as the zander, for these species of fish are captured by fine-mesh nets in which small zanders become entangled. Finally, a fishery can be considered as rational only when it not merely leads to the greatest possible catch of a given species but if it adequately uses the natural food resources of a body of water.

If food is present in excess and the zander stock is not great, then it is necessary to set aside the goal of obtaining the largest possible catches irrespective of the magnitude of the natural mortality. Rather, when food stocks in a body of water are limited, natural mortality should be kept to a minimum.

Let me illustrate this by an example. When zander fishing starts at age 3, the greatest possible catch of 173,400 centners may be obtained with a fishing intensity of 30%. Losses from natural mortality in this case are very large; they are estimated at 45,300 centners, which amounts to about 20% of the total production (see Table 7).

At the same time with a fishing intensity of 40% the catch would be only 9,600 centners less (163,800 centners), while the loss from natural mortality decreases 26,100 centners and amounts to 19,200 centners or only 10% of the total production. It is clear that in this situation the food will be utilized more economically, but the intensity of fishing will not be optimal or the catch a maximum.

Considering the varied factors that determine optimum catch, it is often difficult to find the correct and individually applicable solution to each case by means of a "hand-made" model, as I have done here. But this goal can be easily achieved by using rapid machine computers.

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Fig. 7. [Page 160] Intensity of removal of age 3 Azov zanders, as a percentage of the total commercial yield of each year-class.

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Table 1. Age composition of the zanders from archeological and other excavations, in numbers. [From data of V. D. Lebedev (1960), and papers cited by him--details in the original].

Location	Time	Materials	Age 3	4	5	6	7	8	9	10	11	12	13	14	Total
Lower Don, balka Krivskaia	End of Tertiary to start of Quat.	Vertebrae	..	..	2	1	...	...	..	..	..	..	..	..	3
Lower and middle Don	Khozarskie strata	Vertebrae and basi-occipital	2	..	7	16	10	10	10	4	3	..	2	1	65
Tanais (Don delta)	II-I BC	Scales, vertebrae	..	..	...	1	2	2	...	1	..	..	..	..	6
Pantikapea (Gulf of Kerch)	IV BC - IV AD	Bones	..	..	...	...	1	...	..	...	1	..	..	..	2
Chumian redant (region of Primorsko-Akhtara, Kuban delta)	II-III AD	Scales	..	5	25	25	5	1	...	...	..	..	..	..	61
	Total, %		1.4	3.6	24.8	31.4	13.2	9.5	7.3	3.6	2.9	..	1.5	0.8	

Table 1 cont'd.....

Table 1 (cont'd)

Location	Time	Materials	Age 3	4	5	6	7	8	9	10	11	12	13	14	Total
Selishch (Desna R.)	III-II BC	Scales	...	...	...	...	1	...	2	..	1	1	..	..	5
Pesochnyi Rov (Desna R.)	II-IV AD	Scales	...	...	...	...	2	...	...	1	..	..	..	..	3
Staraia Ladoga (Volkhov R.)	VII-X AD	Scales, bones	...	3	7	9	7	2	5	2	4	3	4	4	50
Bystrinskov (Desna R.)	VIII-IX AD	Scales	1	11	28	62	63	55	32	26	10	11	5	1	305
Trubchevskoe (Desna R.)	X-XII AD	Scales	...	1	3	2	3	3	1	2	1	..	..	..	16
Staraia Riazan (Oka R.)	XI-XIII AD	Scales	1	...	2	..	5	3	1	..	4	..	..	..	16
Rodonova (Kama R.)	X-XIV AD	Vertebrae	..	..	..	1	2	2	2	..	1	..	..	..	8
Ancient fortress of Grodno (Neman R.)	VIII-XIV AD	Vertebrae	..	..	1	..	2	1	..	..	..	..	..	..	4
	Total, %		0.5	3.7	10.1	18.2	20.9	16.2	10.6	7.6	5.2	3.7	2.2	1.0	

Table 2. Average length at successive ages of fossil and living zanders, cm. [page 149]

Age	Khozarskie strata of the lower Don, Lebedev (1960)	Don zanders 1952-58 (Boiko, 1962)
3	...	40.4
4	...	46.9
5	37.5	53.5
6	43.5	59.8
7	45.0	64.0

Table 3. [Page 150-151] Size composition of zanders from archeological and other excavations.

[This table has not been reproduced in this translation].

Table 4. [Page 153] Natural mortality of the ancient zanders.

Age	Age Composition		Mortality co-efficient, %	
	Number	%	From age composition	From the 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	53	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

Улов и убыль судака (в тыс. шт.) при разной интенсивности промысла (лов с трех лет)

Возраст	Интенсивность промысла, %																																				Естественная смертность после указанного возраста, %
	10				20				30				40				50				60				70				80				90				100				
	запас	улов	остаток	убыль	запас	улов	остаток	убыль	запас	улов	остаток	убыль	запас	улов	остаток	убыль	запас	улов	остаток	убыль	запас	улов	остаток	убыль	запас	улов	остаток	убыль	запас	улов	остаток	убыль	запас	улов	остаток	убыль	запас	улов	остаток	убыль	
3	10000	1000	9000	—	10000	2000	8000	—	10000	3000	7000	—	10000	4000	6000	—	10000	5000	5000	—	10000	6000	4000	—	10000	7000	3000	—	10000	8000	2000	—	10000	9000	1000	—	10000	10000	—	—	—
4	9000	900	8100	—	8000	1600	6400	—	7000	2100	4900	—	6000	2400	3600	—	5000	2500	2500	—	4000	2400	1600	—	3000	2100	900	—	2000	1600	400	—	1000	900	100	—					—
5	8100	810	7290	—	6400	1280	5120	—	4900	1470	3430	—	3600	1440	2160	—	2500	1250	1250	—	1600	960	640	—	900	630	270	—	400	320	80	—	100	90	10	—					—
6	7290	729	6561	787	5120	1024	4096	491	3430	1029	2401	288	2160	864	1296	156	1250	625	625	75	640	384	256	31	270	189	81	10	80	64	16	2	10	9	1	—					12
7	5774	577	5197	1195	3605	721	2884	663	2113	634	1479	340	1140	456	684	157	550	275	275	63	225	135	90	21	71	50	21	5	14	11	3	1	1	1	—	—					23
8	4002	400	3602	1009	2221	444	1777	498	1139	342	797	223	527	211	316	89	212	106	106	30	69	41	28	8	16	11	5	1	2	2											28
9	2593	259	2334	747	1279	256	1023	327	574	172	402	129	227	91	136	44	76	38	38	12	20	12	8	3	4	3	1	1													32
10	1587	159	1428	514	696	139	557	200	273	82	191	69	92	37	55	28	26	13	13	5	5	3	2	1																	36
11	914	91	823	321	357	71	286	111	122	37	85	33	35	14	21	8	8	4	4	2	1	1	—	—																	39
12	502	50	452	190	175	35	140	59	52	16	36	15	13	5	8	3	2	1	1	1																					42
13	262	26	236	106	81	16	65	29	21	6	15	8	5	2	3	1																									45
14	130	13	117	58	36	7	29	14	7	2	5	2	2	1	1	1																									50
15	59	6	53	34	15	3	12	8	3	1	2	1																													65
16	19	2	17	17	4	1	5	5	1	—	—	1																													100
Итого..		5022		4978		7597		2405		8891		1109		9521		479		9812		188		9939		64		9983		17		9997		3		10000		—		10000		—	

Table 5. [Page 155] Catch and mortality of zanders (in thousands of pieces) at different fishing intensities (fishing begins at age 3).

Улов и потери судака (в тыс. *ц*) при разной интенсивности промысла (лов с трех лет)

Возраст	Интенсивность промысла, %																				Средний вес, *кг*
	10		20		30		40		50		60		70		80		90		100		
	улов	потери	улов	потери	улов	потери	улов	потери	улов	потери	улов	потери	улов	потери	улов	потери	улов	потери	улов	потери	
3	10,0	—	20,0	—	30,0	—	40,0	—	50,0	—	60,0	—	70,0	—	80,0	—	90,0	—	100	—	1,0
4	13,5	—	24,0	—	31,5	—	36,0	—	37,5	—	36,0	—	31,5	—	24,0	—	13,5	—			1,5
5	17,8	—	28,2	—	32,3	—	31,7	—	27,5	—	21,1	—	13,9	—	7,0	—	2,0	—			2,2
6	21,1	—	29,7	—	29,8	—	25,1	—	18,1	—	11,1	—	5,5	—	1,9	—	0,3	—			2,9
7	20,2	27,5	25,2	17,2	22,2	10,1	16,0	5,5	9,6	2,6	4,7	1,1	1,7	0,4	0,4	0,1	—				3,5
8	16,0	47,8	17,7	26,5	13,7	13,6	8,4	6,3	4,2	2,5	1,6	0,8	0,4	0,2	0,1	—					4,0
9	10,9	42,4	10,7	20,9	7,2	9,4	3,8	3,7	1,6	1,3	0,5	0,3	0,1	—							4,2
10	7,1	33,6	6,2	14,7	3,7	5.8	1,7	2,0	0,6	0,5	0,1	0,1		—							4,5
11	4,2	23,6	3,3	9,2	1,7	3,2	0,6	0,9	0,2	0,2	—	—									4,6
12	2,5	16,4	1,8	5,7	0,8	1,7	0,3	0,4	0,1	0,1											5,1
13	1,3	9,9	0,8	3,1	0,3	0,8	0,1	0,2	—	0,1											5,2
14	0,7	5,9	0,4	1,6	0,1	0,4	0,1	0,1													5,6
15	0,4	3,5	0,2	0,8	0,1	0,1		0,1													6,0
16	0,1	2,1	0,1	0,5		0,1															6,1
17		1,0		0,3		0,1															6,2
Итого	125,8	213,7	168,3	100,5	173,4	45,3	163,8	19,2	149,4	7,3	135,1	2,3	123,1	0,6	113,4	0,1	105,8	—	100	—	—

Table 6. [Page 156] Catch and natural mortality of zanders (in thousands of centners) at different fishing intensities (fishing begins at age 3).

Улов и потери судака от естественной смертности (в тыс. q) при разной интенсивности промысла (лов с трех, четырех и пяти лет)

Возраст	Интенсивность промысла, %																			
	10		20		30		40		50		60		70		80		90		100	
	улов	потери	улов	потери	улов	потери	улов	потери	улов	потери	улов	потери	улов	потери	улов	потери	улов	потери	улов	потери
Лов с трех лет																				
3	10,0		20,0		30,0		40,0		50,0		60,0		70,0		80,0		90,0		100	
4	13,5		24,0		31,5		36,0		37,5		36,0		31,5		24,0		13,5		—	
5	17,8		28,2		32,3		31,7		27,5		21,1		13,9		7,0		2,0		—	
6	21,1		29,7		29,8		25,1		18,1		11,1		5,5		1,9		0,3		—	
7—10	54,2	151,3	59,8	79,3	46,8	38,0	29,9	17,5	16,0	6,9	6,9	2,3	2,2	0,6	0,5	0,1	—	—	—	—
11—17	9,2	62,4	6,6	21,2	3,0	6,4	1,1	1,7	0,3	0,4	0,0	—	—	—	—	—	—	—	—	—
Итого	125,8	213,7	168,3	100,5	173,4	45,3	163,8	19,2	149,4	7,3	135,1	2,3	123,1	0,6	113,4	0,1	105,8	—	100	—
Лов с четырех лет																				
4	15,0		30,0		45,0		60,0		75,0		90,0		105,0		120,0		135,0		150	
5	19,8		35,2		46,2		52,8		55,0		52,8		46,2		35,2		19,8		—	
6	23,5		37,1		42,6		41,8		36,3		27,8		18,3		9,3		2,6		—	
7—10	60,2	168,0	74,9	99,2	66,8	55,5	49,9	29,1	32,1	13,9	16,7	6,7	7,7	1,9	2,4	0,5	0,3	—	—	—
11—17	10,4	69,3	8,1	26,3	4,4	9,0	1,8	2,7	0,5	0,6	0,3	0,3	—	—	—	—	—	—	—	—
Итого	128,9	237,3	185,3	125,5	205,0	64,5	206,3	31,8	198,9	14,5	187,6	7,0	177,2	1,9	166,9	0,5	157,7	—	150	—
Лов с пяти лет																				
5	22,0		44,0		66,0		88,0		110,0		132,0		154,0		176,0		198,0		220	
6	26,1		46,4		60,9		69,6		72,5		69,6		60,9		46,4		26,1		—	
7—10	67,0	186,8	93,8	123,9	95,3	79,3	82,9	48,3	64,2	27,8	44,0	14,6	25,8	6,8	11,9	2,4	3,0	0,5	—	—
11—17	11,5	77,1	10,1	32,9	7,1	14,1	3,9	5,7	2,1	2,3	0,2	0,3	0,1	0,1	—	—	—	—	—	—
Итого	126,6	263,9	194,3	156,8	229,3	93,4	244,4	54,0	248,8	30,1	245,8	14,9	240,8	6,9	234,3	2,4	227,1	0,5	220	—

Table 7. [Page 157] Catch and natural losses of zanders (in thousands of centners) at different fishing intensities (fishing begins at age 3, age 4 or age 5).

Table 8. [Page 159] Zander losses from natural mortality (percentage of total production) at different fishing intensities (in %) and in relation to the age of first commercial utilization.

	In numbers			By weight		
Fishing intensity	From age 3	From age 4	From age 5	From age 3	From age 4	From age 5
10	50	55	61	63	65	67
20	24	30	38	37	40	45
30	11	16	23	21	26	29
40	5	8	13	11	13	18
50	2	4	7	5	7	11
60	1	2	4	2	4	6
70	0.2	1	2	0.5	1	3
80	0	0.2	1	0.1	0.3	1
90	0	0	0.2	0	0	0.3
100	0	0	0	0	0	0

Note: Production is defined as catch plus natural mortality (in weight).

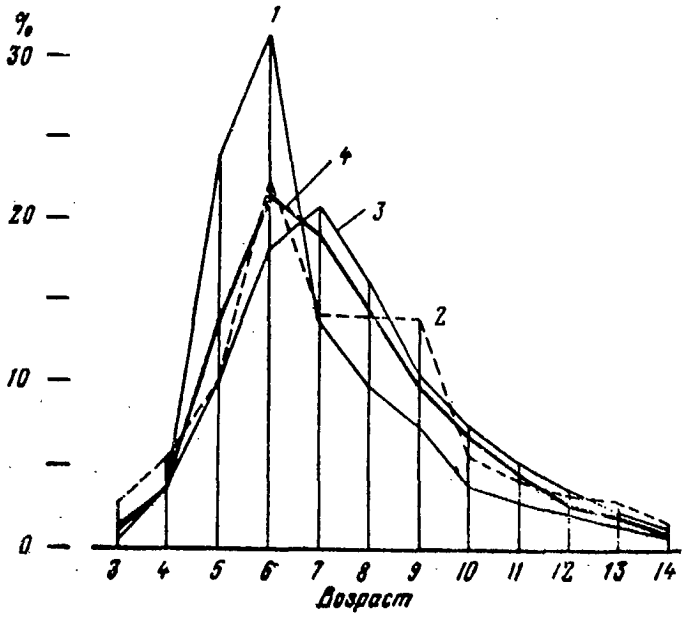

Fig. 1. [Page 147] Age composition of zanders from archeological and other excavations: 1 - Don and Kuban watersheds (137 fish); 2 - Khozarskie strata of the lower Don only (65 fish); 3 - Rivers of the central zone of the European part of the USSR (407 fish); 4 - All paleoichthyological data (combined curve, 554 fish).

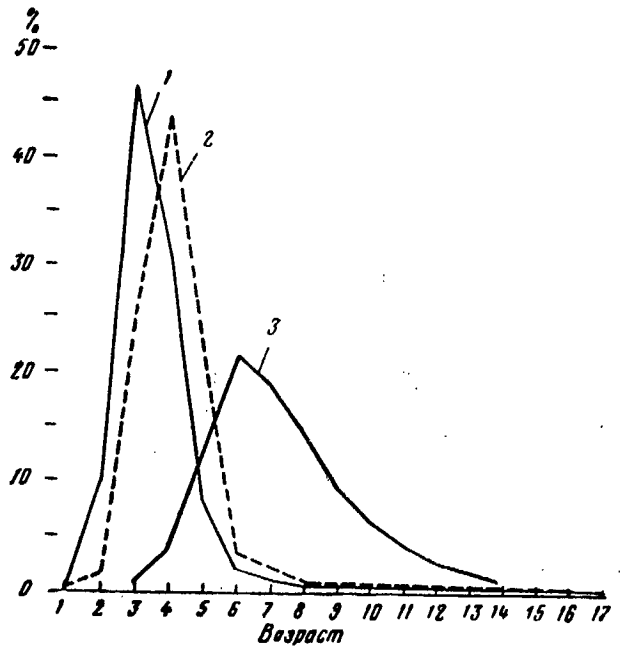

Fig. 2. [Page 148] Age composition of zander stocks: 1 - Commercial catches of Azov zanders in 1951/52 and 1960/61; 2 - the same, in 1939/40 and 1950/51; 3 - Archeological and other excavations, the unfished spawning population.

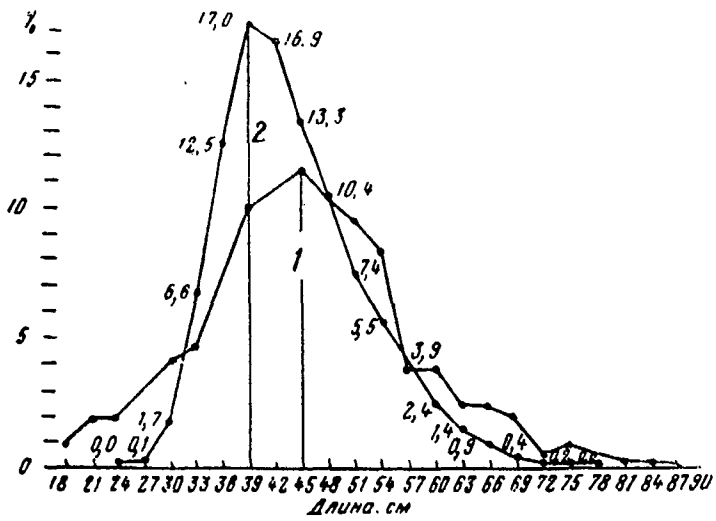

Fig. 3. [Page 149] Size composition of the stock of Azov zanders. 1 - Ancient excavations in the Don and Kuban watersheds (571 fish); 2 - size composition in 1951-1962, weighted to the size of the catches in the various fishing regions (44,000 measurements).

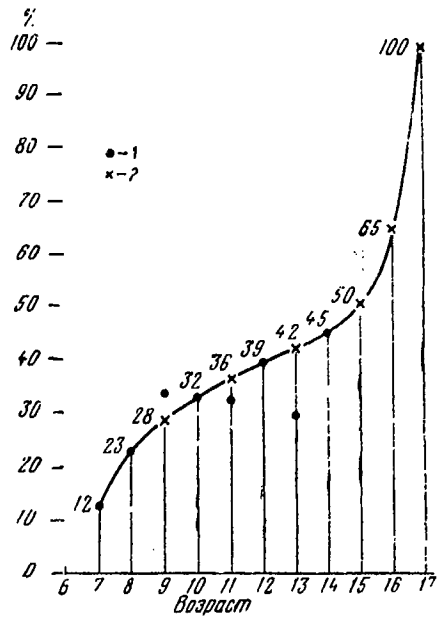

Fig. 4. [Page 152] Natural mortality of zanders from the 7th to 17th year of life, from data on the age composition of ancient zanders. 1 - extrapolated; 2 - interpolated.

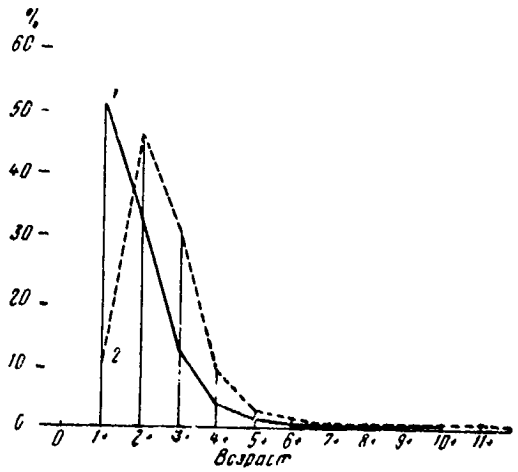

Fig. 5. [Page 154] Age composition of the Azov zanders: 1 - the stock fished in the places where it forages in the sea (catches of experimental trials in October, 1953-1961); 2 - commercial catches for 1951, 1952, 1960 and 1961.

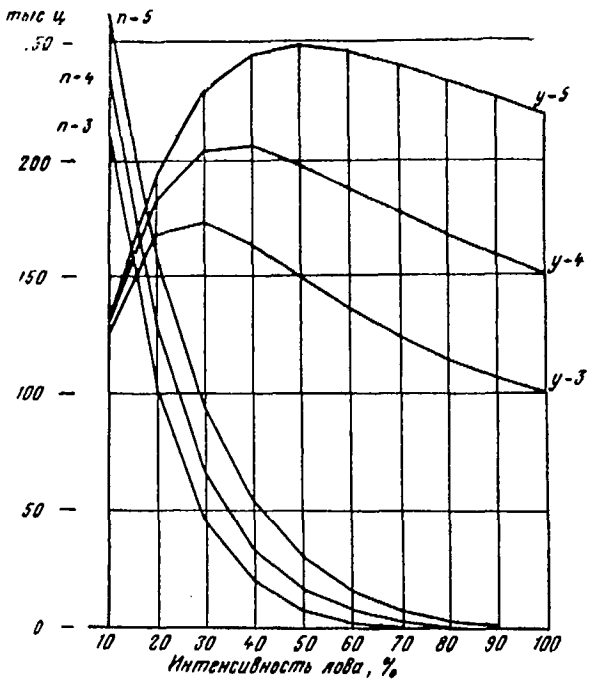

Fig. 6. [Page 158] Natural mortality and catch of Azov zanders at different fishing intensities:
n-3, n-4, n-5 -- natural mortality when fishing begins at ages 3, 4 and 5 respectively;
y-3, y-4, y-5 -- catch when fishing begins at ages 3, 4 and 5 respectively.

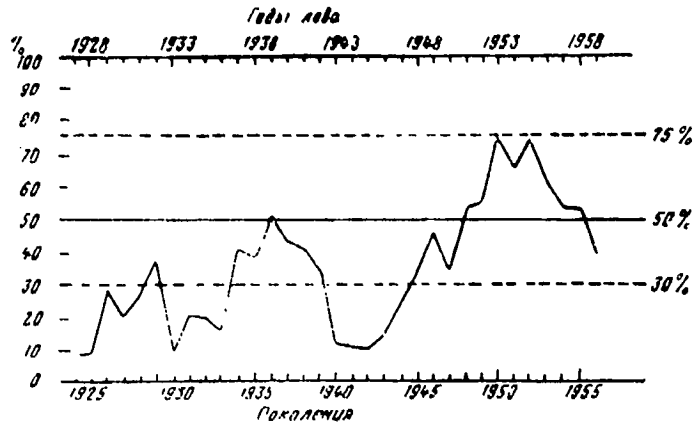

Fig. 7. [Page 160] Intensity of removal of age 3 Azov zanders, as a percentage of the total commercial yield of each year-class.