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THE STOCK OF VOBLA IN THE NORTH CASPIAN SEA, AND METHODS OF ASSESSING IT

By G. N. Monastyrsky

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Translated by W. E. Ricker

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Foreword

This work of Monastyrsky's is being brought to the attention of western fishery biologists principally because of the information it contains concerning the history of the stock of vobla, or rudd, in the Astrakhan region. The biological characteristics of this population, and the economic health of its fishery, have for many years been the subject of heated arguments, which have many interesting parallels closer home. While echoes of the vobla controversy have appeared in the Latin-alphabet area from time to time, no comprehensive review has been available. Monastyrsky's presentation was made following a period of several years' activity in research, by himself and his colleagues, which marks a great advance in knowledge and understanding of the vobla stock. Along with the obvious advantages of close association there comes, of course, some difficulty in maintaining objectivity. Traces of this may appear in places; for example, it is not clear that it is possible to dismiss so easily the evidence, in Table 8, that restricted fishing during civil war years permitted an accumulation of older age groups in the population.

The translation presented will inevitably bear the imprint of imperfect acquaintance with the Russian language, but it is hoped that there are no really serious lapses. Since there is no summary in the original, an abstract has been provided.

Abstract

Methods of estimating fluctuations in numbers and absolute numbers of fishes in large bodies of water are of three general sorts. The first kind of method relates the abundance of fish to the abundance of pelagic eggs, as determined using plankton nets. Used by Hensen and Apstein in the North Sea just before the turn of the century, this procedure has not attracted much attention subsequently.

Methods of the second type are called statistical methods, because they depend primarily upon statistics of catch and fishing effort. C. G. J. Petersen's study of the plaice fishery of the Belt Sea suggested a close relationship between density of stock and the rate of growth of the fish and, more generally, that the abundance of food set a limit to the fish production of the sea. This idea was developed quantitatively by Baranov in 1925. He argued that if an unexploited fish stock is in equilibrium with the production of its food supply, the removal of part of the stock must make surplus food available for new growth over and above what is needed to replace natural losses. In a developed fishery, the catch taken is equivalent to the production from this "surplus" food (i.e., that in excess of what is needed to maintain the current low level of stock), and in this way "a fishery itself creates the production which sustains it". From a comparison of fisheries before and after World War I, Baranov calculated the ratio between the amount of food necessary to produce a unit of stock, and the amount required to sustain a unit for a year; this ratio (y) he estimated as 3 for two fisheries, the North Sea plaice and the Caspian vobla. However, there are numerous objections to this presentation, and for the vobla at least the value of y obtained is quite arbitrary. It is not surprising then that when computations of stock in the vobla fishery are made over a series of years, on the above basis, the catch eventually exceeds the supposed stock!

A statistical method of much less theoretical interest, and no practical value, is that of Morozov, who divided a series of levels of the vobla catch into "stages", using criteria which are largely subjective.

Failure of the statistical methods leaves us with only the biostatistical approach to assessing stocks and making catch predictions. This type of analysis has been developed by a number of students, of whom the more important are mentioned. Derzhavin in 1922 divided the catch of a sturgeon fishery into the ages represented and, considering this to be fixed, computed the total stock present, in a succession of years, which would eventually contribute to the fishery (i.e., omitting those which would die naturally). When this approach was applied to the North Caspian fisheries by local ichthyologists, about 1930, a constant age composition could not be assumed, and yearly information on age composition and size of the individual fish was sought. In this way large individual fish size (at a given age) was associated with a relatively small and relatively young stock, which in turn was associated with relatively severe exploitation. However, the facts fail to substantiate the latter association, and the data suffer to some extent from faulty age determinations.

In Lissner's study of North Sea herring (1930) it appeared that growth and year-class strength were inversely related. However, in determining the fishery in any year, age at maturity plays an important role, since slow growth makes for delayed maturity, and it is largely the mature fish which are vulnerable to fishing. Farran, publishing on an Irish herring stock (also in 1930), estimated survival rate from year to year from the age composition which he observed,

and from it and the catch he computed relative year-class strengths. However, the selectivity of the gill nets used to capture the fish make his analysis questionable. Hodgson in 1932 used a similar approach, but calculated an average rate of decrease for all fully-vulnerable age groups. For catch prediction he used the estimated survival of already-recruited classes, plus an estimate of the most important class of recruits that was derived from a different fishery directed at small fish.

Oskar Sund analysed the Norwegian cod catch on the basis of length, since age analysis seemed impractical, and introduced the method of plotting each year's frequencies as deviations from a long-term mean. Rollefsen, however, not only found it possible to determine cod ages from otoliths, but he distinguished between first-spawners and recidivists. This permitted an improved analysis of the stock along the lines introduced by Farran and Hodgson, and better prediction of the next year's catch.

A similar analysis of the Caspian vobla stock is now possible, since spawning rings have been identified on the scales. The vobla fishery takes place in the sea off river mouths in autumn, and in the rivers in spring; in both places almost all fish caught are those which mature during the current biological year. Recruitment occurs largely during the 3rd and 4th years of life, varying with rate of growth of the year-class in question. Natural mortality is considerable, and affects older fish more severely just after spawning, since the stock returning from spawning grounds is of a younger complexion than that which had ascended. Rate of exploitation cannot be estimated accurately, but it appears to average about 20%, or 30% on a weight basis, for the stock aged II and older. This is to be compared with the 50 to 60% postulated by Baranov.

The vobla catch is about 1,000,000,000 fish per year, on average. Fluctuations in catch are largely the result of fluctuations in stock, which varies in response to favourable or unfavourable water levels at time of reproduction and fry life. Recent decreases in the level of the Caspian have been accompanied by the sharp deterioration in spawning conditions on the Ural and Emba Rivers, but the Volga is not yet much affected. Flood-control measures proposed for the Volga will seriously impair reproduction there.

Introduction

About 50 years ago, in connection with complaints about the decreasing fish catches in the North Sea and the unexplained falling off of certain fisheries, great interest was aroused in the problem of fish populations. It at once became evident that widespread investigations in the sea were necessary. The first attempt to determine the size of a stock of fish was made in 1895 at the time of Hensen and Apstein's expedition in the North Sea, on the basis of a computation of eggs produced. Later, in connection with the development of methods of determining age, especially after the work of Hjort devoted to the problem of fluctuations in the stocks of important species, there were proposed a number of methods of evaluating and enumerating stocks of commercial fishes, based upon an age analysis of the catches. Year by year information on the lives of fishes became more complete, and was put to much use immediately after the end of the world war. A comparison of the results of observations on fisheries before and after the war showed that the decline of fishing in the North Sea occasioned a quick restoration and increase in size of the stock. As a result new hypotheses were formulated concerning the dynamics of a fishery, which were presented first in the works of Petersen and became the basis of the methods of determining the size of stock of fish by the statistical method.

Although catch predictions are intimately associated with studies to determine fish stocks, they began to receive attention only about 10 years later.

The importance of catch predictions is very great. However, the scientific workers whose field of study is close to practical questions commonly shy away from prediction. The reason lies in the inadequacy of our knowledge of the biology of different species of fish, and also in our poor understanding of fluctuations and interrelations among the factors to which govern the lives of fishes most closely.

In the U.S.S.R. predictions have been evolved with a view to verifying accepted approaches to the solution of this question, but not as "directives for practical work" (Baranov, 11). Although catch predictions have attracted the attention of most ichthyologists, some of them have adopted a negative position. For example [page 116], A. Morozov (25) states that "requests for forecasts and prognoses are as yet quite premature since we do not possess the exhaustive data which would permit us to detect the laws which exist among the different factors", and on the basis of this he has suggested that in general we should "refrain from making any kind of prediction". Others have commented in the following manner: "If science cannot predict in advance the yield of grain on a field that is cultivated and sown, how then can it possibly predict the catch of fish that are swimming in the sea?" (27).

Thus in spite of persistent demands which the fishing industry has made of science to develop catch predictions, science has remained distrustful of them.

In the U.S.S.R. catch predictions began to be made first for the vobla of the North Caspian.

Much later came the catch predictions for White Sea herring (Dmitriev, 16), for Kuban zanders (Boĭko, 12), for the Azov bream (Troitsky, 32) and so on.

Over about the same period the question of making catch predictions has been considered in foreign countries, where too they have not yet passed the experimental stage. For example, Lissner (44) believes that attempts at catch prediction are still in the earliest stage of development, but nevertheless that specific examples of incorrect prediction must not lead to abandoning such work, because of its enormous economic importance.

Hodgson (41) expresses a hope for a rapid solution of the question of predictions which, he affirms, will become ever more reliable, just as have the daily weather predictions by radio from meteorological stations.

Among all works on fish stocks and fishing forecasts the work of Hensen and Apstein stands apart because it is based upon an estimate of eggs produced. The remainder, as has been indicated, are based upon catch statistics or on an analysis of growth from the catches. Hence in what follows we will group the studies in that manner, but we will consider only the most important of them, and those which involve the vobla.

We will consider works on fish stocks and catch predictions in sufficient detail to show the more important factors which determine fluctuations in fish populations, and also to show how the method which we propose for the vobla differs from other methods.

The method of estimating fish stocks from the abundance of their eggs

Using data on the fecundity of fishes, mean time of incubation of the eggs, time of spawning, sex ratio, distribution and so on, Hensen and Apstein (38) at the time of the "Expedition to the North Sea" in 1895, made an attempt to compute the stocks of cod, haddock, "river flounder", plaice, Limanda and rosefish on the basis of a quantitative determination of pelagic eggs and larvae.

The estimation of the eggs was done from the second half of February to May, in the manner of plankton investigations. They used nets with sufficiently large meshes (No. 3 bolting silk) that the apparatus had excellent filtering capacity.

The period of egg-laying of the fish mentioned lasts two months and always has a maximum at which time more eggs are produced than at other times. Incubation of the eggs of these fishes lasts 1-2 weeks, depending on temperature. Having made frequent observations of eggs and larvae in the regions studied, and also taking into account [page 117] rate of incubation of the eggs and the effect of temperature on the length of the incubation period, Hensen and Apstein determined the general abundance of the eggs of the different species that were spawned in 1895.

The computation of the total number of eggs was made on the basis of the number per square meter of sea surface. The mean density of cod eggs was 354.8, on the basis of 167 catches. The area of the sea over which they were discovered was 547,623 million square meters.

From these data, and also considering that the mean fecundity of female cod is 4,398,700 eggs, Hensen and Apstein calculated the abundance of spawning females. This number came to 44,172,000. On the basis of the sex ratio, the total abundance of reproducing cod of both sexes was calculated. Hensen and Apstein took the necessary data from published sources. To determine the total abundance of these fish they used information on the quantitative ratio between mature and immature individuals. The fishery provided the necessary material, which, however, had to be adjusted because this ratio varies with time of year, place and method of capture. Hensen and Apstein computed that the total abundance of cod, haddock, plaice, river flounder, Limanda and rosefish was 9816 million individuals, of which 8180 million were immature fish, and 1206 million were mature females.

Apropos of this attempt to estimate these fish, D. Johnston (36) has written that this figure can be regarded only as "a first attempt at a fish census", and he also states that "there is no attempt to determine accurately what part of these fish are caught out by fishermen in the course of a year". Others have noted that the adjustments made by Hensen and Apstein are so great that they many times exceed the original figures (for example, 8180 as compared with 1206 million pieces). In the long run this attempt has not gained acceptance.

Methods based upon catch statistics

Because of the world war, fishing decreased. As a result, there was an increase in the stock of a great many commercial fishes. Changes observed in the fishing industry because of the reduction in fishing led to a series of works, among which most attention has been attracted by one from the Danish scientist Petersen (45). His analysis of the plaice fishery in the Belt Sea before and after the war led him to the following conclusions:

1. Stocks of fish are not unlimited; they are limited by the amount of food in the water.

2. Reduction in the amount of fishing is accompanied by a decrease in rate of growth, and conversely, an intensive fishery acting on a fish population results in rapid growth of the fish as a result of the surplus of food.

3. Increase in intensity of fishing is limited by the economic profitability of the fishery.

4. An intensive fishery, or a restricted one, does not always have the same effects in different bodies of water.

Petersen's views received further development in a series of articles by Professor F. I. Baranov, which were devoted to the theory of the dynamics of the fishing industry. His basic propositions were the following:

1. The density of the fish population in a body of water is determined above all by its food supply; all other natural or historical factors are of importance mainly insofar as they affect the food supply.

2. Food supply (quantity of food produced in a body of water) and all similar factors remain unchanged.

3. [page 118] Change in the intensity of exploitation exerts an influence upon a fish stock.

4. The average size of the pre-war catches was equivalent to the yearly growth of the stock.

In developing his thesis Professor Baranov states that "the production of fish in a body of water is a quantity which can be substantially varied, and it is determined by the surplus food which remains in the body of water, after the requirements of fish living in it to merely maintain their existence have been met. The greater this surplus of food, i.e., the fewer the fish that remain in the water, the greater is the production". Briefly, "a fishery, acting upon a population, itself creates the production by which it is maintained" (5). In general Baranov (9) considers that the size of fish populations and catches is determined by the food production of the body of water and the intensity of fishing. A "crop" of young fish, considered in the sense of a harvestable surplus, has no meaning. In this connection, he gives the following explanation: "Whatever may be the intensity of the fishing (for practical purposes), there can be no question of over-fishing in the biological sense of that term", and he says that "the expedient limit of exploitation is determined almost wholly by economic considerations" (4).

An analysis of the statistics of the vobla catch of the North Caspian led Baranov to the conclusion that "to maintain the existence of a given quantity of fish for a year requires three times less food than would the production (growth) of the same quantity" (5). Proceeding from this position, and on the basis of an equality between mean pre-war catch size and the yearly growth of the stock, Baranov calculates the stock of vobla and makes predictions.

Assuming that the stock of vobla in pre-war times was in a state of equilibrium, and that consequently it was being recruited at the same rate as it lost fish to the fishery, Baranov postulated that with a mean pre-war catch of 150,000 metric tons the stock of vobla was 300,000 tons. This latter figure was used by him for calculating the stock after 1917 (11). The catch in the autumn of 1917 and spring of 1918, that is for the "fishery and biological" year, amounted in all to 114,000 tons. From this he determined by the subtraction 300,000 - 114,000 that the "remainder" in the stock of 1918 was 186,000 tons. The size of this remainder was 36,000 tons greater than in the base period prior to the war. These excess 36,000 tons, according to Baranov, require for their maintenance a quantity of food which could <u>produce</u> $\frac{1}{3} \cdot 36 = 12{,}000$ tons of fish. Consequently the production of the stock was 12,000 tons less, i.e., it was 150 - 12 = 138,000 tons. Hence in the autumn of 1918 the stock was determined as 186 + 138 = 324,000 tons. In the same manner the computation of the stock for all later years up to 1931 was followed through. To illustrate it, we print in abbreviated form Baranov's (11) table (Table 1).

From the table it is evident that the stock of vobla at first increased (up to 1922-23), and then gradually decreased and in 1931-32 reached 287,000 tons, that is almost the same as before the war. The dynamics of the residual stock showed a similar picture: however, production (growth) changed in an inverse manner, reaching a minimum in 1920-21, and in 1930-31 it became greater than in pre-war years. Thus the best years for size of vobla stock were 1920-23, and in 1930-31 the stock differed very little from the pre-war stock.

The table presented was compiled by Baranov following his revised presentation based upon statistical material compiled by him. He explains that earlier he had used catch data from the Astrakhan Ichthyological Laboratory, which proved to be too low. The table he used was made up [page 119] by considering corrections to the catch statistics made by L. I. Gurvich (13) in "A review of the fishing industry". Here the mean pre-war catch is taken by Baranov to be 150,000 tons instead of the 125,000 tons which he had used as a base in his earlier computations (5, 6, 8, 10).

In spite of this larger figure, it ultimately turns out that a year's catch is greater than the stock calculated by Baranov (see Table 2). This circumstance has evoked serious thought concerning the suitability of the proposed method of estimating a fish stock from catch statistics.

Following publication of Professor Baranov's theory (3), several biologists made sharp criticisms of it. Among them we may mention Professor N. M. Knipovich (18) and S. V. Averintsev (1).

Since we will not be able to give a review of the criticisms of his theory, we will try to make an evaluation of the method used by Baranov in determining the size of a fish population and in predicting the catch.

For reasons given above, Professor Baranov uses the formula:

$$B_1 + yb_1 = B$$

showing the relationship between annual catch b_1, the basic stock B_1, and the original natural stock of fish B.

To determine the coefficient y, Professor Baranov solves the two equations:

$$B_1 + yb_1 = B$$

$$B_2 + yb_2 = B$$

whence

$$y = \frac{B_2 - B_1}{b_1 - b_2}$$

For the Astrakhan region he finds that B = 100 million poods, and y = 3. [1 pood = 16 kg.]

It is evident that the size of the coefficient varies with the size of $b_1 - b_2$, since catch is continually changing; B_1 also varies in magnitude, and this in its turn makes for change in y.

In this connection, we must point out a contradiction in Professor Baranov's reasoning when he establishes the relation between basic stock, catch, and intensity of exploitation on the basis of a stabilized fishery. For example, he writes: "Let us postulate that...a fishery, which gives each year the same yield, is present in a body of water which is in a state of equilibrium (3, page 8). But in the same paper he remarks: "the fishery has never been in a state of complete stabilization, neither in post-war years nor yet before the war" (op. cit.). Consequently we can have an unlimited number of combinations B_1 and B_2, and b_1 and b_2; therefore the value of "y" will vary without limit and can even become indeterminable. For example, the situation $b_1 = b_2$ is quite possible. Hence the coefficient y = 3 obtained by Baranov (for the Astrakhan region) is nothing more than an accidental magnitude and it is impossible to use it in computations.

This point is graphically illustrated in the table below, showing the dynamics of the catches and stocks of vobla computed by us using Baranov's method, on the basis of the latest, most nearly accurate data of the Volga-Caspian Fishery Research Station (Table 2).

The data of this table differ from those of Table 1. Here there is no residual stock of fish left in the autumn of 1931, since the catch in 1930-31 was greater than the autumn stock of 1930!

This shows first of all that the picture which Baranov has drawn of the vobla stock and its fishery does not correspond to reality. In his presentation, it took about ten years for the stock of vobla to increase by approximately 50 per cent over the pre-war period (425,000 tons as compared with 300,000), and afterward it took as much time again to get the stock back to the pre-war level. According to Baranov, the processes of recruitment and mortality of the stock take place very slowly, with insignificant fluctuations. This can scarcely be true of the vobla.

Baranov presented his approach to catch predictions as follows: "The size of a catch is determined by two factors:

1) the size [page 121] of the stock of fish present;
2) the percentage of exploitation, which depends upon the quantity and distribution of all the fishing apparatus and also upon the external conditions prevailing along the course of migration" (6).

He acknowledges that a certain arbitrariness lies at the basis of predictions of the size of the catch, because of "the impossibility of determining in advance the intensity of exploitation, which is affected by external conditions along the course of migration" (7).

Some of the predictions which he published proved accurate, and might be explained as accidental conformity. On the whole, however, his predictions proved unreliable (11).

What then was Professor Baranov's mistake? A partial answer to this question has been given above. It is now necessary to treat his data from the biological point of view. To this end we will consider in Table 1 the "Remainder" and the "Increase" of the stock. By Remainder, Baranov means simply the difference between the size of the stock and the catch of fish in a year (the "fishery" year). It is obvious that such a concept is an extremely simplified one, not only in the case of fish which die off completely on the spawning grounds (for example the chum and pink salmons, the blackspined and Volga shads), but also in the case of the vobla. It is impossible to ignore the phenomenon of death of vobla from natural causes. Furthermore it is impossible to assume that in the stock fished in autumn there is to be found the whole of the vobla left alive after spawning; apparently a part of the vobla do not spawn every year, as is true also of the stellate sturgeon and some other fishes.

Thus the Remainder of the stock is the aggregate of individuals of different age categories whose abundance depends partly upon the catch and natural mortality of the fish, partly upon the number of fish that are becoming ready for another spawning. The Remainder of the stock in Baranov's sense does not correspond to this description, but is an abstract concept devoid of any kind of biological content and possessing no particular characteristics. For example, according to Baranov the Remainder does not grow, since the Increase constitutes a separate part of the stock.

Considering the column of figures (Table 1) headed "Increase", we see that they vary inversely with the stock, but vary directly with, and almost parallel to, the yearly percentage removal. It follows that the greater the Remainder of a stock of fish, the less is its Increase, and vice versa. This proposition can be regarded as generally acknowledged. However, in this case, it is not applicable, since the variations in Increase depend not only on the rate of exploitation, but also on the recruitment to the stock.

By "Increase" of the stock of vobla Baranov means the quantity which we calculated above from the equation:

$$150 - \frac{\text{Remainder of the stock} - 150}{3} = \text{Increase}$$

where 150 is the mean pre-war catch of vobla in thousands of tons and 3 is the coefficient described earlier. From the equation it is evident that with an increase in the Remainder of the stock the Increase will become smaller, and conversely a smaller Remainder makes for a large Increase. If we consider fishes which are subject to complete reproductive mortality (chum and pink salmons, blackspined shad, etc.), then in their case the Remainder must be practically zero, and this would mean that among such fishes Increase is constant from year to year - a situation which never occurs in nature.

By "Increase" we understand, on the one hand, recruitment to the stock of that part of the population which has not yet taken part in spawning, and on the other hand the ordinary increase of the remainder of the stock because of growth in length and weight of its component individuals.

The determination of the component parts of Increase is completely impossible. Professor Baranov does not do it. The fact is that even if intensity of exploitation has had a direct [page 122] effect upon the part of the population already subjected to fishing, yet it cannot play any significant role in determining the number of new recruits to the population, particularly in the absence of a special fishery for fish which have not yet achieved sexual maturity. And, as a matter of fact, for the vobla which Baranov uses as an example, there is no indication of a special fishery for immature fish.

What might be the Increase of a stock resulting from the growth of its component individuals? There is only extremely fragmentary information on this question in the literature. For example, according to V. R. Aleev (2) in one summer a marked salmon that was reaching sexual maturity increased in weight to more than two times (to 2.17 times). From the data of the Volga-Caspian Fisheries Station (34), for an increase of 1 centimeter in the length of the basic age-groups of vobla, the increase of the stock under the action of an intensive fishery is 15-18 per cent. As for the increase in a stock as a result of recruitment, much interest can be attached to the opinion of Lissner (44), who considers that "a very good generation may be three times larger than a poor one".

The whole of the literature concerned with fluctuations shows how overwhelming an influence a new generation and its peculiarities can have upon a stock. This Baranov does not take into account; on the contrary he minimizes the significance of the young, which in his opinion are always present in excess.

From the above it is obvious that intensity of exploitation cannot change in proportion to changes in Increase of the stock. Therefore, the percentage removals calculated by Baranov must also differ from the true ones.

Thus Baranov makes the following basic errors:

1) he fails to give the influence of fluctuations their due effect;

2) he confounds the effects of growth and renewal of stock;

3) he does not ascribe any importance to mortality from natural causes;

4) he operates with a Remainder which is the difference between stock and catch, forgetting that the Remainder consists of fish which remain alive after spawning, and among them, only of those which will be spawning again the following year;

5) in general he gives no attention to biological factors which influence a stock of fish.

It is obvious that if we are given an incorrect estimate of a fish stock, then there will be an element of error in any prediction. Nevertheless Baranov (8) considers his predictions as "one of the links in a chain of logic", and that his "calculations, with inexorable logic, impel us to predict (definitely - G. M.) the size of the impending catch" (op. cit.).

The path followed by Baranov toward predictions, on the basis of determination of fish stocks and intensity of exploitation, is a formal one. Actually, knowing the size of the stock would be quite insufficient if we still had to guess at some particular value for the rate of exploitation in order to determine the forthcoming catch. For example, it is possible to imagine two cases when stock and intensity of exploitation are the same, but the result will be different. There might also be such a combination as when with the same intensity of fishing, but with different sizes of stock, the catches will be the same, and so on.

The size of a catch is determined by numerous conditions, among which the most important are:

1) the size of the stock;

2) its age, size and sex composition;

3) the density of the population;

4) peculiarities of the path of migration;

5) the intensity of fishing (quantity and kind of nets, their distribution, etc.).

Therefore, even if we know exactly the size of the fish stock, yet, if we set ourselves the problem of determining the intensity of exploitation, as Baranov does, we are doomed to failure before we start.

In summary, we must regard Professor Baranov's attempt as too simple and not in accordance with the requirements necessary for catch predictions.

[page 123] In view of the great commercial importance of the vobla, it is necessary to consider the attempt made by A. V. Morozov to estimate the status of its stock on the basis of a comparison of statistical data.

Morozov (23) states that it is possible to "approach the question of the status of fish stocks by way of a comparison of the intensity of the fishery and the quantity of fish caught" (page 54), and that sometimes "a comparison of the intensity of the fishery with the quantity of fish caught deserves the most careful attention", because "there is already a sufficiently rich literature concerning other attempts, and they have to a large degree been sterile" (page 54).

In Morozov's opinion, in the Volga-Caspian region the number of "licences issued for fishing in the marine waters of the Volga-Caspian region" can be used as a measure of the intensity of the fishery. Data on the number of fishing licences, and hence the number of fishermen, he takes from K. A. Kiselevich[1] for the period from 1868 to 1915 and from the Volga-Caspian Fisheries Research Station from 1923 to 1929. "For the period of time from 1915 to 1923", writes the author, "unfortunately there are no data, and for that interval it is impossible to determine the exact number of fishermen. The number of fishermen during this time has been estimated by us very approximately from the dynamics of the resulting fishery" (page 54). Considering the different origins of his figures, however, Morozov observes that "their comparative sizes, without any doubt, will indicate the dynamics of the industry and its degree of intensity" (page 55).

The table he compiled showing the yearly number of sea fishermen (in thousands) from 1890 to 1930 is shown (Table 3).

We print also Morozov's table containing data on the catches of vobla (in millions of centners)[2] with which he compared the number of fishermen (Table 4). [1 USSR centner = 100 kg.)

[page 124] From the numerical material presented Morozov draws a diagram to show the relation of catch to number of fishermen or, as he puts it, to the "coefficient of intensity" (Fig. 1).

In his explanation of the graph, Morozov dwells upon the following points:

1) "the points group themselves along the following loci (ochagi[3])";
2) there are five such loci (A, Б, В, Г and Д);
3) "the points in each locus are distributed along a curved line, approximately of the character of logistic curve";
4) the catches of each locus stand in direct relation to the intensity of the fishery.

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[1]K. A. Kiselevich, Kaspiisko-volzhskie seldi, ch. III, "Promysel", 1918.

[2]The figures were taken by him from the article by K. Kiselevich: On the fat resources of the Volga-Caspian fishery, "Nizhnee Povolzhye" No. 7, 1930.

[3]In another place (page 5a), Morozov calls these loci stages (stadii), but what they represent biologically is not made clear.

To explain what the loci represent the author divides the time from 1898 to 1930 into nine periods of 2-5 years each. The results of this division are shown in Table 5 (see also his figure in reference 23).

[page 125] Although Morozov comes to the conclusion that there is no direct relationship between number of fishermen and catches, he considers that this relationship exists "within the limits of each stage of the composition of the stock", "up to the point when the increasing intensity reaches its critical limit (which is different for each stage of the stock composition)"; hence each of the nine periods gets a specific interpretation. As an illustration we will cite a part of his work. Morozov writes ..."from 1908 to 1911 we observe a further increase in the intensity of the fishery up to 16.4 and parallel with this an important increase in catch (to 1.49 million centners). But we must not think that this increase in catch is the result of the increased intensity of exploitation, because a further increase of intensity in the fourth period, up to 20.6, does not give the expected effect and leads again to a mean catch of about one million centners. The increased mean removal of the third period, reaching one million centners, is to be explained not by the intensity of the fishery leading to increased catches of fish of normal commercial size, but by shifting of the center of gravity to the removal of small fish. This immoderate and artificial increase of the catch in 1908 and 1909 by means of small under-sized individuals gave such a shock to the vobla stock in 1910 and 1911 that it shifted again from stage B to stage Г, where it had previously been at the time of the second period ...."

"Excessive removal of small fish in 1908, 1909 and 1910 attracted the attention of the authorities in charge, and in 1911 the well-known "Law of May 9, 1911" was proclaimed, which established a minimum size limit for vobla and prohibited the catching and processing of undersized fish" (page 59).

Morozov points out further that "temporarily the adoption of a size limit led to an improvement in the vobla stock, and we see that in spite of the sharply increasing intensification of the fishery which took place during the fourth period (from 1912 to 1914), the condition of the stock, which prior to that time had descended to a very low level, did not deteriorate much but remained stable" (page 59). Later on, in spite of a decrease in intensity "the catch of vobla in 1915, 1916 and 1917 increased markedly (from 0.84 to 1.61 million centners)". This increase of catch Morozov ascribes to an improvement in the stock "under the influence of the law limiting size, acting over the course of three years". "During this period of time", he explains, "the vobla of commercial size were able to accumulate, which was reflected in an increase in catch". According to Morozov the increase in catch of 1915-18 was caused by the fact that "the stock shifted from stage Д to stage Б, skipping stages Г and B" (page 60).

Let us cite one more of Morozov's explanations: "The increase in intensity of fishing which occurred in the following years (1922-25) did not disturb the condition of the vobla stock; it continued to remain in the same stage, and only the great catch of 1925 (1.7 million centners) forced it to shift to the new stage B. In this stage (the stage of the pre-war level of 1898-1902) the stock remained up to 1930. If the data of the 1931 catch show us that the vobla stock is still in stage B, the maximum possible catch will be about three million centners. But this, apparently, is the limiting boundary of the level which might be attained by an intense fishing effort. Judging by the regular periodicity of the catch fluctuations (3-4 years of large catches, 3-4 years of lower catches), on the other hand, we must unfortunately consider that in the next three or four years there will be a decrease in the stock" (page 60).

For a broader verification of the results of his comparisons, Morozov joins them with a biological analysis of materials [page 126] showing the mean size of the fish in the catch, which were available only for 1919-1930. The essential part of this analysis is the discovery of a change in mean age under the influence of the fishery. Also very important is the admission by Morozov of the absence of information on the number of fishermen over the period from 1915 to 1923.

In summary, we believe that Morozov presents the following points of view:

1) the stock of fish is regulated by the intensity of the fishery, or in other words, the intensity of the fishery determines the shifting of the stock from one state to another;

2) changes in the stock are also possible by setting a size limit for the small fish;

3) the age composition changes under the influence of the fishery.

Passing over the incorrect interpretation made by Morozov of the significance of the intensity of the fishery, which has already been discussed in a note to the editor of the Bulletin of the Caspian Expedition (see No. 1-2 for 1932, page 54), and also neglecting the erroneousness of his interpretation of the role of the "Law of May 9, 1911" and all his other explanations relative to the dynamics of the vobla fishery, which by themselves lack any foundation, we will try to analyze only the nature of the approach which he used.

First of all, it is necessary to say a few words about the nature of the numerical material which the author uses. The number of fishermen is a quantity which is not only variable, but as between different years it is entirely non-comparable. Therefore changes in the number of fishermen, without introducing corrections for their qualifications, methods of fishing and so on, tell nothing if we are trying to use data on number of fishermen in the manner that Morozov does. The picture of the dynamics of the number of fishermen which he presents is incorrect because he does not take into consideration the river fishermen and does not consider the different changes in the organization of the fishing industry in his various periods. For example, in the Guryev region, where before 1930 there had occurred a shift of the fishery to the sea, in that year, as in earlier times, the catching of fish again took place mainly in the Ural River. The sea was only partly familiar to the newly-arrived fishermen. If we consider also the circumstance that the number of fishing licences has depended upon the inspector of the district, the use of Morozov's index based on number of fishermen is hopeless.

The question of the number of fishermen is a difficult one, therefore we believe that the dynamics of the amount of fishing, as presented by Morozov, has no foundation.

With reference to size of the catches, in particular the catches of vobla in earlier years, there is no general agreement (Gurvich, 13). However, even considering all the uncertainties in Morozov's determination of the size of the vobla catches (especially in the earlier years), we can assume that a catch trend of the type which he has presented does not deviate seriously from the truth. Nevertheless it is necessary to point out these facts:

1) every catch figure applies to a calendar year and also represents the sum of catches in the river and in the sea;

2) there are no early statistics for the Ural River.

Inasmuch as Morozov has found a relation between catch of vobla in the whole Caspian and number of sea fishermen (within the boundaries of the Volga-Caspian region), it will be interesting to cite the relationship between river and sea catches, which unfortunately can be done only for recent years. In the period 1927-1931 the river provided 32-41 per cent of the yearly catch of vobla. Earlier the river had held first place (Gurvich, 13), and this was not only after the early development of the <u>chernev</u> fishery in the 90's of the 18th century, but also during almost the whole of the period up to 1914.[page 127]. Therefore the mixing of the sea and river catches is a methodological error. But a still graver error is the utilization of catches for the calendar year. The facts are that the schools of mature vobla on which the fishery operates are formed in autumn, and cease to exist in spring, after spawning. Consequently, if the catch is considered to reflect the size of the stock, there is no basis for using data of a calendar year.

Lacking as they do any biological basis, Morozov's comparisons and judgments concerning the stocks are only speculations based on mathematical quantities. It is not hard to be convinced of this from consideration of Morozov's five stages for the composition of the stock. In his opinion each stage (A, Б, B, Г and Д) is characterized by the fact that its catches are distributed along a logistic-type curve, peculiar to the stage in question. However, suppose that over the course of a long series of years the number of fishermen does not vary significantly, then the results of a comparison of their number with the catch is represented graphically by means of points scattered in a manner similar to those we have shown in Morozov's graph for the interval 12-18 thousand fishermen (see Fig. 1). It appears that this interval embraces 19 observations and the other intervals contain 14 observations. But since the conditions of the stocks A and Б belong to a period (from 1915 to 1923) relative to which, according to Morozov, there is no information on the number of fishermen, and he has estimated them on the basis of "the dynamics of the resulting fishery" (see p. 54), then, deleting these eight cases as not based on any factual material, we have, out of the total of 14, only 6 cases: 3 for the condition of the stock in stage A and 3 in stage Д . Stage Б disappears; however, we also observe that stages B and Г do not exist separately but constitute the one field of scattered points about which we spoke earlier.

Let us suppose that within the limits of a locus, or for a given condition of the stock (for example, in stage B), the catches are really distributed along a curve which according to Morozov is of the logistic type. Insofar as we have such a curve, we must come to the conclusion that the condition which it represents can be represented by a mathematical law, i.e., the stock is fished under fixed conditions, and no recruitment to it occurs while fishing is in progress. It is quite apparent that in such event a catch must without fail have the appearance of a differential curve with a maximum. But then we are led to the conclusion: <u>a maximum of catch corresponds to some intermediate number of fishermen, between the limits of the extreme figures.</u> Consequently up to a pre-determined moment an increase in number of fishermen is accompanied by an increase in catch, and then with further increase in number of fishermen there occurs a decrease in catch. However, the logistic curve in Morozov's figure (see Fig. 1) has as its ordinate the size of the catch, as a consequence of which it loses all the meaning ascribed to it by Morozov. Equally groundless is his hypothesis of a shifting from one condition to another as a result of changes in the intensity of the fishery, or in other words, of jumping from one logistic curve to another. Such shifts seem impossible. Because he ascribes fundamental significance to the intensity of fishing as a factor determining the condition of the stock, Morozov only superficially touches on the questions of recruitment to the stock and the evaluation of the strength of the year-classes which comprise the commercial concentrations. Yet these factors are of the greatest importance, since the commercial concentrations or the commercial stock depend upon them.

On recruitment the fishery has no effect, because the recruits consist of fish which are attaining maturity for the first time. On the other hand, at the present time there is no clear indication concerning whether the size of the Remainder depends upon the action of the fishery or [page 128] upon natural deaths, and also concerning whether or not the fishery is a complete substitute for deaths from natural causes. Nevertheless, we are inclined to believe that the fishery does not exert so decisive an influence on the size of the Remainder as to result in a change in the size of the stock. The size of the stock is determined by biological factors.

From this point of view the connection postulated by Morozov between the mean age of the fish in the catch and the intensity of the fishery has no adequate basis, the more so as the information on size composition between 1919 and 1930 corresponds partly to the period in which information on number of fishermen is lacking, however, Morozov got such information "from data on the resulting fishery" (24). In passing, we must point out that in another of his works Morozov (26) casts doubt upon the data of the Volga-Caspian Fisheries Research Station concerning the age composition of the catches, although in practice he uses them. Therefore, it is no wonder that he observes "a convergence of two different paths to one and the same point" (p. 62). In spite of Morozov's affirmation that is "analysis of the condition of the North Caspian vobla stock is close to the truth", we permit ourselves the following observations:

1. There is no relation (neither direct nor, still less, anything of a logistic type) between the number of fishermen, which Morozov identifies with the intensity of the fishery, and the catch.
2. The basic assumption of Morozov concerning the shifting of the stock of vobla from one "condition" to another under the influence of the intensity of the fishery will not stand up to criticism.
3. Any single factor, such as deaths from fishing, or, in few words, any single statistic from the catches, is a poor basis for judging the condition of a fish stock, and is even worse for developing catch predictions.

Biostatistical methods

The biostatistical analysis of catches is the basic method for estimating stocks and for making catch predictions. Hjort (39,40) pointed out its great importance in the course of his studies of the cod fishery. He showed that one of the causes of changes in catch is fluctuations in year-class strength.[1] This view has been repeated by a large number of investigators, and recently it has been presented in articles and works devoted to the prediction of catches.

A. N. Derzhavin (15) was among the first to use age analysis of the catch to determine the size of a fish stock. He thought that the question of a quantitative determination of a stock subjected to continuous exploitation could be solved with fair accuracy. For this purpose the following information was necessary:

1) statistics of the catch over a series of years equal to the life cycle of the fish;

2) knowledge of the age composition of the catch;

3) the assumption that this composition has remained constant over the period under review.

By <u>size of a fish stock</u> Derzhavin means the sum of "a series of year-classes, equal in number to the maximum age attained by the fish, the abundance of each brood in a given year being estimated by adding up the total of all which are later taken by the fishery". This means that an estimate of the abundance of each year-class can be obtained by adding up the portions of it which appear in the catch in all the years following its first appearance in the fishery. However, at the start of any year the stock of fish consists partly of the catch of all age groups which will be made that year, partly of all the remainders of these broods, which will be present in future years, and partly of the broods which are too young to be taken by the fishery.

[page 129] "If", writes Derzhavin, "we represent by R_n the stock of fish at the start of year n, the maximum age of the fish in years by z, the catch of a series of years by P_n, P_{n+1}, P_{n+2}.........., the percentage composition of the recruits in the catch by x, of those a year in the fishery by x_1, those two years in the fishery by x_2, ..., then the formula which defines the unknown quantity R_n can be expressed by the following equation:

$$R_n = (1 - x)P_n + (1 - x - x_1)P_{n+1} + (1 - x - x_1 - x_2)P_{n+2} + \dots\dots\dots + (1 - x - x_1 - x_2 - \dots\dots\dots - x_{z-1})P_{n+z-1}\text{"}.$$

Here P_n[2], P_{n+1}, P_{n+2} ....P_{n+z-1} are the size of each year-class of fish taken by the fishery over the period during which each separate brood is present in the fishery, and x, x_1, x_2, ... x_{z-1}, are the relative average sizes of the age groups in the catch as determined from observations over a series of years. Since the youngest age groups of the population are not always vulnerable, x, x_1 and even higher members of the series can be equal to zero.

Derzhavin makes some very significant reservations in presenting the three propositions above. In the first place, he shows that the assumption of constancy of age composition of the catch "is not likely to be free from error, and in fact is contradicted by the observed fact of quantitative changes in fish stocks". But he considers it possible to introduce appropriate corrections by means of periodic observations on changes in age composition. In the second

[1]The predominance in the catches, for a series of years, of individuals belonging to an abundant brood.

[2]The quantity P is the number of individuals.

place, Derzhavin considers that because of the impossibility of taking into account "the number of fish which die a natural death from old age or epizootics, and also those consumed by aquatic predators", the figures which he obtains "give a picture only of the stock of fish actually used by the fishery sooner or later, and not of the whole body of individuals which are alive at a given time" (p. 14). Relative to such a determination of the stock on which a fishery can depend, Derzhavin says that it "has obvious importance commercially and, on the other hand, is a step toward knowledge of the quantitative aspects of life in the water" (ibid.).

From the above it appears that Derzhavin attempts to assess the whole body of fish of successive broods, with the exception of that part which dies from natural causes. His computation is based on the assumption of a steady intensity of the fishery, since with a weak fishery there would be no justification for applying this method. Another very important condition is the completeness of the catch statistics for the fishery in question. Obviously the principal characteristic of the method is its dependence upon data obtained from the fishery.

Returning to the formula, we must observe that each of its terms really corresponds to an ordinate of a mortality curve for the fish population. For such curves it is known that it is not usual for the whole population of a species to be fished, but only the mature portion of it, principally in the period of spawning migration. This part of the population used by the fishery is characterized by the fact that the abundance of the younger age groups gradually increases to a maximum, and then the abundance of older age groups gradually falls off until they disappear. Such a rise and fall is explicable as the resultant of two opposed processes - recruitment and mortality. We note that recruitment takes place as a result of certain broods releasing the portion of their members among whom the sexual products are first reaching maturity. But the youngest age groups play a very insignificant role in the commercial schools, because the number of individuals first reaching maturity is small in relation to the whole age group. In this connection the coefficients $1-x$, $1-x-x_1$, and so on, which must be called <u>coefficients of decrease</u>, indicate an unrepresentatively small amount of decrease for the younger mature fish.

[page 130] From the above it follows that the age composition of the schools used by the fishery may not correspond to the age composition of the whole body of fish. Therefore the attempt by V. Borishchev (27a, pp. 41-53) to compute the stock of vobla using Derzhavin's formula leads to an obvious incongruity. He estimates the entire number of mature and immature vobla which have reached their third summer of life or more; but the fishery, as is well known, is based upon the capture of mature fish[1] almost entirely.

It is evident that the above-mentioned defect of this method precludes the possibility of using it from a practical point of view.

At about the same time [as the above] a method of estimating fish stocks was developed at the Astrakhan Ichthyological Laboratory. We present an account of it based upon a study of materials presented at the Second Conference of Fishery Research Stations and Laboratories working on the Caspian Sea, which was held in 1929 in the city of Makhach-Kala (28).

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[1]The catch of immature vobla varies from year to year within the limits 2-10.5%.

Since there are, at the current level of scientific knowledge, no methods for exact quantitative (piece by piece) enumeration of stocks of fish in the sea, it was proposed at the Conference "to estimate stocks in terms of a series of relative indices, referred to pre-war conditions which could be regarded as normal". The basic idea in this was the consideration that, excluding the effects of accidental variable factors, the annual catches from a constant fishery reflect the composition of the stock.

From the above was drawn up the following list of materials needed to estimate the status of a fish stock: 1) statistical information on the catch; 2) data on the mean length and weight of the fish; 3) information on age composition of the catch and the mean length of each age group.

A comparison of the yearly stocks of North Caspian commercial fish one with another, and also with the corresponding mean abundance, showed that "if in the period of decline in catch from the effect of a contracting fishery the fish stocks increased as a result of the accumulation of larger fish of the older age groups, then in recent years (to 1929, G. M.), with increasing intensity of fishing, the results of that fall have been almost liquidated, and the fish stocks have again approached the pre-war norm" (p. 52).

A more graphic picture is given by a comparison of the age composition of the stock for a series of years with the mean length of the corresponding age groups. Data on the vobla were used for this, shown in Tables 6 and 7.

[page 131] Consideration of these tables leads to the conclusion that an increase in the older age groups is accompanied by a decrease in the mean length of every age group, which apparently is the result of the "overpopulation" of the body of water (p. 53).

This method of evaluating the status of a fish stock received much application in the works of the Caspian Scientific Fisheries Expedition of 1931-33. For example, conclusions were arrived at concerning the stocks of fish studied by the Expedition, on the basis of whether accumulation of the older age groups in the catch did or did not take place. If there was observed a decrease in percentage of the older age groups and an increase in percentage of the younger ones, it was concluded that the stock was in a strained condition, that it was being intensively exploited, that an increase in catch could not be anticipated, and so on. If, however, an increase in the percentage of the older ages in the catch was observed, then the stock was said to be in a safe condition (Tambovtsev, 29, p. 123; Morozov, 24, p. 59). Evidently in all such cases they had in mind that a change in age composition of the catch occurred as a result of the action of the fishery.

Let us try to verify this point of view. In developing their opinion that age composition depended upon intensity of fishing, they used the material on vobla presented in Tables 6 and 7, and also data on the catch. Therefore, first of all it is necessary to subject these materials to analysis.

From Table 6 it is evident that the youngest age group in the catch are the three-summer fish (more accurately, the three-year-old fish), and that in some years, for example 1923 and 1924; these are lacking. At such times the youngest fish are the four-year-olds. On the basis of these data a picture of the relation of the age groups entering the Volga was formulated. The three-year-old fish were considered to be the youngest group first maturing their sexual products. This opinion stems from the year 1913, when the first review of the life history of the vobla was made. The author of the review, K. Tereshchenko (31), wrote as follows: "The time at which both male and female vobla reach sexual maturity is in the third year of life" (p. 28). Later he noted that "among the vobla migrating in spring, the youngest are third-year fish" and that fourth-year vobla constitute the main mass of the catch (p. 29).

Before 1937 there had been no special study devoted to the question of age determination from vobla scales. Tereshchenko worked at the problem of age in 1913, but used a different material, the bones. In the years that followed, scales constituted the principal material used. The determination of age from [page 132] scales of the vobla occupied many people, who then presented their own interpretations of the age of these fish.

Thus, in the work of the Expedition to Study the Volga Delta, which took place in 1914 and 1915, the "juvenile" or "downstream migration" ring on the vobla scale was not recognized because of insufficient knowledge of the biology of the young at the time of its descent to the sea. In later works, on the other hand, it was usually recognized that the first ring was a "juvenile" one.

By 1933 evidence had accumulated indicating that a juvenile ring was not always present. Thus merely as a result of differences in interpretation of the juvenile ring there have arisen different opinions concerning the age of vobla. Furthermore, at the same time an opinion became rooted that there was a close connection between the age of a vobla and its length, and corrections to age determinations were even made on the basis of the length of the fish. For example, A. V. Morozov (26), adopting Mitscherlich's formula to express the relation between age and length, came to the conclusion that "the question was cleared up by the discovery of a mean length of the vobla for each age" (p. 32). However, as N. I. Chugunov (33) has recently shown, Morozov "was endeavouring, by means of complex mathematical computations and arguments ..., to reconcile the observed discrepancies between empirical determinations of size up to 13 years of age and the results of back-calculations to age 1, discrepancies which were caused by inaccuracy in age determination principally and also by his failure to consider variations in rate of growth".

The attempt to establish a mathematically-exact correspondence between age and length of a fish is equivalent to the determination of the age of a fish by its length.

At the time of the work of the Caspian Expedition in 1933 there arose the question of whether two-year-old vobla might take part in the breeding migration. The results of studies of the scales showed clearly that two-year-olds do ascend the Volga for spawning.

In the same year a check of the earlier age determinations on vobla, for the years 1924 to 1934, was made at the Volga-Caspian Fishery Research Station. The result somewhat changed the picture of the distribution of the age groups, and showed that two-year-olds became an ordinary age in the catch only in 1931; that is, the two-year-olds are the first age group present, but they do not attain sexual maturity in any very great numbers.

For comparison with the data of Table 6, Table 8 is presented, showing the result of the revision of the age material and representing the new interpretation of the vobla scales.

[page 133] The most informative feature of this table is that it contains no trace of the above-mentioned tendencies, either for older age groups to accumulate or for them to disappear. The data of the first three years alone stand apart, evidently because of peculiarities in the method of collecting the material as compared with later years.

However, along with this absence of any definite succession in the renewal of age groups, the mean length and weight of the fish does change periodically. Table 9 demonstrates this, showing the complexion of the catches of vobla in the Volga as regards mean length and weight of the individual fish.

Data on the rate of growth of individual age groups are in agreement with this table.

All these data show that the catch in the Volga, the average weight of the fish, and their mean length vary in a similar fashion. That is to say, if the weight and length of the fish decreases, and also if the growth of the fish worsens, the catch falls off. And with an increase in the number of the older age groups (for example, in 1936 as compared with 1935) the catch can also fall, as it can also when there is a great quantity of young fish (for example, in 1933 and 1934).

The same data emphasize that following a high level of catch no improvement in rate of growth is observed. On the contrary, when growth is good there are also good catches. Consequently, the primary factor is the growth of the fish, and not the size of the fishery as was assumed at the Conference mentioned above. Thus the hypothesis of the effectiveness of the fishery in determining the age groups present in the catch and in affecting rate of growth is completely untenable.

It is also impossible to discover that the fishery exerts any influence upon the proportion of the vobla which matures at a given age. The makeup of the part of the stock which sets forth to spawn in spring differs very markedly from the relative magnitudes of the broods from which it is drawn [page 134], especially in rate of growth, which influences the time at which sexual maturity is attained. Therefore, both the age composition of the commercial stock and that of the catch depend in large part upon growth. In this way, the hypothesis of an influence of the fishery upon age composition of the catch and growth of the fish can lead to incorrect practical conclusions. And indeed there have been instances when such inaccurate conclusions concerning the stock of vobla have been accepted as a basis for the management of the fishery. For example, in 1932 A. V. Morozov presented his conclusion that it was possible to harvest 2,700,000 centners of vobla. Nevertheless, the catch was only 1,194,000 centners (N. Knipovich, 19). Morozov's principal error consisted in using as the basis of his estimate an age analysis of the part of the population which had already been used by the industry. But since in 1931 a preponderance of older age groups was observed and a big catch obtained, Morozov concluded that "there are no impending symptoms of depletion of the vobla stock".

It is not possible to evaluate the circumstance just mentioned without first considering the method to be employed.

In 1930, Lissner (44) proposed a very interesting approach to the characterization of fish stocks and to the question of forecasting fisheries, based upon an analysis of fluctuations and of the catch. By "analysis of the catch" Lissner meant a study of curves of length distribution, age and sex composition, stage of maturity and the weight of the fish, in representative samples taken from trawl catches.

The object of his studies was the autumn-spawning herring on the banks of the North Sea, a short review of which is given below.

Lissner maintains that in the North Sea the quantity of herring is completely adequate for the reproduction of the stock. But in spite of this, because of different conditions from year to year, variations in the quantity of larvae hatched from the eggs are produced. However, Lissner did not attempt to make a direct quantitative estimate of the year-classes, either in the larval stage or as young fingerlings; this he considered a hopeless task. Thus he writes that "the catch of first- and second-year herring in the mouths of the German rivers is influenced by so many factors, that up to now it has not been possible to establish a relationship between their abundance and the catches of the trawlers and drifters. Apparently it is just as hopeless to try to judge the final result of a spawning by making catches of larvae or eggs".

The number of young surviving in a given year constitutes the size of the generation which will be recruited, in the sexually-mature state, to the schools of older herring. As a consequence of this, "the age composition changes from year to year", and "individuals belonging to an abundant year-class constitute an important part of the catch for a considerable period of time". In almost every case "one and the same brood plays a conspicuous role over a period of approximately eight years, and predominates in the catch for about three years on the average". In this connection, Lissner considers it likely that there is a three-year cycle of renewal of the composition of the herring stock, and this renewal of the stock as a result of a new brood he considers an important cause of fluctuation in the catches.

Another important cause of fluctuations in catches, in Lissner's opinion, is growth. If a brood is large, it "at first strongly depresses true mean length and weight of fish in the catch, and only in later years, when its members grow up, does its influence on the catch become favourable".

Discussing in this connection the question of changes in rate of growth, he puts forward an hypothesis concerning a limitation to the food resources of the North Sea, basing his position on the following.

"In the first place, after a series of abundant year-classes following one after the other (for example 1917, 1918 and 1919) there is produced an over-population of herring in [p. 135] the sea", and, "in the second place, an influx of Atlantic water can have an unfavourable influence upon the abundance and composition of the plankton food of the herring of the North Sea", a kind of influx which was actually observed in 1924 and 1925, as English investigators have shown.

As an illustration of what has been written there are presented below Lissner's data of the age composition on the Fladen grounds, and also the mean length of the age groups (Fig. 2 and Table 12).

On the basis of these data, it is possible to make an estimate of the growth and abundance of the year-classes.

The results obtained are shown in Table 13, where the symbols used are as follows: a strong year-class or rapid growth (+); average abundance or growth (0); and a weak year-class or slow growth (-). But since each year-class does not live in isolation, but is mixed with a number of others, it is necessary to look at year-class and growth in their proper interdependence.

The principal age-groups on which the fishery of the Fladen grounds is based are III to VII. Therefore, knowing the characteristics of these five age-groups separately, we will be in a position to make an estimate of the stock of herring each year. Such an estimate, on the basis of Table 13 and the age composition of the catches, is shown in Table 14.

Before considering this table, it is necessary to note that the dots which stand under the plus and minus signs indicate the relative strengths of the principal age groups in the catches. Each dot represents about 10 per cent.

From Table 14, it is evident that growth and abundance of mature herring vary in parallel fashion; on the other hand, the indices showing the total weight of herring, and growth, vary inversely. This observation [p. 137] agrees with the proposition of Lissner concerning the limitation of the plankton food in the North Sea, and leads us to believe that stocks of fish are limited by the food available in a body of water.

A comparison of the figures of the last graph with the other data makes it possible to conclude that the intensity of the fishery, which has not achieved its limit, does not exert any important influence upon the stocks of herring and does not affect their dynamics. Therefore, in my opinion, the latter can be assessed from an analysis of the following two important factors: 1) the strength of the year-classes; and 2) the rate of growth of the fish.

In Lissner's studies, very great significance is attached to the following peculiarity of his materials. As is well known, trawl samples are greatly to be preferred to gill-net samples, since the latter select fish in accordance with the specific size of the net. Therefore, we believe that the information given by Lissner in his figures of age composition of the catches characterizes the corresponding age groups of mature herring. Because of this fact, the relative strengths of the age groups, as given by Lissner, can be used not only for an evaluation of the strengths of the year-classes, but also for making an estimate of the rate of recruitment or renewal of the stock.

In this connection, consider the following example. The year-classes 1921 and 1922 are two of the strongest. From Figure 2 it is evident that the first of these was represented very weakly in 1924 and very strongly in 1925, and particularly strongly in 1926; in later years the importance of this year-class falls off rapidly. The second year-class (1922) maintained itself at a comparatively high level in all five years after 1925. From this it follows that the 1921 year-class was recruited more rapidly than that of 1922. Obviously the attainment of sexual maturity in fishes depends upon growth.

Accepting this as a working hypothesis, we can without difficulty harmonize the results of our evaluation of the stocks of herring with those of Lissner (see Table 14). For example, the "minimum" of stock in 1925 is explained by the fact that a comparatively small number of individuals of the very numerous broods of 1921 and 1922 attained sexual maturity, because of retardation of growth. [Page 138] The great preponderance of these year-classes over the others at ages III and IV was the cause of the very small mean length of the fish during the period in question. This resulted in a considerable decrease in the catch.

For characterizing the stock and making reliable forecasts, the determination of the strength of the year-classes is, by itself, not enough. Data on growth are likewise insufficient. What is needed is a series of years with analyses of year-class strength and rate of growth, in order to estimate the rate of replacement of the stock.

In 1930, Farran (35) proposed an original method of determining fish stocks, based on age analysis of herring catches taken by means of drift nets along the north coast of Donegal. In his presentation, he proceeded from the following:

1. Representative samples reflect the age composition of the schools at the place of fishing.

2. The rate of mortality of the fish, as computed from determinations of age composition, is constant from year to year.

3. The relative abundance of fish of ages III and IV, which are the primary object of the fishery, was approximately the same for each year-class.

The data necessary for the estimation of stocks of herring by Farran's method are given in Table 15.

Here, in addition to the age composition of the catches by years, there is shown: the average age composition over eight years (from 1921 to 1928), the coefficient of decrease, and the coefficient of survival.

The calculation of mean age composition needs no explanation. As for the coefficients of decrease and of survival, they are computed in the following manner. On the average the second-year fish constitute 27.76 per cent, the third year fish 26.01 per cent. This means that as the first-named age grows to be a year older, 1.75 per cent are lost. Compared to the initial magnitude of 27.76, this decrease amounts to 6 per cent. The fourth-year fish, in growing to be fifth-year, decrease by 31 per cent; and so on. Thus the second row of figures from the bottom constitutes [p. 139] a norm of mortality. But if third-, fourth-, and fifth-year fish, etc., in growing into the next age group, decrease by 6 per cent, 31 per cent, 31.5 per cent, etc., the remainders, 100-6, 100-31, 100-31.5, etc., will represent the number of survivors, in percentage.

From these data, Farran expressed in relative figures the stock of fish in each year studied, using the stock of 1921 as a standard of comparison.

In 1921 the stock is taken as 100 units, distributed by age as follows (Table 16).

To calculate the number of individuals surviving to 1922, it is necessary that the indices of the age groups decrease in proportion to the mean percentage survival. Thus we get (see Table 15):

94%	of	16.4	=	15.4
69%	of	25.1	=	17.3
68.5%	of	16.5	=	11.3
65%	of	11.3	=	7.3
60%	of	19.5	=	11.7
52%	of	8.8	=	4.6
36%	of	2.3	=	0.8
27%	of	0.8	=	0.2
25%	of	0.2	=	0.05
Total..........				68.6

To this number remaining alive is added in 1922 the third-year fish, which, from Table 15, constitute 6.3 per cent of the catch. Thus in the catch of 1922 new fish will be 6.3 per cent, and fish surviving from 1921, 93.7 per cent. These 93.7 per cent of the 1922 stock constitute 68.3 per cent of the stock of 1921. Consequently the new fish in the stock of 1922 will not be 6.3 per cent, but correspondingly less, namely 4.6 per cent. Thus we find that the stock of 1922 constitutes 73.2 per cent of the stock of 1921. This figure, expressed in the same units as was 1921, is distributed in proportion to the age groups in 1922, as follows (see Table 18, second line from the top).

On the basis of these data the 1923 stock is estimated in relation to that of 1921. The computation proceeds in the same manner. Then the 1924 stock is estimated in terms of 1921, and so on. Finally a complete table is obtained, showing the changes in the stock of herring from 1921 to 1928 (Table 18).

[page 140] Farran uses these data not only for estimating the size of the stock of herring, but also for evaluating the abundance of the individual year-classes, which he expresses also in arbitrary units, by summing diagonally. For example, the year-class of 1918 comprises 16.4 + 19.0 + 16.2 + 13.8 + 8.6 + 2.9 + 2.1 + 0.3 = 79.3 units. Therefore, for convenience in use, the foregoing table is recopied in such a form that the lines represent not years of the fishery, but year-classes, using the data from 1921 to 1929. The corresponding table will have the following form (Table 19).

It is evident that some of the year-classes were used by the fishery before 1921, to a greater or less degree. Such are the 1914, 1915, 1916, and 1917 year-classes. Other year-classes were scarcely used at all (1918 and 1919), that is, they lived in the sea, in greater or lesser numbers, without being captured. For computing the unused fish Farran proposes the following method, illustrated by the year-classes of 1925 and 1924. The year-class of 1925 yielded, in the catch of 1928, 41.6 arbitrary units. From Table 15, third-year fish on the average constitute 27.76 per cent of all individuals used by the fishery. Hence we must conclude that of the 1925 year-class 72.24 per cent remained unused. But since 27.76 per cent corresponds to 41.6 units, the remainder x must correspond to 72.24 per cent, i.e.,

$$x = \frac{41.6 \times 72.24}{27.76} = 109.0$$

Thus the whole 1925 year-class is equal to 109.0 + 41.6 = 150.6. The year-class of 1924, according to Table 15, yielded 92.3 + 85.7 units in the catch. It is known that on the average third- and fourth-year fish constitute 27.76 + 26.01 = 53.77%. Consequently there remained 46.23% unused.

In the manner just described the remainder x is calculated from a simple proportion:

53.77% corresponds to 178 units
46.23% corresponds to x units

whence

$$x = \frac{46.23 \times 178}{53.77} = 153.0$$

The whole 1924 year-class is therefore equal to 178 + 153 = 331 units.

In the last-mentioned table, x̲ represents not only the remainder of the population not yet used by the commercial fishery, but also that part of the year-classes of 1914-1917 which were used up to 1921. Calculation of this part of the year-class is done in the same manner on the basis of Tables 15 and 19.

A single glance at the result of Farran's calculations will suffice to indicate the imperfection of his method.

[page 142] It is scarcely possible to consider that a random sample from the catch of a gillnet fishery, which has a selective action, can represent the age composition of the herring at the place of capture. It is most probable that the actual age composition of the schools will be quite different; that is, there will be a large number of individuals of the younger age-groups, but also a lesser number of individuals of the very youngest age, which prematurely become vulnerable to the fishery by reason of the good growth which distinguishes them from the main mass of year-olds. In other words, the curve of age composition must rise, reach some maximum, and then gradually fall.

Also, is it really permissible to estimate the coefficient of decrease from average age composition? The fact is that the percentage representation of the age groups from year to year varies so significantly, that calculation of mortality from two adjacent groups cannot correspond to reality. Thus the percentage of third-year fish is 27.76 on the average, but it exhibits variations from 1921 to 1929 of 6.3 to 45.5 - that is, from 4.4 times less to 1.6 times greater than the mean for the period. The percentage of fourth-year fish equals 26.01 on the average, but varies from 11.7 to 52.4, i.e., it was less than the mean by 2.2 times and greater than it by about the same amount. Hence it is impossible to base calculations on the constancy of this mean, the way Farran does.

The magnitude and abruptness of the variations in age composition are a natural phenomenon depending partly on the size of the year-classes, but principally on their growth.

Many data, Farran's among them, show that fishes with a faster rate of growth mature and are used by the fishery sooner than fish having slow growth. In other words fish reaching sexual maturity at different ages have different rates of growth. For example, considering Farran's data shown below, it is evident that the length of third-year individuals at the time the third annulus is laid down on the scales is greater than the corresponding length for fourth-year fish (Table 20). Inasmuch as the rate of growth of fishes is very variable, and the number reaching sexual maturity depends on rate of growth, hence so does vulnerability to the commercial fishery; therefore there is no basis for assuming that the relative abundance of third- and fourth-year fish of different broods will be approximately constant.

Thus the working hypothesis put forward by Farran is not verified; consequently his method cannot have any practical value.

A very interesting method of evaluating the composition of fish stocks and making catch predictions was worked out by Hodgson in 1932 (41). His investigation concerned the drift net fishery for herring conducted along the eastern shores of England in late autumn - from October to December - and based on the capture of schools of spawning fish.

[page 143] The central point of Hodgson's work is a study of the process of recruitment to the stock of as-yet-non-participating individuals, and the determination of an average rate of decrease of the year-classes from death. He shows that recruitment to the spawning stock of herring takes place at the time of attaining sexual maturity by individuals which have completed their third, fourth or fifth summer's growth, the greater part being fourth-summer. Of the third- and fifth-summer type there is only an insignificant number. After 5 years, practically all the herring take part in spawning. On the basis of a study of the distribution of age groups in the catch, Hodgson comes to the conclusion that each of the year-classes increases in number (in the spawning assemblage) up to 4 or 5 years, after which its numbers begin to fall. Variations in the abundance of the year-classes he explains as due to variability in numbers of the year-class being recruited. At the same time Hodgson admits the possibility of variation in the rate of mortality of the different year-classes. From this it follows that a mean age composition of the catches is the raw material for determining the rate of increase in abundance of the age groups and their rate of decrease.

From Hodgson's data for the period of observation 1923 to 1931, the rate of increase from 3 to 4 years is 290%, and from 4 to 5 years there is a slight decrease of 4.3%[1]. The abundance of the latter ages is practically the same, since the rates of recruitment and decrease between 4 and 5 years are nearly equal.

Later a sharp decrease in abundance of the age groups results from the increasing importance of mortality (from natural causes or from fishing) in the absence of immigration. Obviously there is a break at age 5. From that time on it is possible to compute a rate of decrease. To explain the change in abundance of age groups older than 5 it is necessary to know: 1) the rate of decrease from one age to the next (from 5 to 6, 6 to 7, etc.); and 2) the average rate of decrease for the whole age-interval from 5 to 11 years.

The calculation of the former rate is by the formula:

$$100\left(1 - \frac{b_6 + c_6 + d_6 + \dots\dots + n_6}{a_5 + b_5 + c_5 + \dots\dots + n_5}\right) \qquad (1)$$

where a, b, c, n are the years of observations.

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[1]According to a new calculation, the rate of increase is 270% from 3 to 4 years, and from 4 to 5 years it is 2%.

a_5, b_5, c_5 ...... n_5 are the total numbers of fifth-summer individuals in these years.

The formula is used to calculate rate of mortality for the interval between the fifth and sixth years. In the same way rates for other intervals are calculated.

$$100\left\{1-\left[\frac{(b_6+c_6+d_6+\ldots+n_6)+(b_7+c_7+d_7+\ldots+n_7)+\ldots+(b_{11}+c_{11}+d_{11}+\ldots+n_{11})}{(a_5+b_5+c_5+\ldots+n_5)+(a_6+b_6+c_6+\ldots+n_6)+\ldots+(a_{10}+b_{10}+c_{10}+\ldots+n_{10})}\right]\right\} \quad (2)$$

The above formula is used to calculate the mean rate. The average percentage decrease for the East Anglian herring is 36.9%.

For each interval Hodgson gives the following average rates[1]:

Age	%.	Age	%	Age	%
5-6	27.9	6- 7	32.1	7- 8	42.7
8-9	56.4	9-10	63.8	10-11	69.6

[page 144] Let us explain the process of calculation of age composition for the year to come, using the average rates of decrease cited. The computation will be done for 1931. The age composition of herring in 1930, according to Hodgson, can be expressed as follows (Table 21).

Two-year-olds (fish which have completed two growing seasons) are without importance, since in the spawning schools this group is commonly present in negligible numbers.

In 1931 the 3-year-olds become 4-year-olds, the 4's become 5's, etc., therefore:

4-year-olds will constitute 13.1 × 2.9 = 38.0 (increase to 290%)
5-year-olds will constitute 31.9 × 0.957 = 30.5 (decrease of 4.3%)
6-year-olds will constitute 10.3 × 0.721 = 7.4 (decrease of 27.9%)
7-year-olds will constitute 21.8 × 0.679 = 14.8 (decrease of 32.1%)

and so on.

In this way we get the following series (Table 22).

These figures, by which the age groups of 1931 can be represented, are of the correct relative magnitude but they are not percentages. Absent are the 3-year-olds, which play a rather significant role in the catch. To estimate the 3-year-olds Hodgson used data on the variation of 2-year-olds in comparison

[1]In the article "East England herring fishery" published in "Fishing News", Hodgson presents the following norms:

Age	%	Age	%
5-6	26	8- 9	60
6-7	35	9-10	63
7-8	42		

with 3-year-olds in another region (Northshields in Northumberland), on the assumption that these fluctuations correspond to the fluctuations of 3-year-olds in the East Anglian schools the following autumn. According to his data the increase in the interval from 2- to 3-year-olds averages 90%. Multiplying this figure by 0.1 (the percentage of 2-year-olds in the 1930 catch) we get 9.0.

The final total gives the following proportions for the age groups in the 1931 catch (Table 23).

[page 145] In Hodgson's opinion, the calculation of abundance has proved to be sufficiently close to observation. However, such computations correspond to the normal course of the fishery and give a preview only of the stock of fish. They "do not predict the abundance of fish available to the drifters, since in some years storms upset all calculations". But not only storms, but other factors also can have an effect upon the catches. Concerning them Hodgson writes as follows: "It is possible that when young fish are abundant in the schools there is an early fishery; and when young fish are scarce, fishing begins late". "In addition to this we must consider the movement of organisms definitely obnoxious to herring, like Phaeocystis, known to the fishermen by the name 'tobacco juice'. Water contaminated by it they call 'stinking' or 'grassy' and they always associate such water with poor catches of herring. The presence of large masses of Phaeocystis and so on can drive fish away from shore or in some cases bring them close to shore, depending on the position of the concentration. In this way even a small migration of the herring can upset all calculations concerning the abundance of the fish, because the region fished is of comparatively small extent".

To the list of factors detracting from the catch Hodgson adds the abnormal influx of Atlantic water in the North Sea, the presence of strong offshore winds which drive the fish away, any massive development of Rhizosolenia, failure of the fishing period to coincide with a full moon, poor market demand for the fish, and so on. In Hodgson's opinion these factors must be considered in predictions, since without them it is impossible to make a quantitative evaluation of the expected catch, or even give its qualitative characteristics.

The method outlined leads to a determination of the age composition of the next year's catch on the basis of a calculated normal rate of mortality and of recruitment, which gives also the qualitative character of the fish stock. It is possible to specify the size of the catch only in the case of normal conditions[1].

Let us consider now the basic foundations of Hodgson's method. Is it really true that different year-classes have a more or less uniform rate of decrease? This question is not sufficiently examined by Hodgson; for our part, we do not have direct evidence against the hypothesis which he favours. However, on the basis of the consideration mentioned earlier, that the rate of recruitment to the stock varies from year to year, we are inclined to the view that there must be a reconsideration of the question of a fixed norm, not only of recruitment but also of mortality. Still another circumstance speaks in favour of this view. Some years are characterized by a small mean length of the fish because of strong representation in the catch of the smaller age groups, which thus are fished out more intensively. In spite of this they exhibit a rather wide range in rates of growth, which implies not only a diversity of age composition of

[1] "East England Herring Forecast for 1933".

the catches in association with the selective property of the nets, but also variation in abundance of the individuals that are ready to spawn.

The computation of a standard rate of mortality and rate of recruitment on the basis of average age composition is the only possible procedure. But it should be fully appreciated that for the calculation of age composition of the expected catch the mean values cannot have real significance, and a very important role is played by deviations from the mean values. Hodgson's reservations in connection with the calculation of rate of recruitment emphasizes our opinion; and we believe that the reliability of a calculation of the age composition of a future catch is entirely determined by the magnitude of the deviations from Hodgson's norm.

It is a number of years now since O. Sund (47) undertook the study of [page 146] the Lofoten and Finmark stocks of cod by the biostatistical method. However, because of the difficulty and inaccuracy of age determinations of cod more than 7 years old, especially from scales, Sund used the results of measurements of the length of the fish, since there is a direct correlation between the length of the fish and its age.

In view of the fact that a correct representation of the length distribution of fish in the catch usually comes from a series of samples, in constructing Petersen-type curves he enumerated the length frequencies in each sample alongside the corresponding catch. Further, in summing these series he used the so-called "weighted series", which for comparability was reduced to 10,000. We must observe that this attempt at obtaining a weighted series of fish lengths was applied by Sund starting with the year 1921.

To study the curves of the distribution of length in the catch at different times of year, and from year to year, he proposed the following method of analysis. If $\underline{x}$ represents the average number of fish of a certain centimeter length-interval over a series of years, $\underline{a}$ is the number of fish of the same length in a particular year, and $\underline{b}$ is the number of the same in a second year, then curves are constructed so that:

> the first represents the deviation a-x from the mean curve; the second is the same kind of deviation, i.e., b-x; and the third is the difference b-a.

It is useful also to construct the percentage curves for the expressions $\frac{a}{x}$, $\frac{b}{x}$ and $\frac{b-a}{x}$. Here x, a and b represent each centimeter length interval in the catch.

It is obvious that the deviations will be both positive and negative, and in constructing a graph they will fall both above and below some straight line. Included between the curve and the straight line is an area representing the excess or defect of abundance of each centimeter length interval.

Such diagrams, constructed for a series of years or for the period in question, makes it possible to form an opinion about changes occurring in the stock of fish from the point of view of age and, indirectly, growth. From this it follows that by Sund's method we can roughly determine the significance of deviations, and in addition estimate changes in stocks.

Since this method differs little in principle from earlier methods using age composition analysis, we have not presented Sund's abundant material on cod (see Norges Fiskereier).

A very significant advantage of this method consists in the possibility it affords of utilizing voluminous records of fish lengths. Obtaining any similar quantity of age material is tied up with the difficulties which arise in determining the age of cod.

In spite of the known role in science of the law of large numbers, the usefulness of measuring great numbers of fish is limited by the properties of the length itself. From this point of view Sund's method has a number of drawbacks. For example, two strong year-classes might occur in immediate succession, having different rates of recruitment to the stock and different rates of mortality. Obviously it would be impossible to separate them by means of length. There are also other circumstances. One (older) brood exhibits poor growth, and another (younger) brood is distinguished by good growth, neither being exceptionally numerous. It is clear that the result of adding the frequencies in each centimeter group would show a peak in some length group which in fact does not correspond to the real position of either year-class.

In studying curves of length distribution, we encounter the phenomenon of the unrecognizability of the year-classes, which is [page 147] a serious disadvantage since individual properties of the year-classes cannot be studied by themselves. And in the absence of observations, or more exactly, inferences, concerning variations in the year-classes, it is not possible to speak seriously of predictions or to assess the status of a fish stock.

Sund's method originated partly because the catch of cod can be represented by a long series of centimeter groups. Obviously this method would fail if he had had to deal with fish characterized by only a short series of such groups (for example, the sprat, anchovy and so on).

The limited applicability of the method under review is a second inadequacy which indirectly testifies to its artificiality.

On the other hand, it must be acknowledged that in some instances, because of its graphic presentation of massive length data, Sund's method is helpful and facilitates the study of the biology of fish.

As a result of his study of the otoliths of cod, Rollefsen (46) came to the conclusion that there is a connection between the appearance on the otoliths of a zone of growth of a characteristic type, and the sexual condition of the fish.

From characteristic zones of growth on the otoliths of the spawning cod (skrei), it proved possible to determine how many times the fish had spawned. Hence it was possible to compute by means of a definite formula the recruitment and mortality in the stock. Consequently, on the basis of the appropriate number of first spawners of an age group, it is possible to determine the corresponding number of first-spawning fish of the next age group, and so on, and in addition to compute the age composition of the whole mass of fish which is attaining sexual maturity for the first time.

Rollefsen determined that on the average the mortality of the stock of mature cod (skrei) was 40%. This shows that each age group in this stock of fish will be represented by only 60% of its members which were present in the previous year. The number of spawners in the following year will be proportional to the number of first-spawning fish of the corresponding year-class in the given year.

The factor of proportionality, which the author calls the "maturing factor", is the ratio of the number of old year-classes to the younger ones, calculated on the basis of data on the age composition of the catches extending over many years.

Proceeding on the basis outlined above, Rollefsen makes the computation shown in Table 24. Here the number of fish of each age group is entered in the column for the age in question, according to the number of its spawning zones. For example, of the whole number of 114 eight-year-olds in 1934, 6 individuals already had one spawning zone, the remaining 108 were spawning for the first time; of 117 nine-year-old fish, 24 had one spawning zone and the other 93 were spawning for the first time, and so on. The column of observations for 1934 shows the number of fish examined and their age composition in percentage.

To make a prediction of the catch of cod in 1935, Rollefsen proposes the following procedure. Let us take as an example the first-spawning eight-year-olds, of which there are 108 in the 1934 sample. According to prediction, the number of these fish is proportional to the ratio $N_9/N_8 = 2.8$, that is, the first-spawning nine-year-olds in 1935 will be 303. As for nine-year-olds spawning for the second time, they will be 40% fewer, i.e., 65 (108 × 0.6). Proceeding in a similar manner with the computation using ten-year-olds, we find in 1935 for eleven-year-old first-spawners 75 individuals (68 × 1.1); for second-spawners 41 individuals (68 × 0.6); for third-spawners 25 individuals (41 × 0.6) and for fourth-spawners 7 individuals (11 × 0.6).

[page 148] The computation for 1935 gave in all an increase from 1012 to 1490 individuals, which means a corresponding increase in the stock of fish as a result of first-spawners of approximately 37% in comparison with the previous year 1934.

A comparison of the calculated age composition of the catch, at the beginning of migration, with observations made in 1933, 1934 and 1935 showed a close agreement between the calculated and observed data.

Rollefsen proposes to calculate not only the age composition of the expected catch, but also the length composition of the catch on the basis of determinations of the length of each age group of mature cod. Naturally, [page 149] from the length of the fish the mean weight can be estimated, and the distribution of weight determined.

In calculating the age composition of the expected catch difficulty is encountered in determining the significance of the very youngest ages represented in the stock of mature cod. These difficulties are removed with the aid of studies of the age composition of immature cod (loddetorsk). The data on the corresponding groups in the immature cod stock, from which the stock of mature cod is directly recruited, affords a basis for estimating the first age groups in the stock of mature cod.

In spite of the satisfactory result of the prediction of the age composition of the mature cod, we must notice that the method proposed by Rollefsen has certain drawbacks. Mention has already been made of one of these, which the author himself points out - the difficulty encountered in determining the relative importance of the youngest age groups in the schools of mature cod. Considering the other difficulties we must make the following observations.

At the base of Rollefsen's method lies the contention that on cod otoliths at time of attaining sexual maturity zones of a special character are laid down, which record the fact of spawning. In view of the fact that these zones are also zones of growth of the otolith, and no special characteristics (apart from the fact that they appear at an earlier age) distinguish them except that their hyaline part is more broadly opaque, the author's assumption needs further confirmation. Naturally a basic assumption of the Rollefsen method must be an accurate determination of spawning rings. However, the formation of spawning rings can be modified by the rate of the growth of the fish, which can change as a result of its sexual condition, its feeding, and other factors.

It is well known that as a result of the lack of uniformity in time of sexual maturity and variation in the abundance of year-classes the age composition of the stock of ripe fish changes. The age composition of this stock is also affected by the number of ripe fish which remain alive after spawning. In general, since many factors determine the age composition of a stock of mature fish, it does not remain constant from year to year; their importance also varies. Therefore, a mean value for the "maturing factor" and a mean annual mortality of the stock of ripe cod equal to 40%, used by Rollefsen in his calculation, is an additional poorly-established assumption.

At the basis of Rollefsen's predictions lie the arithmetic means of the indices cited, therefore we can postulate that if it is necessary to work with an arithmetic mean, then we will have to keep in mind also the error in it. Thus a certain number of the predictions by Rollefsen must depart from the truth, and in any particular case his prediction should be given only accompanied by a certain percentage of probability. What reliability do Rollefsen's predictions really have? The author passes over this question. We must consider that their reliability will be the greater, the fewer the assumptions on which they are based.

However, even with all the limitations which have been indicated in the method under review, it is a very important contribution, which must give a great impetus to investigations concerning fish stocks. Rollefsen has indicated the possibility of making predictions of age composition of catches on the basis of spawning marks, or speaking more accurately, on the basis of spawning zones on cod otoliths. It is obvious that this idea will find application in developing predictions for a great many commercial fishes.

Concluding this brief resumé of methods of determining fish stocks and predicting catches, we can arrive at the following conclusions:

1. [Page 150] The important factors on which changes in fish stocks depend are the size of the broods, growth, recruitment and mortality.
2. Recruitment of the stock by any single year-class takes place over several years. The absolute and relative rate of recruitment varies from

year to year, and is determined by the size of the year-classes and their rate of growth.

3. Changes in age composition of a stock of fish and its rate of growth are not the result of the intensity of fishing.

4. A biostatistical analysis of the catches, considered in its broad sense, has very great importance for determining fish stocks.

These conclusions were used as a basis for our consideration of catch predictions and stocks of vobla in the North Caspian, as presented below.

The vobla population of the North Caspian Sea

The data collected over many years on the catches of vobla in the North Caspian have one common property: The catch reaches a maximum in autumn and in spring. The yearly catch curve reflects biological peculiarities of the fish, of which the more important are the following:

1. The greatest concentrations of vobla occur in autumn as they approach the north shore for wintering, and in spring at the time of the breaking up of the ice on the sea, and also at the time of the spawning migrations in the sea and in the river (14).

2. These concentrations occur at temperatures less than 14-15°.

At the time of migration of the vobla to their winter quarters all age groups take part. The same composition is found at the time of the break-up of the ice. In the spawning migration, the vobla schools consist of all age groups except the yearlings (those hatched the previous year). At the same time, the important part of the catch of vobla in autumn and in spring consists of individuals of a fairly advanced stage of maturity of the sexual products (III, III-IV and IV). The catching of non-maturing fish amounts to only 2-10.5% in all, this being the result of the method of fishing, which is principally by trap nets in the sea.

In spite of the different nature of the assemblages in autumn and in spring, vobla which show signs of sexual maturity in the autumn do not differ in age composition or in length from the vobla which migrate up river to spawn in spring.

The observations of Dementeva (14) on the ripening of the sexual products of vobla in the course of the autumn indicate that from the beginning of September there is a gradual increase in the number of individuals in which the gonads have passed the II-III stage of development. The increase in number of maturing fish follows an S-shaped curve, showing that the composition of the stock of mature vobla which will be spawners in the spring is already determined during the autumn.

According to Meĺen's (20) studies, the vobla which will spawn in spring can already be distinguished in autumn.

The formation of dense schools of vobla in autumn, mostly near the mouths of the river, is a result of emigration of fish from the central parts of the sea where, as the winter studies of 1935-36 and 1936-37 show, neither mature nor young vobla remain in winter (Dementeva, 14). From the results of marking experiments performed by Karavaev (17), vobla are inclined to congregate in a distinct region, but their attachment to it is temporary; for one thing, there is sometimes an interchange of vobla from one region to another as a result of prolonged strong winds (autumn of 1935), and in addition, part of the stock of vobla, which goes up to spawn from one region, will scatter to another region after spawning.

Thus on the basis of the above, the following phenomena are clearly established: 1) the concentration of dense schools of vobla in the shoreward region of the north Caspian in spring and in autumn at temperatures less than 14-15°; 2) the tendency of [page 151] the vobla to remain in their own localities through the autumn and the following spring; and 3) the common origin of the autumn and spring vobla which are reaching maturity. Therefore on the basis of studies of the stock of vobla in autumn, it is possible to speak of the prospects for the spring vobla fishing and vobla stock.

It is to be understood that one of the most essential points in answering questions concerning the stock of vobla is the question of representative sampling. In this connection, the discussion of Heincke (37) has very great interest; he distinguished three kinds of samples: 1) samples from the stock or samples made by fishing using experimental nets; 2) samples from catches of ordinary commercial gear; and 3) so-called "market samples" from catches of fish when brought to the port of landing, or on the market.

Evidently greatest reliability should be attached to samples taken by experimental gear of such a type as to take fish of all age groups which occur in the area in question. Samples from the commercial catch have a secondary significance for us in that commonly they are the result of selection by the fishing gear. These samples we will not consider.

Market samples of vobla consist of the abundant material which is collected in the North Caspian at the many points to which fish are taken, from the place of fishing, to be processed. Such points are found in the Volga delta at the Oranzherey, Kirovsky, Tumansky, Samoĭlovsky and Verkhne-Lebîazhy plants, and in the Aral delta at the Novy Litsevy plant, and also in the sea on the floating fish plants (barges).

It is well known that the requirements imposed for taking different kinds of samples cannot be uniform. Samples from experimental catches must be entirely based upon the distribution and migration of the fish. Obviously it is sensible to take them at the time the fish are concentrated in a small area and are collected in dense schools. But in spite of the fact that schooling fish form dense aggregations at known times and in known places, such aggregations are very variable in their composition, especially in respect to length. Therefore every sample from an experimental catch is not of identical composition. Hence to assess a fish stock it is necessary to meet the following conditions: 1) synchronization of the time of capture of the samples, and 2) an abundance of samples from regions where the fish are aggregated.

Failing these conditions, samples from experimental catches cannot enlighten us further, especially if each of them consists of an arbitrarily determined number of specimens. It is obvious that this matter of numbers must be determined on the basis of real requirements, inasmuch as studies of fish stocks demand a large outlay in work and expense.

Einar Lea (43), studying Norwegian herring, shows that "for them samples of 200-300 make possible a completely satisfactory solution of two opposed conditions: a large number of samples and a large number of specimens in each sample. For other species, in which the number of year-classes is not so great as in the herring[1], the desirable minimum is 100 individuals.

Undoubtedly this conclusion is fully applicable to the vobla, which has commonly 6-7 age groups, that is, 2-3 times fewer than the Norwegian herring. We believe that a sample size of 100 specimens is quite sufficient not only in respect to age (and still more to sex) composition, but also in respect to the distribution of length.

Although the autumn inshore migration of vobla begins at the end of August, and the fishery for them ends no earlier than the middle of November, there is no need to take a series of samples from the experimental catches during this 2.5 months or even longer. According to Dementeva's (14) [page 152] data the composition of the schools of mature vobla is determined as early as mid-October, and all individuals which have reached stage II or III at that time, will be capable of spawning the following spring. Consequently observations on the fish in the sea in autumn can be limited to a single month - from mid-October to mid-November, when the most important schools of vobla are produced. The period of breakup of the ice and migration of vobla in the sea lasts about 1.5 months - from the end of March to the first half of May. During the course of this time too the vobla are found in concentrated aggregations, which we take into account in assembling samples from the experimental catches.

Because in autumn and in spring the larger vobla are caught at the first, and later on the smaller ones, it is necessary to take samples quite frequently. However, a trial showed that in any given region it is sufficient to take two samples, or even only one, per five-day week.

The extent of the total range of the aggregations of vobla is a very important consideration in deciding the magnitude of the stock. It was accomplished by means of five vessels of the scientific fishery survey, which worked in the western, central and eastern parts of the North Caspian, distributed as follows: three vessels in the regions from Briânsk to Baksaya, and two from Baksaya to Prorva. A vessel took samples every day except stormy ones, but the samples were worked up once or twice every five days. The fishing was done with a 30-foot trawl having meshes 22-24 mm.

For the analysis of the commercial catches we collected samples at the control points enumerated above. Clearly the samples from the industry and those from the experimental catches will differ in their composition. The former must by their very nature reflect first and foremost the composition of the catches delivered to the fish plants. In that event the considerations, mentioned earlier, concerning the period over which the series of samples is to be taken from the experimental catches, lose their importance. Evidently it is necessary to collect samples over the whole period of the fishery, and at such important points as receive the catch from the principal fishing grounds. A trial showed that in this case it was quite satisfactory to take a sample of 100 individuals every 5 days.

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[1] Norwegian herring are caught from 3 to 20 years of age.

In collecting samples on the boats and from the observation points, each fish was given the following treatment: the length was measured, scale samples were taken, sex was determined and degree of maturity of the gonads recorded, and the fish was weighed. All data were written down on a special form and in the scale book.

Samples from the commercial catch of vobla, in spite of their limitations, have great significance for deciding many important questions. Among these are the decrease of the year-classes of vobla as a result of fishing, and the characteristics of the spawners ascending the Volga and Ural Rivers. Samples of the catches from these rivers, where there is a seine fishery which gives a catch almost unselected by length, have just as great interest as do samples from the experimental catches in the sea.

Studies of the age composition of the catches in the river and in the sea show that the usual assortment of age groups among the vobla is from 2-8 years (in autumn, those in their second to eighth year of life) (Fig. 6). As a rule the first age group of mature vobla is present in insignificant numbers (0.2 to 4.7%). Also poorly represented in the catches are the 7-year-olds, which, however, amount to more than the 2-year-olds when expressed in terms of weight rather than numbers. Eight-year-olds amount to only a fraction of a per cent in all. Thus the important groups in the catch are the 3-, 4-, 5-, and 6-year-olds (in autumn, fish in the corresponding years of life).

Since the preponderance of the vobla catch consists of mature vobla, it is convenient to name all aggregations of ripe individuals the <u>commercial stage</u> or the <u>commercial stock</u>.

The commercial stock of vobla consists of 1) the remainder or residual stock, which is left after the spawning of the previous spring; 2) the <u>recruits</u> [page 153] which are just reaching sexual maturity; and 3) the residual stock which consists of individuals that have missed one or two seasons of spawning. The last-named part of the commercial stock is apparently very insignificant, since vobla normally spawn every year. A small number of individuals will skip a spawning and their sexual products undergo degeneration in the spring (Dementeva, 14).

Let a_2, a_3, a_4, a_5, be the abundance of second-, third-, fourth-, and fifth-year fish which are becoming sexually mature for the first time. Let b_3, b_4, b_5, b_6, b_7 be the number of vobla of each age group which remain after spawning the previous spring and which are again about to become mature. Finally, let c_4, c_5, c_6, c_7 be the fish which have skipped one spawning season. Then the commercial stock is represented schematically as follows:

$$a_2 + a_3 + a_4 + a_5 = Sa$$

$$b_3 + b_4 + b_5 + b_6 + b_7 = Sb$$

$$c_4 + c_5 + c_6 + c_7 = Sc$$

$$\overline{a_2 + S(ab)_3 + S(abc)_4 + S(abc)_5 + S(bc)_6 + S(bc)_7 = Sa + Sb + Sc}$$

Each of the three rows includes several year-classes, but only such parts of the latter as are becoming sexually mature. Each of these items has its own special characteristics, which it is necessary to understand as fully as possible, since otherwise it is impossible to make a correct diagnosis or prognosis. Detailed information concerning the residual parts of the commercial stock is obtained from studies of its age composition, to which we turn immediately.

The age composition of the commercial stock of vobla was determined by us from samples of trawl catches after rejecting from the latter the non-maturing fish. The data for 1934-37 are shown in Table 25.

From the table it is apparent that the older age groups are present in insignificant numbers or may even be completely absent. This brings up the question, does the absence or scarcity of the older ages have any particular significance for us?

A comparison of this table with Table 26, in which is shown the age composition of the autumn catches by gillnets which select the big fish, indicates that the deficiency of old age groups is only a few per cent in all.

Therefore we can assume that the scarcity or even absence of older age groups in the samples from the experimental catches, on the basis of which we determine the age composition of the commercial stock, has no important significance.

[page 154] The age composition of the commercial stock can be considered a starting point for studying the vobla population. Determination of the age groups has special importance in view of the fact that they result from year-class strength, rate of growth and mortality. It is necessary to consider indices for each of these.

In the North Caspian the strength of a year-class of vobla has been measured every year by means of a count of the young of the year. At the present time, we have at our disposal adequate information concerning the fluctuations in abundance of young over 8 years. In V. Tanasiĭchuk's (30) work, the data are presented from which we have constructed a graph of the variation in production of young vobla in the North Caspian (Fig. 3).

If we consider that in the 1933 catch third-year fish were the most important age-group (54.5%), then by comparison with Table 25 there is evident a complete agreement between the results obtained on the basis of the experimental catches, and the picture obtained from the quantitative catches in the sea. The year-classes 1934 and 1931 were especially strong, and 1933 was very poor. It is quite evident that one of the causes of changing age composition of the commercial stock is fluctuation in the size of the year-classes.

Tereschchenko (31) was one of the first to give attention to the non-uniformity of time of sexual maturity of fish, in relation to rate of growth. "Obviously individual peculiarities in time of maturity must be related to the effect of an exceptional rate of growth and, in particular, rate of feeding of the fish: thus vobla reaching maturity in their third year are on the average always somewhat heavier than their non-maturing congeners" (p. 29).

Einar Lea (42) also gives attention to the variability in time of maturity of fishes in its relation to growth rate, and shows that it is this cause which determines Rosa Lee's "phenomenon" (the phenomenon of apparent change in growth rate).

[page 155] We ourselves have determined (22) that the relation between mature and immature vobla in samples from the experimental trawl fishery is closely associated with growth, i.e., the more mature individuals, the larger the fish; and that almost all the fish reaching 20-21 cm. in length were maturing in autumn (Fig. 4).

The data assembled in Table 27 show that the number of mature individuals was greater in those years when the fish grew faster, and conversely, in years of slow growth the number of mature fish was less.

From this we correctly conclude that the percentage representation of mature individuals in samples of the population is an index of degree of recruitment to the commercial stock.

Having succeeded in identifying a spawning ring on the scales of vobla (33), the possibility arose of determining directly the recruitment to the commercial stock on the basis of a count of those individuals which have and those which do not have such a ring on the scale. Obviously fish with one or more than one spawning rings constitute the so-called residual stock, and ripe fish lacking spawning rings are the recruits to the commercial stock.

From 1934 to 1937 inclusive, the representation of both categories in the stock had the following magnitudes (Table 28).

Let us consider again the recruitment of the commercial stock whose age composition is shown in Table 29.

[page 156] From the table it is evident that recruits consist of second-, third-, fourth- and fifth-year fish. From this we conclude that a year-class does not attain sexual maturity all at once; rather, one and the same year-class produces recruits over a period of 3 (1933 year-class) or 4 (1932 year-class) years.

Evidently the length of the period of recruitment is the same for scarce as for abundant year-classes. As for the distribution of recruitment over the various years, the great bulk become mature in their third or fourth year of life. To determine in which cases most intensive recruitment occurs in the third year, and in which it occurs in the fourth, consider the following data (Tables 30 and 31).

In Table 30 is shown the mean length of the age groups of the commercial stock, and in Table 31 are indices of the rates of growth of third- and fourth-year fish which prevail in the stock.

[page 157] A comparison of the indices for the year-class 1933, shown in Tables 29, 30 and 31, leads to the conclusion that in 1935, thanks to the good growth, a great part of the year-class attained maturity in its third year of life; the remainder became mature in its fourth year. The 1934 year-class, because of poor growth in 1936, gave its maximum recruitment in its fourth year of life. Thus the relationship considered above: on the one hand - the dependence of maturity upon growth - and on the other hand - the dependence of intensity of recruitment to the stock upon rate of growth - shows that the age composition of the commercial stock of vobla is closely dependent upon growth.

Of course, side by side with recruitment to the commercial stock there exists the opposite phenomenon - mortality. Theoretically the mortality in the stock must equal the recruitment. However, it is necessary to bear in mind that, qualitatively, mortality does not correspond to recruitment. A comparison of the age composition of the vobla catches with the age composition of the commercial stock (see Tables 25 and 26) indicates some preponderance in the catch of the oldest age groups. This excess, apparently the result of the selective action of the fishing apparatus, to some degree affects the composition of the residual stock after spawning. For example, a study of the age of vobla which have returned from spawning and are captured in the sea shows a smaller percentage of old age groups, by comparison with the commercial stock. At the same time, the mean length of an age group of descending vobla remains almost the same as at the time of its upstream migration to the spawning grounds (Table 32; see also Tables 25 and 31).

It is quite evident that the relative increase in numbers of the younger age groups among the residual vobla is the result of a rather large destruction of fish of the older ages after spawning. Although we have no quantitative data on the post-spawning mortality of vobla, nevertheless we consider that the above-mentioned change in age composition of residual vobla [page 158] is to be mostly attributed not to the selective removal of the older fish by fishing, but to other causes. Confirmation of this view is found in a consideration of the "remainder" of the commercial vobla stock.

In Table 33 is shown the age composition of that part of the commercial stock which has already spawned at least once. In their age composition these recidivists of 1934-37 reflect the same significant elimination of the oldest fish, as did the downstream-migrating vobla. However, in spite of this the recidivists of 1934 and 1935 constituted more than 60% of the commercial stock, and even in such poor fishing years as 1936-37 and 1937-38 they were 40% (see Table 28). It would seem that if the intensity of fishing were great, the recidivists would scarcely be as numerous as is indicated by the figures in this series.

It was shown above that 3- or 4-year-old fish (in autumn, third- or fourth-year fish) comprise the main part of the catches. In spring of 1934 there were 51.8% of age 3 fish in the catches; in spite of which, in autumn of the same year their survivors (now fourth-year fish) comprised 68% of the recidivists, or 42.7% of the total commercial stock. Thus even a strongly-fished age group does not bear any traces of that action of the fishery concerning which many have written as though it were a paramount cause of change in the size of stock, age composition and rate of growth (Baranov, Morozov, Petersen, Heincke and so on). In connection with what is said above, we can say that the age composition of the commercial catch of vobla does change as a result of mortality, but to a larger degree from natural mortality than from fishing.

Knowing the nature of the relationship of the commercial stock of vobla to the size of the year-classes, growth, recruitment and mortality, we can determine the character of this stock and predict the nature of the catch a year ahead. In the light of the 1934-37 data given above (see Tables 25-36), the following characteristics of the commercial stock of vobla can be given:

1. In autumn of 1934, because of significant improvement in rate of growth, an intensive recruitment to the commercial stock took place, which resulted from an increase in the percentage of mature fish.

   Recruitment was introduced principally to the year-classes already in the fishery, in particular to the brood of 1931 (51.8%). In spite of this, recruitment constituted only 37.2% in all. From that it is clear that in the autumn of 1934 and spring of 1935 the stock of vobla was very considerable.

2. In autumn of 1935 the amount of recruitment to the commercial stock decreased as a result of a decline in growth and change in age composition of the recruits such that the representation of the 1933 year-class was especially reduced (35.8%). Nevertheless the total percentage of recruits scarcely changed, by comparison with 1934. Therefore, we must conclude that in 1935-36 the vobla stock decreased relative to 1934-35.

3. In autumn of 1936 there was an important general renewal of the commercial stock (57.8%). However, in this year recruitment occurred along with a further decrease in growth and in spite of the fact that it was attributable [page 159] principally to one numerous year-class (1934) which was completing its third summer of growth.

4. In the fall of 1937, recruitment was also considerable, but consisted largely of two year-classes distinguished by the following characteristics. The 1934 year-class (70%) was numerous, and the 1935 year-class, by comparison with that of 1933, was more numerous and had made better growth. From this it is correct to conclude that in 1937-38 the stock increased somewhat. However, in spite of their good rate of growth, the vobla were little different from the vobla of the previous year.

These characteristics apply to the North Caspian in general, even in the cases when the indices of year-class strength, growth, recruitment and so on are not the same for different parts of it. An evaluation of the stock of each of these regions is possible only by considering such indices. Let us look at a few examples.

According to V. Tanasiĭchuk's (30) data, the production of young vobla in the Volga and Ural-Emba region has varied more or less synchronously. The year 1932 is the only exception, when there were very few young in the Volga region and very many in the Ural-Emba region.

The age composition and growth of the vobla in different regions also vary in a similar manner, more or less, as Tables 34 and 35 testify.

[page 160] These tables permit the following conclusions: In 1935 and 1936 the age composition of the commercial stock of vobla in different regions of the North Caspian was uniform. The mean length of the age groups in 1935 was the same over only the western and eastern regions. In the central region the mean lengths were less. In 1936 vobla of the eastern region were characterized by better growth than those of the central and western regions. With reference to growth of vobla in 1937 we can say it was everywhere the same;

but as for age composition, the western region was characterized by a certain preponderance of the younger age groups.

The stocks of vobla in different regions of the North Caspian have varied in relation to their quantitative distribution in the sea, as shown in the graph (Fig. 5) which has been constructed from statistics of the fishing operations of the Volga-Caspian State Fish Corporation. The basis of this graph are the abundant data on catches of vobla taken in gillnets in the sea during the autumn migrations of 1934-37. From the graph it is evident that over this time there was a marked change in the stock of vobla, as follows: In the eastern regions a steady decrease of the commercial stock is evident up to 1937, and in the western regions there was a decrease in density of population to 1936 and then an increase in 1937. Therefore an opinion concerning the stock of any given [page 161] region can be in error if we do not take into consideration also the quantitative distribution of the fish.

Between vobla caught in autumn and those caught in spring, there exists a very close correspondence in respect to age composition and growth, so that there is no difficulty in predicting in advance the age composition, mean length of the age groups and the weight of the fish in the migration of the following spring. A comparison of compositions shows that such predictions can be fairly accurate (Fig. 6).

From the figure it is apparent that it is possible to forecast the age composition of the catches of vobla in the Volga and Ural Rivers. Because of the fact that in autumn growth of vobla ceases, prediction of length and weight on the basis of autumn material can be very accurate (Table 36).

Thus, after studying the vobla in autumn we can say quite definitely what will be their length, weight and age composition in the catch of the following spring, and also what will be the condition of the stock and how the catch will change - whether it will increase or decrease. What we cannot do is to determine exactly the size of the stock of North Caspian vobla, because we have obtained almost no quantitative information on the natural mortality of the fish. At the present time we can only make a guess at the relative sizes of the vobla stocks.

In the North Caspian (including Dagestan) on the average about one billion (milliard) pieces of vobla are taken yearly by the fishery. Even so, as was shown above, the fishery has not had any important influence upon the age composition, growth, year-class abundance, recruitment and survival of the stock. Catch is mortality. For equilibrium to be maintained, mortality must be [page 162] equal to recruitment. Consequently, the vobla stock (the commercial stock) must have a size which is in any case greater than two billion individuals. On the basis of the fishing mortality, we once calculated the size of the commercial stock in the autumn of 1934 as 2270 million pieces (22). Actually there were more than this, since mortality from natural causes was not taken into consideration. Considerations to be mentioned immediately also lead to the conclusion that the average size of the stock is more than twice the mean yearly catch.

As a result of an experiment of the Volga-Caspian Fishery Research Station in 1934-36 on the Loshchina bayou (ilmen), it was determined that over its area of 23 hectares 160,000 fish spawned on the average, of which number 20,000 (12.8%) were females; or for the whole period of spawning there were about 1000 females per hectare. According to estimates of the same station, there are in the Volga delta about 500,000 hectares of spawning space. Having in mind this area only, and neglecting the vobla's other spawning areas (in the Ural and Emba Rivers, and in many waters near the sea) which do not have much importance now because of the fall in level of the Caspian, we can compute that about 0.5 billion females take part in spawning. Together with the males the total number of spawning vobla becomes 3.5-3.9 billion. If we consider the 1 billion vobla caught, the total number of mature fish (or the commercial stock) is of the order of 4.5-4.9 billion.

Mature vobla are captured which have two or more summers' growth. In samples from experimental catches in late autumn, at the time of the dense aggregations on the wintering grounds, the catch of non-maturing vobla is 25-30%. But since a part of the young (consequently for the most part immature) fish are able to pass through the trawl, the total abundance of immature vobla (excluding young of the year) is greater, and apparently comprises about 40% of the mature vobla. A more plausible size for the vobla population of two summers and older is given by a figure of the order of 5.5-6.5 billion.

In our computation all the figures except the area of the spawning grounds are obtained by direct calculation. However, taking into account that in determining the size of the spawning area use was made of cartographic material and a large-scale experiment made by collaborators at the Volga-Caspian Fishery Research Station, we believe that the vobla spawning area mentioned above corresponds fairly closely to reality. Therefore, taking the commercial stock which we have calculated as a basis, we find that the intensity of exploitation of vobla is not less than 20% of that stock, and calculated [page 163] on a weight basis, it is approximately 30%, since the fishery has a tendency to select the heavier individuals.

There are in the literature many figures for the intensity of exploitation of the vobla. The figure of Mesiatsev (21, p. 9) has attracted particular attention; it estimates that in the North Caspian the intensity of exploitation was 12%. If we accepted this figure, then in our computation the area of the spawning grounds would be increased to more than twice (to 230%), which would be in contradiction to the observations made by the Volga-Caspian Fishery Research Station. Assuredly the intensity of exploitation suggested by Professor Mesiatsev is much too low. We must also observe that a trial of any considerably greater rate of exploitation also leads to results clearly incompatible with reality. For example, the suggestion of Professor Baranov (11) and others, that the intensity of exploitation of vobla is 50-59%, on being translated into terms of our data would mean that the catch equalled the recruitment to the stock and that vobla do not die from natural mortality at all, while at such a magnitude of rate of exploitation the spawning would be decreased to 200-250 thousand hectares. Thus we believe it is impossible to accept the data of Mesiatsev, Baranov and others, and submit that the figure we have computed is closer to reality.

To the spawning grounds there go a tremendous number of mature vobla. In spite of this catches in the river have fluctuated quite strongly. The catches in the Ural and Emba have exhibited particularly violent changes (Table 37).

The causes of fluctuation in the catches of vobla in these rivers are various. In the Volga they depend principally upon the size of the stock. This is shown by the data presented in Table 38.

From this table it is apparent that catch, mean length and weight vary in the same direction. Considering what was found earlier concerning changes in the commercial stock in relation to growth, we must emphasize that this factor, thanks to which such a correlation exists [page 164], is an important one. Although data on the characteristics of the post-spawning survivors are still scanty, they all suggest that there is a direct relation between them and the catch: i.e., the greater the spring catch on the river, the more fish return to sea, and the greater is the number of survivors of the commercial stock. Apparently the size of the catch of vobla in the Volga depends on the size of the commercial stock.

The decrease in catch in the Ural River is the result principally of the fall in level of the Caspian Sea. In recent years its level has fallen 124-127 cm. below the mean of earlier years, as computed from the Baku depth gauge up to 1928. As a result the level of the lower Ural River has decreased greatly, and former spawning areas above the town of Guryev have lost their importance as a result of the decrease in spring flooding. Today the important vobla spawning grounds are in the delta of the Ural, below the river fishing grounds, and as a result few vobla are caught in the river. Nevertheless in recent years marking experiments on vobla (17) have shown that there is frequent exchange of vobla from the Ural-Emba to the Volga region. It is very probable that as a result of the lowering of the level, conditions for wintering vobla in that region have worsened, and they have begun gradually to abandon it.

The fluctuations in catch in the Emba River, which does not empty its water into the sea every year, depend mainly upon unfavourable physical conditions. The influence of these conditions has increased particularly as the level of the sea has gone down. The reduced catches in recent years are a direct result of the action of driving winds at the time of the main spawning migration of vobla into the river.

Changes in conditions, in relation to variations in catch in the rivers of the North Caspian, allow us to draw in very general terms a picture of the probable future course of the vobla stock in the event there is a further fall in water level.

In the Ural-Emba region, the future of the vobla stock is determined by the fact that there is no need to consider any other hypothesis than that the important cause of their decrease is the fall in water level.

In the Volga region the decrease in level has affected the vobla stock only slightly. At the present time the delta of the Volga has enormous importance in the reproduction of the vobla stock. Evidence of this is provided by the following calculation of its commercial return, based on materials from the Volga-Caspian Fishery Research Station obtained by experimental work in 1934-36 on the Loshchina bayou. It was determined that at the moment of their departure from the bayou there were fry averaging 2.35% of the number of eggs laid. Since the mean fecundity of the vobla is 25,000 eggs, we must compute that for every female on the spawning grounds 587 fry are produced. As already noted, over the whole spawning period there are about 1000 females per hectare, and in the whole Volga delta, comprising 500,000 hectares of spawning grounds, there are 0.5 milliard females. Thus we find that at the time of their descent to the sea there is the colossal quantity of about 270-300 milliards of young vobla. In relation to this quantity, that is to the number of descending fry, the quantity of fish caught by the fishery is about 0.3%. Suppose that the spawning area were to increase to double or even triple what it is. In that event the commercial return must be correspondingly increased. But considering passive descent, which in the work at Loshchina was not taken into consideration and which, as V. Tanasiĭchuk (30) shows, is of greater importance in some years than is active descent, we can affirm that the commercial take of vobla would not exceed 1% of the young going downstream even in that event.

Spring floods have great importance for vobla reproduction, above all in providing food for the young. It can be said that [page 165] if the flood provides a broad distribution of spawners in the delta and a dispersion of their eggs over it at the time when inundation begins, then its importance becomes even greater at the time the new generation is feeding in the delta.

A change in the flooding regime of the delta must be reflected not only in the spawning of the vobla but also in their nutrition. Obviously a shift in flood-time as a result on regulating the water discharge of the Volga to other seasons, or its liquidation, would be very destructive for vobla. In that event the production of vobla would be disrupted, and the Volga delta would scarcely produce the tremendous number of young which it does at present. Undoubtedly young vobla will not be sufficient as long as they are destroyed in large numbers by predators (sander, zherekh (Aspius), frogs, etc.). In spite of the fact that it is in the sea that the wandering and growth of the fish take place and the young spend the greater part of their life there, a decrease in the number of fry will certainly have unfavourable consequences.

In the event of further lowering of the level of the sea, wintering conditions for the vobla will apparently worsen because of restriction of the wintering areas and a different distribution of the water flow as a result of natural drying up of the arms of the delta and approximation of the delta to the 3.7 meter contour. The vobla do not winter in the central part of the sea. Here the winter temperature of the water reaches -0.4°, at a time when the water offshore near the river mouths is 3.0°.

A decrease in abundance of young as a result of the circumstances described and a deterioration of wintering conditions undoubtedly would result in a decrease in the vobla population. The decrease will be the greater, the more seriously the present flooding regime is altered - whether floods are only diminished, or whether they are eliminated completely.

LITERATURE

BRK = Bi͡ulleten Rybnovo Khozi͡aĭstva
RK SSSR = Rybnoe Khozi͡aĭstvo SSSR
VNIRO = Vsesoi͡usnyĭ Nauchno-issledovatelskiĭ Institut Rybnovo Khozi͡aĭstva i Okeanografii

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TABLE 1. Dynamics of the catches and stocks of vobla in thousands of metric tons.

Year	Catch			Stock[1]				Exploitation in %
	Autumn	Spring	Year	Autumn	Spring	Year	Increase	
Pre-war mean	37	113	150	300	263	150	150	50
1917-1918	40	74	114	300	260	186	138	44
1918-1919	34	72	106	324	290	218	127	33
1919-1920	3.3	27	30	345	342	315	95	9
1920-1921	25	47	72	410	385	338	87	18
1921-1922	25	97	122	425	400	303	99	28
1922-1923	32	88	122	402	370	282	106	30
1923-1924	27	75	102	388	361	286	105	26
1924-1925	37	105	132	391	354	249	117	33
1925-1926	62	127	189	366	304	177	141	51
1926-1927	87	34	121	318	231	197	134	38
1927-1928	62	60	122	332	270	210	130	37
1928-1929	60	100	160	340	280	180	140	47
1929-1930	89	100	189	320	231	131	156	59
1930-1931	..	..	..	287	..	..	..	..

[1]The calculation of increase is according to the formula:

$$150 - \frac{\text{Remainder of the stock} - 150}{3} = \text{Increase (in thousands of tons).}$$

TABLE 2. Dynamics of the catches and stocks of vobla in thousands of tons.

Year	Catch			Stock			
	Autumn	Spring	Year	Autumn	Spring	Year	Increase
1924-1925	33	92	125	391	358	266	111
1925-1926	81	128	209	377	296	168	144
1926-1927	92	35	127	312	220	185	138
1927-1928	62	57	119	323	261	204	132
1928-1929	62	102	164	336	274	172	143
1929-1930	99	121	220	315	214	95	168
1930-1931	127	150	277	263	136	..	..

TABLE 3.

Year	0	1	2	3	4	5	6	7	8	9
1890	4.0	4.9	6.0	7.3	10.3	11.8	11.9	13.4	13.2	14.8
1900	13.3	14.6	14.1	16.7	14.9	15.6	13.5	15.0	14.8	16.1
1910	17.6	16.9	20.0	21.0	20.7	13.6	12.0	11.5	8.7	6.5
1920	4.5	6.5	8.5	7.5	8.0	9.2	14.0	13.7	16.9	15.6
1930	17.5	..	..	..	..	..	..	..	..	..

TABLE 4.

Year	0	1	2	3	4	5	6	7	8	9
1890	..	..	..	..	..	..	..	..	0.98	1.06
1900	0.87	0.88	1.02	0.78	0.71	0.87	0.93	0.78	1.30	1.82
1910	1.60	1.24	0.66	0.83	1.03	1.79	1.43	1.62	0.54	0.73
1920	0.51	0.70	1.28	1.13	1.10	1.71	2.21	0.98	1.19	1.99
1930	2.44	..	..	..	..	..	..	..	..	..

TABLE 5.

Period	Year	Mean catch in millions of centners	Mean number of fishermen in thousands
I	1898-1902	0.96	14.0
II	1903-1907	0.81	15.2
III	1908-1911	1.49	16.4
IV	1912-1914	0.84	20.6
V	1915-1917	1.61	13.3
VI	1918-1921	0.62	6.6
VII	1922-1925	1.30	8.3
VIII	1927-1928	1.08	13.8
IX	1926-29-30	2.21	16.6

TABLE 6. Age composition of spring catches of vobla (from the records of the Volga-Caspian Fishery Station).

Year	Age group							
	3-summer	4-summer	5-summer	6-summer	7-summer	8-summer	9-summer	10-summer
1919	43.6	26.9	22.8	5.6	1.0	0.1	..	..
1920	25.3	49.8	17.7	6.4	0.7	0.1	..	..
1921	8.7	51.7	29.6	7.2	2.0	0.7	0.1	..
1922	0.7	48.6	42.4	6.3	1.5	0.3	0.1	0.1
1923	..	6.7	49.3	36.7	6.7	..	0.3	..
1924	..	13.3	49.3	30.3	6.6	0.5	..	..
1925	0.2	17.5	60.2	20.5	1.2	0.2	..	0.2
1926	8.9	41.2	39.0	9.3	1.2	0.2	0.2	..
1927	32.8	45.8	14.0	3.9	2.9	0.3	0.2	0.1
1928	33.8	57.1	7.8	0.8	0.3	..	0.2	..

TABLE 7. Mean length of the age groups of vobla.

Year	Age group							
	3-summer	4-summer	5-summer	6-summer	7-summer	8-summer	9-summer	10-summer
1919	19.4	20.6	23.2	25.0	26.2	27.5	..	..
1920	18.9	20.0	23.1	24.9	26.0	26.3	..	..
1921	18.7	20.3	22.9	25.1	27.0	29.2	30.3	..
1922	17.7	19.6	22.6	24.4	24.9	30.0	30.0	30.0
1923	..	19.0	21.4	23.7	25.9	..	28.0	..
1924	..	20.1	20.9	21.9	23.0	27.5	..	..
1925	17.0	19.6	21.1	23.6	24.2	27.0	..	27.0
1926	20.0	21.9	22.9	24.5	25.3	28.0	29.0	..
1927	17.8	20.6	22.9	27.6	26.2	27.0	28.5	30.0
1928	17.7	19.3	21.3	22.2	23.2	..	31.6	..

TABLE 8. Age composition of vobla from catches made in the Volga.

Year	Age group							
	2-summer	3-summer	4-summer	5-summer	6-summer	7-summer	8-summer	9-summer
1924	0.2	3.9	18.0	40.6	29.8	6.7	0.6	0.2
1925	..	0.2	15.0	61.6	21.4	1.2	0.4	0.2
1926	0.8	2.9	20.2	41.1	26.3	7.4	1.1	0.1
1927	1.4	24.1	41.0	20.3	8.9	3.3	0.9	0.1
1928	3.7	37.6	49.8	8.4	0.4	0.1	..	..
1929	2.9	42.1	42.3	10.7	1.9	0.1	..	..
1930	0.4	31.0	60.8	7.6	0.2	..	..	..
1931	4.7	16.4	44.6	29.9	4.3	0.1	..	..
1932	19.5	57.6	15.4	5.9	1.3	0.3	..	..
1933	0.3	54.5	41.7	2.9	0.5	0.1	..	..
1934	1.7	51.7	41.2	5.0	0.4	..	..	..
1935	0.4	13.8	68.8	14.6	2.3	0.1	..	..
1936	0.5	8.5	41.8	48.0	1.2	0.02	..	..
1937	2.3	51.1	28.3	15.7	2.2	0.2	..	..

TABLE 9.

Index	Year								
	1929	1930	1931	1932	1933	1934	1935	1936	1937
Catch thousands of centners	510	611	575	348	378	370	490	407	250
Mean length cm.	19.5	19.8	..	19.2	18.6	18.6	19.8	19.0	17.1
Weight grams	152	176	172	155	150	149	160	154	112

TABLE 10. Growth of 3-year-old vobla in centimeters (from samples of the seine catches in the Volga).

Year of catch	l_1	l_2	l_3
1930	8.0	13.4	16.8
1933	7.1	12.9	16.4
1935	8.0	12.9	17.2
1936	6.9	12.9	16.9
1937	7.4	12.5	16.2

TABLE 11. Growth of 4-year-olds in centimeters (from samples of the seine catches in the Volga).

Year of catch	l_1	l_2	l_3	l_4
1930	6.3	12.3	15.5	18.2
1933	6.2	11.6	15.1	16.9
1935	7.7	12.0	15.0	18.7
1936	6.8	11.3	15.3	18.1
1937	6.6	10.8	14.7	17.5

TABLE 12. Deviation of the mean length of the age groups in the catches of 1922-29 from the grand mean for the whole period.

Age group	Year								Mean
	1922	1923	1924	1925	1926	1927	1928	1929	
3-summer	-0.7	..	-0.5	-0.3	+1.0	+0.6	-0.2	..	22.5
4-summer	-1.5	+0.6	-0.3	-1.3	-0.5	-0.8	+1.4	+2.5	24.2
5-summer	+0.4	-0.4	-0.1	-0.7	-1.0	-0.7	+1.1	+1.8	24.9
6-summer	+0.9	+0.2	0	-0.6	-0.8	-1.1	+0.4	+1.0	25.6
7-summer	+1.3	+0.8	+0.6	-1.0	-0.6	-1.0	-0.2	0	26.3
8-summer	+1.5	+0.9	+1.4	-1.8	-0.1	-1.4	0	+0.6	26.8
9-summer	+1.1	+0.9	+1.0	+1.1	-0.4	-1.1	-1.4	-1.6	28.4

TABLE 13.

Year of hatching	1917	1918	1919	1920	1921	1922	1923	1924	1925	1926
Year-class abundance	+	+	0	-	+	+	-	+	-	0
Growth	+	-	-	-	-	-	+	+	?	?

TABLE 14. [p. 137] Fluctuations of the stocks of herring in 1924-29.

Year	Year-class strength and growth	Age groups 3	4	5	6	7	Our estimates of the size of the population and growth	Lissner's estimate of the stock	Mean catch per voyage
1924	Strength	+	−	0 •••	+ ••••	+ ••	Higher than average	Decrease	41
	Growth	−	−	−	−	+	Weak		
1925	Strength	+ •••	+ ••••	− ••	0 ••	+	Maximal	Minimum	37
	Growth	−	−	−	−	−	Very poor		
1926	Strength	−	+ ••	+ •••••	− ••	0	Average	Increase	60
	Growth	+	−	−	−	−	Weak		
1927	Strength	+ ••	−	+ •••	+ ••	−	Greater than average	Decrease	54
	Growth	+	+	−	−	−	Greater than average		
1928	Strength	−	+ ••	− ••	+ ••••	+	Minimal	Increase	62
	Growth	?	+	+	−	−	Good		
1929	Strength	?	−	+ •••	−	+ ••••	Less than average	Further increase	90
	Growth	?	?	+	+	−	Good		

TABLE 15. Age composition of herring caught off the north coast of Donegal.

Year	Age groups									
	3-summer	4-summer	5-summer	6-summer	7-summer	8-summer	9-summer	10-summer	11-summer	12-summer
1921	16.4	25.1	16.5	11.3	19.5	8.8	2.3	0.8	0.2	..
1922	6.3	26.0	22.0	20.0	6.7	13.8	3.6	1.3	0.2	0.3
1923	45.5	16.0	18.6	12.4	2.3	1.3	2.6	0.6	0.6	..
1924	11.6	41.7	14.9	18.0	4.7	6.1	1.1	1.3	0.4	0.1
1925	9.5	21.6	40.3	5.5	14.8	3.7	2.8	1.1	0.3	..
1926	44.2	13.6	14.7	16.4	3.6	4.1	1.0	1.8	0.2	..
1927	63.0	11.7	4.9	10.0	7.4	1.0	1.4	0.3	0.1	0.1
1928	25.6	52.4	11.8	4.7	2.9	1.6	0.8	0.2	..	..
Mean age composition	27.76	26.01	17.96	12.29	7.74	5.05	1.9	0.92	0.25	0.06
Mean smoothed by a curve	27.76	26.01	17.96	12.3	8.0	4.8	2.5	0.9	0.24	0.06
Mortality (%)	6.0	31.0	31.5	35.0	40.0	48.0	64.0	73.0	75.0	..
Percentage survival to the next year	94.0	69.0	68.5	65.0	60.0	52.0	36.0	27.0	25.0	..

TABLE 16.

Age group	3-summer	4-summer	5-summer	6-summer	7-summer	8-summer	9-summer	10-summer	11-summer
Percentage of stock	16.4	25.1	16.5	11.3	19.5	8.8	2.3	0.8	0.2

TABLE 17.

Age group	3-summer	4-summer	5-summer	6-summer	7-summer	8-summer	9-summer	10-summer	11-summer	12-summer	
Percentage of stock	4.6	19.0	16.0	14.6	4.9	10.1	2.7	1.0	0.15	0.2	73.:

TABLE 18.

Year	Age group										Stock relativ to 192
	3-summer	4-summer	5-summer	6-summer	7-summer	8-summer	9-summer	10-summer	11-summer	12-summer	
1921	16.4	25.1	16.5	11.3	19.5	8.8	2.3	0.8	0.2	..	100
1922	4.6	19.0	16.0	14.6	4.9	10.1	2.7	1.0	0.15	0.2	73.2
1923	39.5	13.9	16.2	10.8	2.0	1.1	2.3	0.5	0.5	..	86.8
1924	8.9	31.8	11.4	13.8	3.6	4.7	0.9	1.0	0.3	0.08	76.5
1925	5.5	12.6	23.5	3.2	8.6	2.1	1.6	0.6	1.7	..	58.0
1926	31.2	9.6	10.4	11.6	2.5	2.9	0.7	1.3	0.14	..	70.3
1927	92.3	17.1	7.2	14.7	10.8	1.5	2.1	0.4	0.15	0.15	146.4
1928	41.6	85.7	19.2	7.7	4.7	2.6	1.3	0.3	..	..	163.1

TABLE 19.

Year	Age group 3-summer	4-summer	5-summer	6-summer	7-summer	8-summer	9-summer	10-summer	11-summer	12-summer	Total
1914			(x = 168)	..	19.5	10.1	2.3	1.0	0.17	..	x+33.1 = 201.0
1915		(x = 47.2)	..	11.3	4.9	1.1	0.9	0.6	0.14	0.15	x+19.0 = 66.2
1916	(x = 47)		16.5	14.6	2.0	4.7	1.6	1.3	0.15	..	x+40.8 = 87.8
1917	(x = 22.3)	25.1	16.0	10.8	3.6	2.1	0.7	0.4	..	..	x+58.7 = 81.0
1918	16.4	19.0	16.2	13.8	8.6	2.9	2.1	0.3	(x = 0.3)		79.3+x = 79.6
1919	4.6	13.9	11.4	3.2	2.5	1.5	1.3	(x = 0.5)			38.4+x = 38.9
1920	39.5	31.8	23.5	11.6	10.3	2.6	(x = 4.6)				119.8+x = 124.4
1921	8.9	12.6	10.4	14.7	4.7	(x = 4.8)					51.3+x = 56.1
1922	5.5	9.6	7.2	7.7	(x = 5.7)						30.0+x = 35.7
1923	31.2	17.1	19.2	(x = 27.2)							67.5+x = 94.7
1924	92.3	85.7	(x = 154.5)								178.0+x = 332.5
1925	41.6	(x = 109.0)									41.6+x = 150.6

TABLE 20. Length of herring at the moment of formation of annulus III on the scales.

Year	Age group	
	3-summer l_3	4-summer
1920	25.91	24.91
1921	25.50	23.54
1922	26.48	25.01
1923	25.02	24.40
1924	26.43	24.54

TABLE 21.

Age group	2-summer	3-summer	4-summer	5-summer	6-summer	7-summer	8-summer	9-summer	10-summer	11-summer
%	0.1	13.1	31.9	10.3	21.6	4.4	9.1	8.0	0.9	0.3

TABLE 22.

Age group	4-summer	5-summer	6-summer	7-summer	8-summer	9-summer	10-summer	11-summer
%	38.0	30.5	7.4	14.8	2.5	4.0	2.9	0.3

TABLE 23.

Age group	3-summer	4-summer	5-summer	6-summer	7-summer	8-summer	9-summer	10-summer
Relative abundance	9.0	35.3	32.5	7.6	14.2	2.5	3.6	2.1

TABLE 24.

Factor of maturity		$\frac{N_7}{N_6}$ = 5.5	$\frac{N_8}{N_7}$ = 4.4	$\frac{N_9}{N_8}$ = 2.8	$\frac{N_{10}}{N_9}$ = 1.8	$\frac{N_{11}}{N_{10}}$ = 1.1	$\frac{N_{12}}{N_{11}}$ = 0.67	$\frac{N_{13}}{N_{12}}$ = 0.49	$\frac{N_{14}}{N_{13}}$ = 0.28	$\frac{N_{15}}{N_{14}}$ = 0.17	Observed composition in 1934		Calculated composition for 1935	
Age of first spawning	6	7	8	9	10	11	12	13	14	15		%		%
6	7										7	0.7		
7	4	38 58									58	5.7	42	2.8
8		35 6	255 [108]								114	11.3	290	19.5
9		4	65 24	303 93							117	11.6	372	24.9
10		1	14 11	56 41	168 68						121	12.0	238	15.9
11			7 2	25 14	41 54	75 42					112	11.1	148	9.9
12		1	1 1	8 6	33 44	25 85	28 39				176	17.3	95	6.4
13			4	4 5	27 10	51 29	24 26	17 10			84	8.3	123	8.2
14		3	2 2	3 5	6 8	17 10	16 13	6 10	3 2		53	5.2	53	3.7
15		2 4	1 9	3 12	5 16	6 14	8 19	6 9	1 8		91	9.0	32	2.1
16		2	5	7 3	10 9	8 8	11 12	5 9	5 3	1	45	4.4	53	3.7
17				2 4	5 3	5 4	7 3	5 4	2 3	1	22	2.2	26	1.7
18				2	2 3	2 1	2 1	2	2		5	0.5	12	0.8
19					2 3	1 1	1				5	0.5	3	0.2
20					2	1			1		1	0.1	3	0.2
21							1				1	0.1		
											1012	100.0	1490	100.0

TABLE 25. Age composition of the commercial schools of vobla (in %).

Year	Age group					
	2-summer	3-summer	4-summer	5-summer	6-summer	7-summer
1934	2.4	26.68	62.1	8.8	0.02	..
1935	2.4	17.53	55.5	23.85	0.7	0.02
1936	2.1	47.80	36.0	11.9	2.2	..
1937	5.6	35.10	58.1	1.2	..	..

TABLE 26. Age composition of autumn catches by trawls in the sea.

Year	Age group					
	2-summer	3-summer	4-summer	5-summer	6-summer	7-summer
1934	0.03	8.45	57.1	31.1	3.3	0.02
1935	0.2	5.2	44.1	48.7	1.7	0.1
1936	..	0.7	33.9	54.4	10.6	0.4
1937	..	5.4	36.0	48.6	9.7	0.3

TABLE 27.

Year of catch (autumn)	3-summer fish			4-summer fish		
	% mature	Length	Growth	% mature	Length	Growth
1934	85	18.0	4.4	88	19.0	4.0
1935	75	16.7	4.3	82	18.6	2.8
1936	55	15.6	4.1	82	17.3	3.3
1937	58	15.8	4.0	80	17.5	3.0

TABLE 28.

Year of catch	Recruits %	Remainder %
1934	37.2	62.8
1935	36.8	63.2
1936	57.8	42.2
1937	60.9	39.1

TABLE 29. Age composition of the recruits to the commercial schools of vobla (in %).

Year of catch (autumn)	Age group			
	2-summer	3-summer	4-summer	5-summer
1934	6.6	40.9	51.8	0.7
1935	6.6	35.8	51.5	5.1
1936	3.6	63.7	31.0	1.7
1937	9.2	20.8	70.0	..

TABLE 30. Mean length of the age groups in the commercial stock.

Year of catch (autumn)	Age group						General mean
	2-summer	3-summer	4-summer	5-summer	6-summer	7-summer	
1934	16.8	18.0	19.0	20.8	22.2	..	18.8
1935	14.9	16.7	18.6	20.8	21.9	23.5	19.0
1936	14.0	15.6	17.3	18.7	19.2	..	16.6
1937	14.4	15.8	17.5	17.8	..	..	16.7

TABLE 31. Rate of growth of 3- and 4-summer vobla.

Year of catch	3-summer				4-summer				
	t_1	t_2	t_3	Year-class	t_1	t_2	t_3	t_4	Year-class
1933	7.1	5.8	2.4	1931	6.6	6.2	3.6	2.6	1930
1934	8.5	4.5	4.4	1932	7.3	4.6	3.5	4.0	1931
1935	6.7	6.2	4.3	1933	6.6	5.1	4.2	2.8	1932
1936	6.7	5.3	4.1	1934	6.7	4.4	3.7	3.3	1933
1937	6.6	5.0	4.0	1935	6.4	4.4	3.7	3.0	1934

TABLE 32. Age composition and mean length of downstream-migrating vobla taken in spring of 1935.[1]

Index	Age group				
	2-year	3-year	4-year	5-year	6-year
Mortality %	24.1	69.1	6.0	0.7	0.1
Length	16.6	17.8	19.0	20.7	21.0

[1]The work on downstream migrating vobla was done by V. G. Ivanchinov.

TABLE 33. Age composition of the Remainder in the vobla stock (in %).

Year of catch (autumn)	Age group				
	3-summer	4-summer	5-summer	6-summer	7-summer
1934	18.4	68.0	13.5	0.1	..
1935	6.8	57.2	34.8	1.1	0.1
1936	26.0	42.8	26.0	5.2	..
1937	57.3	39.6	3.1	..	..

TABLE 34. Age composition of the commercial stock of vobla in different parts of the North Caspian

Region	Year (autumn)	Age group					
		2-summer	3-summer	4-summer	5-summer	6-summer	7-summer
Western	1935	2.9	15.9	56.7	23.7	0.7	0.1
	1936	1.5	43.0	39.2	12.9	3.4	. .
	1937	10.6	42.1	46.0	1.3	. .	. .
Central	1935	3.3	16.9	61.9	17.4	0.4	. .
	1936	3.6	54.9	30.2	10.7	0.6	. .
	1937	. .	22.5	73.0	4.0	0.5	. .
Eastern	1935	1.0	19.8	47.8	30.4	1.9	. .
	1936	. .	53.7	37.4	8.9	. .	. .
	1937	0.5	58.2	70.3	1.0	. .	. .

TABLE 35. Mean lengths of the age groups in the commercial stock of vobla in different parts of the North Caspian

Region	Year (autumn)	Age group					
		2-summer	3-summer	4-summer	5-summer	6-summer	7-summer
Western	1935	15.2	17.0	19.1	21.4	23.4	(28.0)
	1936	13.7	15.5	17.1	18.3	18.7	. .
	1937	13.9	16.0	17.5	17.8	. .	. .
Central	1935	13.6	15.8	17.9	19.4	21.5	. .
	1936	13.7	15.2	17.3	19.5	20.2	. .
	1937	. .	15.7	17.6	18.9	20.7	. .
Eastern	1935	15.0	17.3	19.2	21.0	(21.0)	. .
	1936	14.3	16.1	18.1	19.0	. .	. .
	1937	15.0	15.6	17.5	17.5	. .	. .

TABLE 36. Mean length of the age groups and mean weight of vobla in the Volga.

Data	Age group						Mean length cm.	Mean weight g.
	2-summer	3-summer	4-summer	5-summer	6-summer	7-summer		
Predicted for 1935	16.8	18.0	19.0	20.8	22.2	23.5	19.5	180
Observed	15.4	17.4	19.3	21.3	22.5	..	19.2	163
Predicted for 1936	14.9	16.7	18.6	20.8	21.9	28.0	19.0	156
Observed	14.2	16.7	18.2	20.1	22.3	28.0	19.0	154
Predicted for 1937	14.0	15.6	17.3	18.7	19.2	..	16.6	101
Observed	13.7	16.0	18.0	19.2	21.1	23.0	17.1	107

TABLE 37. Catches of vobla in the Volga, Ural and Emba Rivers, in thousands of centners.

River	Year							
	1930	1931	1932	1933	1934	1935	1936	1937
Volga	611	575	348	378	370	490	407	250
Ural	147	163	357	6.5	11.3	11.4	14.1	12.1
Emba	..	..	41.5	20.6	25.8	40.8	2.1	3.1

TABLE 38. Fluctuations of catch in the Volga.

Statistic	Year							
	1930	1931	1932	1933	1934	1935	1936	1937
Catch (in thousands of centners)	611	575	348	378	370	490	407	250
Mean length (cm.)	19.8	..	19.2	18.6	18.6	19.8	19.0	17.1
Weight (g.)	176	172	155	150	149	160	154	112
Remainder (%)	..	..	..	..	62.8	63.2	42.2	39.1

Figures for Translation No. 81 by G. N. Monastyrsky, 1952 (translated by W. E. Ricker)

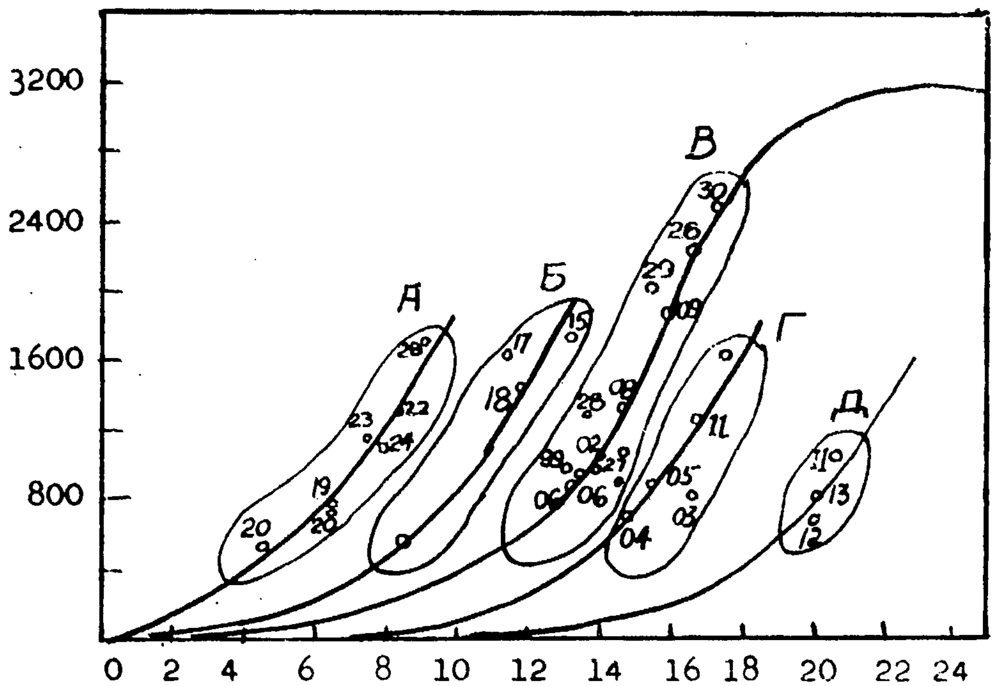

Figure 1. Diagram No. 1 (after Morozov).

(Translator's note: In the above figure the duplication of some years, the absence of others, and the presence of unidentified points, are not explained by Monastyrsky.)

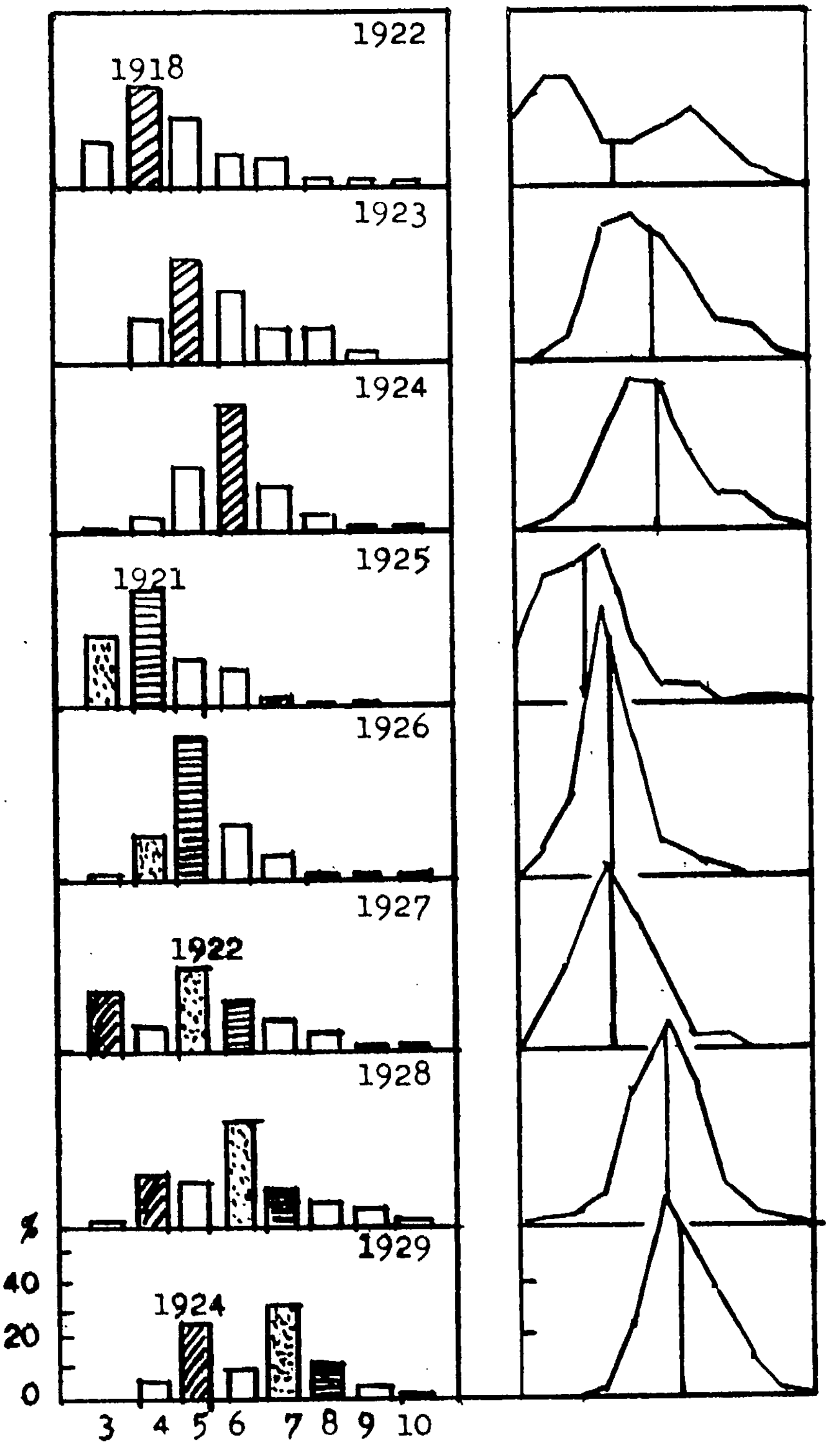

Figure 2. Age composition of herring on the Fladen Bank.
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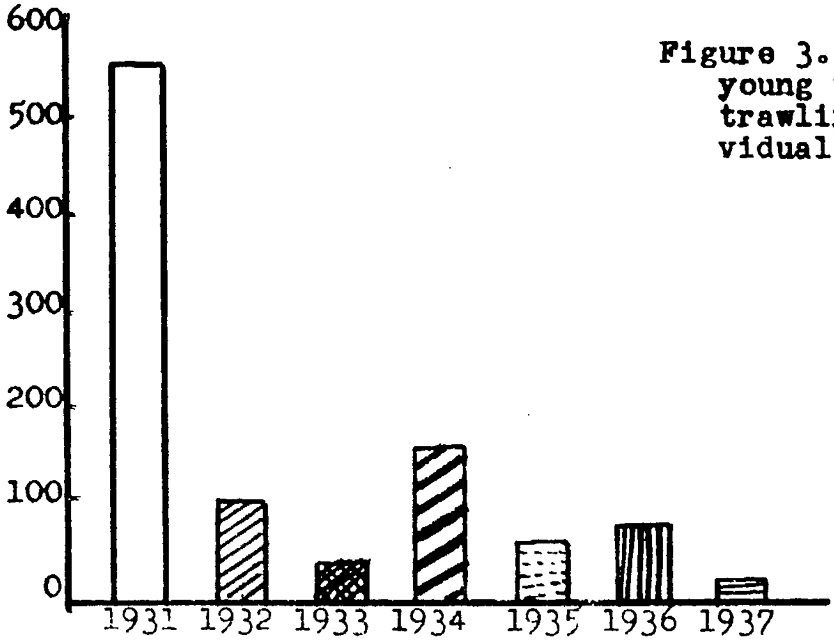

Figure 3. Mean catches of young vobla per hour of trawling (number of individuals).

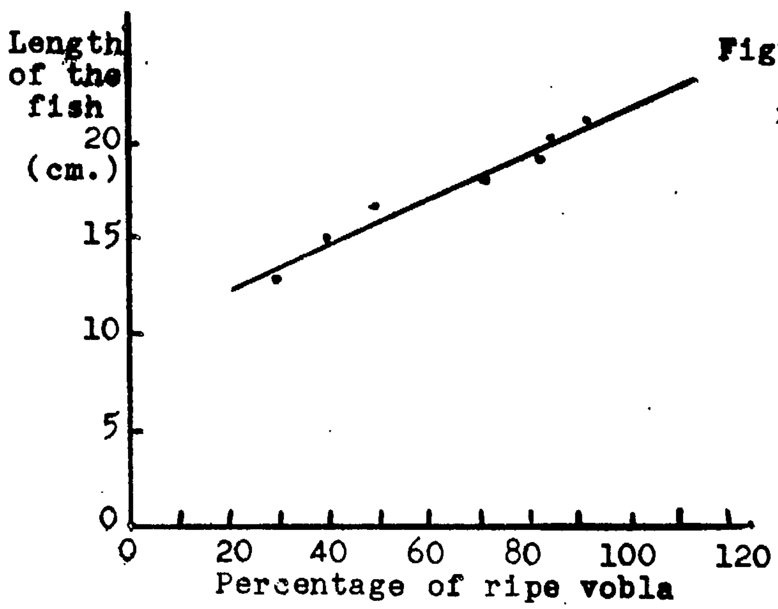

Figure 4. Relation between length and percentage maturity in vobla.

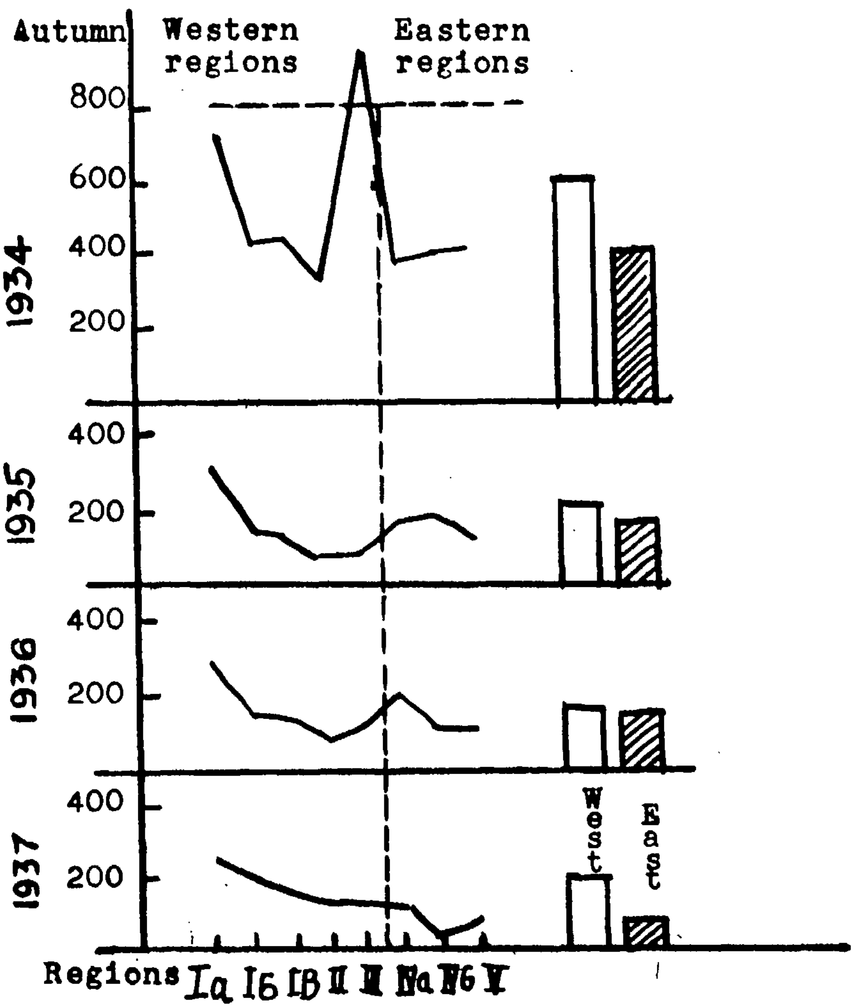

Figure 5. Mean catch of vobla per 100 nets.

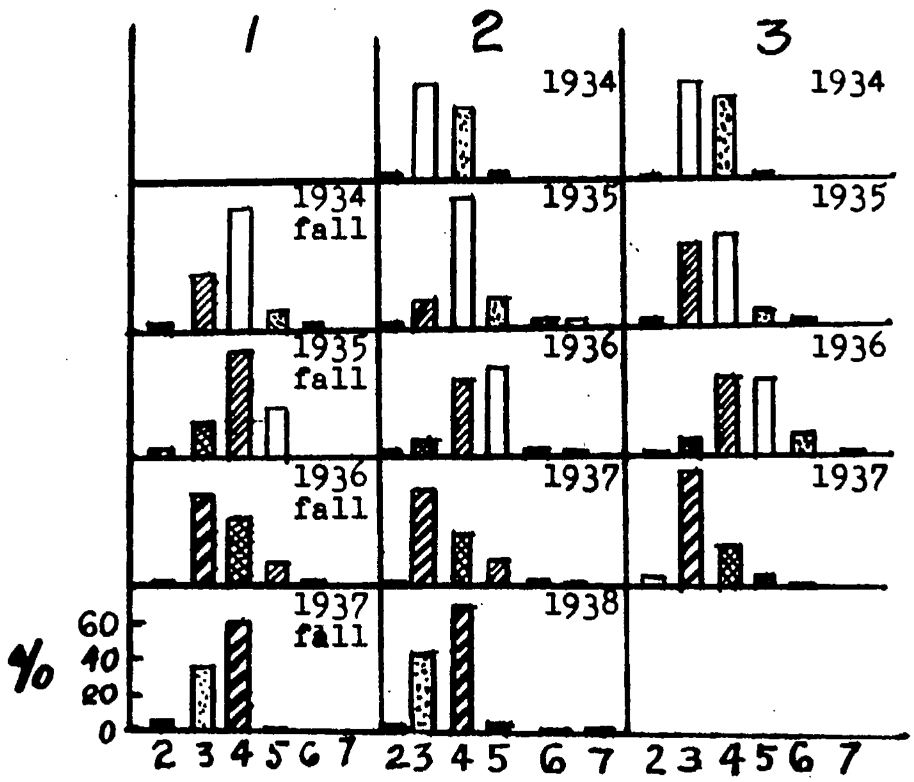

Fig. 6. 1--Age composition of the commercial stock of vobla; 2--Age composition of the spring catch of vobla in the Volga; 3--Age composition of the spring catch of vobla in the Ural River.