THEORY AND ESTIMATION OF FISHING GEAR

Chapter 1, Section 2

Chapter 7, Sections 42-48

by

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CHAPTER 1

FIBROUS MATERIAL AND HARDWARE

S2 Numeration, thickness and strength of thread and twine

In practice, the thickness of the thread is determined on the basis of its weight and is indicated by a number. In the metric system, the number of the thread indicates the length in metres per g. Thus, if 50 m of thread weigh 2 g, this thread is No. 25 (50/2 = 25).

It should be mentioned here, that not so long ago, an English way of numeration was used to characterize the thread. The main inconveniences in using this numeration were the following: the numbers of thread made of linen, hemp and cotton are not the same and; the measurements are expressed in English pounds and yards.

In this numeration, the number of the thread shows how many skeins of a certain thread are in one English pound (454 g). The length of the skein is:

for cotton...................... 840 yards or 768 m
for linen and hemp............. 300 yards or 274 m.

To determine the number of the thread, there are special instruments (described further on) which facilitate the process of taking a certain piece of thread to form a skein of a certain length for weighing. It is also possible to cut a piece of thread several metres long to weigh it on accurate (laboratory) scales and to do a simple calculation.

A twine is characterized by the number of the thread it is made of and also by the number of strands composing it. It is shown by a fraction.

If a twine has No. 24/2, it means it was made of 2 strands of number 24 thread. For example, a twine of double-twist, made of No. 8 thread and consisting of 2 triple strands (that is containing 6 strands) is indicated in the following way: No. 8/2 x 3. However, it very often is indicated simply by: No. 8/6, especially for cotton twine.

A twine consisting of 2, 3, etc. strands weighs 2, 3, etc. times more than a single strand and, consequently, its weight is equal to the weight of that twine whose number is 2, 3, etc. times smaller. In other words, by reducing the fraction which indicates the number of the twine, it is possible to determine the number of a single-twist twine, which corresponds to the multi-twist twine in weight and thickness. The number obtained in this manner is called the strand number. This number provides a possibility of comparing different twines. Thus, twines of No. 24/2 and No. 30/3 can be indicated by the standard numbers, No. 12 and No. 10. Consequently, the second twine is thicker than the first one. The thickness of the twine indicated by the following numbers: No. 24/2, No. 36/3 and No. 50/4 (whose standard numbers are correspondingly No. 12, No. 12 and No. 12 1/2) is practically the same.

It must be pointed out that the calculations described above are not absolutely accurate since, in the process of the twisting the thread into a twine, the total length of the twine is shortened and the twine turns out to be actually heavier than it can be expected on the basis of the calculations. This shortening can be as much as 2-5% in linen and hemp twine of single twist, and 20-25% in thick twine of the double twist. The amount of shortening can be determined if a piece of twine is unraveled and the length of the strands obtained is measured, and this length is compared with the initial length of the piece of twine taken for examination.

Thus, twine can have the following numbers:

1. "structural" number, for instance, No. 24/2
2. the number standard, for instance, No. 12
3. "aggregate" number (actual number, the number of the twine) which is always smaller than the standard number due to the amount of the shortening of the twine in the process of spinning.

Sometimes, in order to bring the "aggregate" number to the same value as the "structural" number, it is necessary to take thread of a lighter and finer kind than is required according to the number of the twine.

It should be kept in mind that all fibrous materials always contain a certain quantity of moisture which they absorb from the air. Normally, cotton materials must contain 8 1/2% of moisture, linen and hemp materials 12%, as compared with absolutely dry material. If a very accurate determination of the number of twine is required, it must be carried out at the percentage of the moisture indicated above. The percentage present when the twine is purchased may be considered to be normal.

The increase in moisture content can take place in the process of the manufacture of twine as well as during the storage of the material. In this connection, the results of the experiments which have been carried out at the Fisheries Station on Lake Krugloe can be cited. Samples of linen and hemp twine were periodically weighed throughout the year, and the changes in the weight, in connection with the changes in the air, were observed. The extremes of the atmospheric moisture were the dry air of the room in winter and the moist air during the damp days in summer. It was found that under these conditions, the weight of linen twine differs by 3%, while that of hemp twine by 3.4% from the mean value.

Therefore, in order to determine the number of the twine, the length (l) of the piece of twine must be measured in metres, the weight must be determined in grams (p.) and the number of the strands (n) must be counted. Then, the metrical number (N) can be determined from the formula:

$$N = un\,(l/p)$$

here, coefficient u is the correction for the degree of shortening in the process of twining. As applied to our materials, it can be used as follows:

for twine of the single twist (hemp) .... $u = 1.03$
for twine of the single twist (linen)........... $u = 1.05$
for twine of the double twist (cotton, fine) . . $u = 1.10$
for twine of the double twist (cotton, medium) . $u = 1.15$
for twine of the double twist (cotton, thick). . $u = 1.20$

Diameter of the twine (and thread), which is of great importance in construction of the fishing gear, naturally depends on the quantity of the material used for the twine. Therefore, the smaller the number, the greater is the diameter of the twine. However, the diameter of the twine depends also on the lay of the twine, i.e. on the softness or hardness of the given twine.

Thus, threads of the same number can vary somewhat in their diameter, so that the determination of the number is somewhat conditional. Measurement of the twine under a microscope with an eye-piece micrometer, or by means of a mechanical micrometer, when a twine is somewhat compressed will give somewhat different results. Therefore, in many cases, it is more practical to determine a theoretical diameter of the thread and twine through calculations based on its weight and number.

Thus, if the length of a piece of thread is (ℓ), diameter (d), its weight (p), and its specific gravity (γ), which for linen, hemp and cotton = 1.5, then,

$$p = (\pi d^2/4)(gr)$$

(where length is in cm, weight in g); on the other hand, on the basis of the metrical number,

$$N = 1/100p \text{ or: } p = 1/100N \text{ then: } 1.5(d^2/4)g = 1/100N \text{ or:}$$

$$d = (4/(1.5\,\pi\,100N))^{0.5} \text{ or approximately:}$$

$$d = 0.1(N)^{-0.5}\,\text{cm} = 1.0(N)^{-0.5}\,\text{mm}$$

It should be pointed out that various scientists have found different values for the numerator of this formula ranging from 0.95 to 0.71 (in mm). The diameter of the twine can also be determined from this formula if the value of the number standard is used. However, in the determination of the diameter of the twine, it is necessary to take into account the difference between its "aggregate" number and the standard number, as well as the fact that the cross-section of the twine is not completely filled up with the strands.

Experimental data give the following formulae:

for twine of single twist $d = 1.1\,(n/N)^{0.5}$

for twine of double twist $d = 1.3\,(n/N)^{0.5}$

where N/n indicates "structural" number of the twine. The strength of the twine depends on quality and quantity of its material; the quantity is, apparently, in direct proportion to the weight of the twine of certain length and in inverse proportion to the number of the twine.

Consequently, the product of the strength of a twine by its number is a constant value

$$r(N/n) = C.$$

where r is the strength of the twine which is characterized by the effort necessary to tear the twine.

It is evident that this product, which is called the standard strength, corresponds to the strength of the twine No. 1 made out of certain material, and characterizes the quality of the material of the twine and the quality of its manufacture.

As can be seen, the value of the standard strength depends on the system of the numeration of the twine. It is convenient for comparison of the quality of twines which are described in the units of the same system of numeration. It also permits a calculation of the strength of a certain twine. The value of the standard strength is not very convenient for comparison of different materials even if they are described in the same system of numeration. For example, cotton threads cannot be compared with linen ones, etc. In such caes, it is easier to use a formula of the "tear length" (R): $R = (r\ell)/p$

From formula $N = un(x/p)$ or $N/n = (u\ell)/p$

we have $C = r(N/n) = (ru\ell)/p = uR$

That is, in metric numeration, the strength of the twine when standardized is equal to the "tear length", that is, if the correction (u) is disregarded.

It is easy to see that the "tear length" is equal to the length of that skein of twine, the weight of which numerically equals the strength of the twine (or in other words, equals the weight which tears the twine). That means that it is a piece of twine which, if hung by one of the ends, will be torn by a weight equal to its own weight.

CHAPTER 7

THEORY OF FISHING WITH GILL-NETS

S 42 Principle of fishing

The principle of fishing with gill nets is based upon a setting of a net wall in the way of the moving fish, and upon the properties of the gill nets, owing to which fish get caught in the net when they approach and touch it.

Nets which have such properties are set either in the way of the moving fish (stationary nets), or are set in such a manner that they are not fastened to the bottom hut drift with the current (drift nets).

The mode of capture of the fish in the net varies in different cases, and depends on the details of the construction of the net as well as on the size and on the shape of the body of the fish. The mesh of the net has to be of such a size that fish cannot pass through. Then, in an attempt to go through the net, the fish tries to force itself through the mesh and the twine is pulled over its body. In this effort, the soft belly of the fish gets compressed and the twine of the net is pulled further over the body to the base of the abdominal and dorsal fins, which put a stop to the further passage of the fish through the net. In an attempt to move backwards, the fish is not able to produce an effort of a sufficient strength in order to take the twine off the body over the head. Fish of larger size are also caught in a gill net because, in an attempt to go through the net, such fish get caught by the gill covers and cannot free themselves. This does not necessarily happen every time: big pike and pickerel sometimes get caught in nets of small mesh by their jaws (maxillae). Furthermore, if it is caught even slightly in a loosely set net, a fish gets entangled in it, twists a part of the net so that a pocket is formed, and even rolls up the net like a rope. In such cases, small fish can be caught in nets of large mesh. Thus, the nets of a certain particular size of mesh can catch the fish of various sizes. However, fish of one size are caught in greater numbers than those of other sizes. It is important to find out what size the mesh of the nets should be in order to catch the fish of a certain size.

It depends on the size of the fish whether it is stuck in the net at its largest diameter or at the gills: the smaller the fish, the further it goes through the mesh. Therefore, considering the case of the fish passing through the mesh until the twine of the mesh stops at the dorsal and abdominal fins, and the cases where the fish is caught in the net by its gill-covers as No extreme cases, it can be assumed that capture by the body is the main method of capture of fish with this net. Therefore, this way of capturing fish deserves a more detailed consideration.

Suppose the fish passes easily through the mesh (Fig. 95) up to the line OO_1. A further movement of the fish forward will result in a pressure of the twine of the net on the surface of the body of the fish. In certain conditions, the surface of the body can be compressed and the fish move still further forward. Let Fig. 96 represent a saqittal section of the fish; O and O_1 are sections across the twine. The attempts made by fish to pass through the mesh produce two groups of forces which are distributed on the perimeter of the mesh: (1) forces which act lengthwise and perpendicular to the plane of the mesh, their resultant force is equal to the effort exerted by the fish; (2) forces which are situated in the plane of the mesh', these produce a pressure on the surface of the body of the fish and their resultant force equals, generally speaking, zero.

Let us examine the equilibrium of a certain position of the mesh at point 0. It is subject to the action of: (1) a longitudinal force OA which tends to pull the threads forming a mesh further on the body of the fish; (2) a pressure of the thread upon the surface of the body of the fish --OB, which depends on the tension of the thread and acts in the plane of the mesh; (3) a resistance of the surface of the body of the fish (OT) which acts in a direction perpendicular to the surface.

It is necessary for the equilibrium of the point 0 (if a friction of the net on the surface of the body of the fish, as well as a compression of the surface of the body, are disregarded) that OC, which is the resultant force of forces OA and OB, be perpendicular to the surface of the body of the fish. As long as the fish remains motionless, the pressure which is acting on the surface of its body is a tension of the perimeter of the mesh directed along the line OO_1. As the effort of the fish (OA) increases, the direction of the pressure on the surface of the body of the fish departs further and further away from the line OO_1, and approaches a perpendicular OC. If the direction of the pressure coincides with OC, the

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'In a schematic examination of the problem, for the purpose of forming an idea on the general character of the phenomenon only, we put aside all circumstances which can lead to complications, such as; friction of the thread of the mesh against the fish, an application of the longitudinal forces in 4 points of the perimeter only, etc.

point 0 will begin to slide and move further and further backwards over the body of the fish.

As it can be seen from the triangle AOC, the highest value of the pressure OCx, at which the thread of the mesh begins to slide backwards upon the body of the fish, is expressed by a formula:

OC = OA(sinα), where the angle α is shown in the drawing.

It can be seen from this formula that the smaller the angle α (that is, the closer the shape of the fish is to a cylinder), the greater is the force OC at the same value of OA, and the smaller need the effort be in order to pull the thread of the mesh on the body of the fish.

In order that captured fish stay in the net, the twine must be pulled tight over the body so that it does not slip off when the fish moves backward.[2] The amount of effort which holds a fish in the net is in direct proportion to force OB and, therefore, is dependent on the size of the angle α (other conditions being equal): the greater is the angle α, the smaller will be the amount of the effort which holds the fish in the net; then, at a certain size of the angle, it will become insufficient and the fish will not be held in the net.

Thus, there are 2 extreme values of the angle α at a constant value of OA, namely, $_1$ and.<2. Those values are such that if4.4<°c, the effort OB will be too great, the body of the fish will become too compressed and the fish will pass through the net. If $\alpha > \alpha_2$, the effort OB

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[2] It must be pointed out here that the body of the fish has such a shape that the fish can easily move forwards. The fish is only slightly able to move backwards, because it cannot make a strong effort to do so.

will be small and the fish will not stay in the net and will be able to go backwards. If the size of the angle α is intermediate between those 2 extremes: (α_1 α_2) then the fish will be held in the net by its body. It is obvious that among different sizes of the angle α, there is one at which the fish is caught in the net the most securely. We will call this value of the angle"o. With the approach of the value of the angle to the extremes α_1 and α_2, more and more fish will be able to slip out of the net and escape.

Considering the actual position at which the fish is caught, in relation to the size of the angle α, we must consider the degree of tapering of the body of the fish. Thus, suppose we measured the perimeter of the section across the body of the fish S_1 at the cross-section 00_1 (Fig. 95), and then measured the perimeter s_2 at the cross-section ee, which lies at a small distance c from the cross-section 001. Then, value B, which is found out from the formula:

$$B = (S2 - S_1)/c$$

will correspond to the angle α (more exactly to the tangent of the angle α). The value B is different in different sections across the body of the fish; the success of the catching of fish in the net depends on the value of B in the section across the body at the point to which the thread of the mesh is pulled over the fish. Since the position of this cross-section depends on the size of the fish, fish of a size which enables them to go through the net right to the point where the angle equals α_0 will be caught most successfully in the net. Smaller and bigger fish will be caught less successfully. However, the fish which can go through the net to the sections where values α_1 and α_2 occur, still can be found in the catch.

In practice, the captured fish is sometimes held very securely[3] in the mesh of the net: the twine can get pressed so strongly over the body of the fish that it makes a groove and the fish is unable to free itself. Sometimes, even the fishermen have difficulty taking it out. As a rule, it is more difficult to free the fish backwards, that is to remove the twine over its head (since the thread gets under the scales), than to pull the fish forwards through the mesh. To facilitate the latter, the fish is compressed with the hand as it is shown in Fig. 97; the height of the fish is thus reduced and the section across the body approaches a circle. Owing to this, the tension of the thread of the mesh becomes smaller since, of all figures which have the same area, a circle has the shortest perimeter.

S43 Besides the size of the mesh, the thickness of the thread is of great importance for the success of fishing. However, in choosing the net, not only the efficiency of the net but also its strength must be

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[3] In considering various ways in which the fish get caught in the net, we disregard actual entanglement of the fish, since it is of a secondary nature and does not occur frequently. The thickness of the thread of the net has a great effect on how securely the fish be caught in it. Thread which is thinner will be pressed deeper into the body of the fish, since the same tension of the thread will be distributed on a smaller area. Therefore, in such a case, the fish will be held better in the net.

considered. First of all, it is desirable that the thread be as thin and as soft as possible. This increases the efficiency of the net. Fish cannot see a thin thread as easily as a thick one and, when all other conditions are equal, a thin thread is pressed deeper into the skin of the fish and, therefore, can hold the fish in the net more successfully. As an example, an observation made during the Caspian Expedition can be cited: the increase in the diameter of the thread from 0.50 to 0.75 mm (at a mesh of about 45 mm bar) led to a 3-5 fold decline in the size of the catch. Thus, a change in the diameter of the thread of the netting leads to a radical change in the type of the netting. By choosing a certain diameter of thread for the net, an increase in the efficiency of the gill nets can be obtained owing to the increased holding properties. Also, in manufacturing fishing gear of the trawling type, in which a capture of the fish in the mesh is undesirable, it is possible to eliminate the entanglement of the fish by using the right thickness of twine for the nets. As the analysis of the existing practice shows, the ratio of the diameter of the cross-section of the thread (d) to the bar measure of the mesh (a) is of decisive importance (in full agreement with rule of congruity). A usual ratio for gill nets is d:a = 00.001. At this ratio, nets have sufficient efficiency and strength. However, sometimes, especially for fishing under the ice in winter when fish are less mobile than in summer and do not struggle so much in the nets, nets with ratio d:a = 0.005 are used. They are highly efficient but not so strong. The net becomes inefficient at a ratio of d:a = 0.02. Netting of this ratio is used for wings of the "nevod" (drag net): however, the fish still get entangled in the mesh which is a hindrance in fishing with a "nevod".

Therefore, the central parts of this, into which all fish are gathered, are made of netting whose ratio is 0.05 or even greater.

As is shown in S2, the diameter of the twine is inversely proportional to the square root of the "gauge number" of the thread. Thus, the value of the ratio d:a is brought to a constant product $a/(No)^{0.5}$. This relationship is shown in Fig. 98, where the bar of the mesh is on the vertical axis and the number of the thread is on the horizontal axis on a logarithmic scale. The diagonal lines correspond to the categories of the nets with ratio d:a = 0.005, 0.01, 0.02, 0.04, 0.08.

Suppose we have to determine the number of the thread so that a net with bar measure 45 mm is to have ratio d:a = 0.02. From point 45 on vertical axis we follow horizontally to the intersection with line d:a = 0.02 and from this point down in the vertical direction. Then a corresponding point on horizontal axis is 2.1, which is the number sought.

The tension to which the thread of the net may be subjected to is not known and depends on many chance conditions: capture of oversize fish; catching of the net on some object; etc. However, the more a net is used, the weaker it becomes. Finally, a net begins to tear when fish are being disentangled and taken out, and has to be rejected.

In a theoretical discussion of nets, it is necessary to distinguish between a general strength of the netting and a local strength of a single mesh. The conception of a general strength of the netting can be formed, if a certain part of the netting is mentally segregated and all the connections with the rest of the netting are studied. Those connections are the knots of the netting and, it is obvious that at a certain definite length of the web, hung in a certain definite way, the number of the knots per unit length is in inverse proportion to the bar of the netting.

Let us take two nets. The bar of the first net is a_1, the "gauge number" (for the definition, see S2) N_1, the diameter of the twine d_1, the strength of the twine ri. The corresponding values, which characterize the second net, are - a2, N2, d2 and r2.

The requirements for equal general strength are expressed by an equation: $r_1:r_2 = a_1:a_2$.

However, it follows from S2 that:

$r_1:r_2 = d_1^2 : d_2^2 = N_2:N_1$,

therefore, $a_1:a_2 = d_1^2 : d_2^2$ or $d_2 = d_1(a_2/a_1)^{0.5}$

$a_1 N_1 = a_2 N_2 =$ const.

If the conditions are such as above, two nets made out of the netting which is of the same quality will have the same general strength.

Local strength of the netting must resist the effort which is made by a fish trying to escape when it is captured in the net. Assuming that this effort is proportional to the weight of the fish or to a cube power of its length, and that the length of the fish is proportional to the bar of the netting (see S46), we find that, in order that the relationship between the effort made by the fish and the strength of the net remain the same, it is necessary (at the same quality of the netting) that the strength of the twine be in direct proportion to cube power of the bar of the netting: $a_1^3:a_2^3 = r_1:r_2 = d_1^2:d_2^3$, or

$d_2 = d_1(a_2/a_1)/(a_2/a_1)^{0 \cdot 5}$

Thus, 2 nets have:

the same efficiency, if d2 = $d_1(a_2/a_1)$

the same general strength, if d2 = $d_1(a_2/a_1)$ [illegible]

the same local strength, if d2 = $d_1(a_2/a_1)(a_2/a_1)^{.5}$

Thus, if there are 2 nets of the same efficiency (di:d2 = al:a2) and a2>al, the second net will be of greater but of smaller local strength than the first one.

Suppose a net whose bar mesh = a = 30 mm, and d of the twine = 0.3 mm answers the conditions of the fishing, then, the net whose bar = 60 mm will:

1. have the same general strength as the first one, if
   d = 0.3 (60/30) [illegible] = 0.42 mm;
2. be of the same efficiency, if d = 0.3 (60/30) = 0.6 mm;
3. have the same local strength, if d = 0.3 $(60/30)(60/30)^{0.}$ [illegible] = 0.85 mm.

Which of the incompatible requirements described above must be chosen in the selection of the netting depends on the conditions of the fishing.

In selection of the material for gill nets, the efficiency of the net is of the greatest importance (requirement: a/N = const.). Thus, large-mesh nets are more liable to be torn by the fish than ones which are made of small-mesh netting. The latter are more liable to be damaged by general tension. Therefore, small-mesh gill nets, which are meant for mass fishing, are made of thicker netting than is estimated from the ratio: d:a = 0.01.

The requirement of the general strength expressed by aN is of great importance in construction of such nets in which the possibility of the fish sticking in the mesh can be disregarded. In stationary nets of the far-eastern seine type, netting of aN approximately 10 is used for the pot and lead. All other parts of those nets are made of aN approximately 40.

S44 Relative efficiency of the nets

Owing to the very principle which is the basis of the operation of gill nets, each gill net is meant to catch fish of a certain definite size. Fish of various sizes are captured in each gill net with unequal success.

Suppose it was possible to carry out certain experiments and they showed that a certain net can capture 40 specimens out of 100 of the most suitable fish for this net (fish of optimal size). It will capture only 20 specimens out of 100 fish of some other size, etc. Then, assuming that relative probability of the capture of fish of optimal size is 100%, we find that relative probability of capture of fish of another size is 50%. Having estimated in the same way the probability of the capture of fish of all the other sizes, we can plot the length of fish on horizontal axis and relative probability of capture (percentage) on the vertical axis. That will give us a curve of the relative efficiency of the net which we call, in short, the efficiency curve. Similarly, having plotted the length of fish on a horizontal axis, and the number of fish of a certain size (in percentage) in a school on a vertical axis, we obtain a curve of the composition of the school. In the same manner, we can plot the curve of the composition of the catch. There is a direct dependency between these curves so that if two curves are known, the third one can easily be determined. Thus, if we know the composition of a school and the composition of the catch, we can plot the curve of the efficiency of the net. If we know the composition of the school and the curve of the efficiency of the net, we can foretell the composition of the catch. Finally, if a composition of the catch, as well as a curve of the efficiency of the net is known, it is possible to reconstruct the composition of the school.

This dependency is shown in Fig. 99: the length of the fish is shown on the abscissa; and the percentage of the fish of different sizes is shown on the ordinate. Curve A represents the percentage of the fish at different length in a school; curve B is a relative efficiency of the net; and curve C is the resultant of the catch, that is, the distribution of fish according to their length in the catch. Curve C was obtained on the basis of curves A and B. Its ordinates are the product of the ordinates of A and B. For example, an ordinate = 22% situated on curve A corresponds to a fish at 18 cm long. For the same fish, an ordinate on curve B is 70%. Then a corresponding ordinate on curve C is 0.22 x 0.70 = 0.15 or 15%. On dashed curve C_1, those ordinates are proportionally increased so that that the maximal ordinate corresponds to 100%. This is the form in which the catch curve is usually obtained. It can be seen that this curve resembles neither curve A nor curve B. Yet, on the basis of the experiments, the curve of the Ci-type can be obtained. The curve of the efficiency of the net as well as the composition of the school remain unknown, and there is little hope that they can directly be determined in experiments under conditions similar to the ones which exist in nature. Therefore, in order to determine the size of fish which is optimal for a certain net, as well as to obtain the curve of the efficiency of the net, one has to resort to an indirect method of determination.

To begin the discussion of the relation between the size of the mesh and the size of the fish being caught, we must turn our attention, first of all, to the fact that the mesh of different sizes, especially if the hang is the same, are geometrically similar. Likewise, fish of the same species are also geometrically similar. Although this statement is not absolutely correct, it pretty closely reflects the actual situation if groups of fish, which to not differ much in size, are compared with each other. Therefore, it is natural to expect similarity also when fish are captured in gill nets of different mesh size.

Let us consider the efficiency of 2 nets (Fig. 100). X1 is length of fish which is optimal for the first net. X2 is optimal length of fish for the second net. Let us turn our attention to the length of fish X_1^1 and X2, which is determined by the condition that the efficiency of the first net for fish at length X_1^1 is equal to the efficiency of the second net for fish of length X. The rule of congruity makes it possible to maintain that deviation $Y = X_1 - X_1^1$ of fish of optimal length for the first net (X1) and the corresponding deviation Y2 are in direct proportion to the bars of the nets, that is: $Y_1 : a_1 = Y : a_2$ where a_1 is the size of the bar of the first net and, a_2 the bar of the second one.

Let us suppose that 2 nets of different mesh were set in quite the same conditions. Comparing the results of the fishing with the both nets, let us turn our attention to the group of fish, the number of which was the same in both catches. The length of those fish is X_0, and they correspond to the point of intersection of the curves of both catches.

Both nets were set in exactly the same conditions. Consequently, an equal number of fish of length X_0 approached the first and second nets. Out of this number, both nets captured exactly the same number of fish. That is, both nets captured exactly the same percentage of fish which had approached them. Therefore, the efficiency with which both nets take fish of the same length, X_0 is the same. Consequently, in relation to both nets, fish of size X_0 possess the same property as the above discussed fish of size X_1^1 and x.

Let us assume, as before, that the bar of the first net is a_1 and that the optimal length of fish for this net is X1 (indicated on Fig. 101 by a dotted line). The corresponding values for the second net are a2 and X_2, then: $Y_1 = X_0 - X_1$ and $Y_2 = X2 - X_0$.

We have seen that:

$$Y_1:a_1 = Y2:a2 \text{ or } (X_o - X_1)/a_1 = (X2 - X_o/a2)$$

whence, $X_o/a - X \qquad X2/a2 - X_0/a_2$

due to the rule of congruity:

$$X_1/a_1 = X_2/a_2.$$

Therefore, $X_0/a_1 - X_1/a = X_1/a_1 - X_o/a2$

then the final formulae for values X_1 and X2 are:

$$X_1 = X_0(a_1+a_2)/2a_2 \text{ and } X2 = X_0(a_1+a_2)/2a_1$$

Thus, the whole problem is a determination of the value X_0.

Here, the following difficulty is encountered. Having subdivided, for the purpose of comparison, the catches into the separate groups of fish, the length of which differ in certain small limits (for instance, by 5 mm), we obtain groups which contain very small numbers of fish, sometimes 2-3 specimens only. It is obvious that under such conditions, a simple comparison of the number of fish in different groups can lead to erroneous conclusions. As it is proved in the theory of probabilities, relative inaccuracy of the separate groups, which are due to random errors, are in inverse proportion to square roots of the values of those groups. That is why it is necessary, in conducting this comparison, to follow the method which enables one to evaluate the general run of the curve of the catch, and to exclude, as much as it is possible, the effect of random deviations.

In exact sciences, this is achieved by means of rather complicated calculations, which are based upon the theory of probabilities. A simpler method of obtaining reliable results consists of the following. The points which correspond to the empirically obtained data are plotted on a diagram, and a smooth curve is constructed which represents the distribution of the points best.

S45 Determination of the relation between the mesh of the net and the length of the fish

As an example, let us analyse Fig. 102, which represents the results of the simultaneous fishing for roach with three nets. The mesh of these nets was, respectively, 24, 28 and 32 mm. The catches were made in spring of 1923 at Krugloozernoy Fisheries Station.

Fig. 102 shows that the curves which express the catches made by the 28 and 32 mm nets have a very regular form, while the curve for the 24 mm net has an irregularity at a certain point which can be smoothed in the manner shown by the dotted line in the figure. In general, the points of the intersection of the curves of the catches in this particular case stand out very clearly and correspond to the following values:

nets with mesh 24 and 28 mm - length of fish - 17.5 cm
nets with mesh 28 and 32 mm - length of fish - 18.7 cm
nets with mesh 24 and 32 mm - length of fish - 18.2 cm.

Using these values in formulae given above, we obtain the following figures for the first pair of nets (24-28 mm):

$$x_1 = 17.5(24+28)/2(28) = 16.3 \text{ cm}$$

$$x_2 = 17.5(24+28)/2(24) = 19.0 \text{ cm}$$

for the second pair of nets (28-32 mm):

$$x_1 = 18.7(28+32)/2(32) = 17.5 \text{ cm}$$

$$x_2 = 18.7(28+32)/2(28) = 20.0 \text{ cm}$$

for the third pair of nets (24-32 mm):

$$x_1 = 18.2(24+32)/2(32) = 15.9 \text{ cm}$$

$$x_2 = 18.2(24+32)/2(24) = 21.2 \text{ cm}$$

Comparing these results, we obtain three values for the optimal length of roach (*Rutilus rutilus*) for each net:

for net 24 mm -	16.3	(15.0)	15.9
for net 28 mm -	19.0	17.5	(18.6)
for net 32 mm -	(21.7)	20.0	21.2

Here, the values shown in brackets are arrived at by means of calculation.

As we see, the analysis of the catches taken with first and third pairs of nets provide results which are in a very good agreement with each other: the second pair gives slightly reduced values. Therefore, it can be assumed that for nets 24, 28 and 32 mm, optimal length of roach is:

for net 24 mm - length of roach - 16 cm
for net 28 mm - length of roach - 19 cm

for net 32 mm - length of roach - 21 cm

Thus, the dependency between the bar of the net (a) and optimal length of roach is given by the formula: $a = 0.15\ L$.

However, certain cases occur where the value X_0 cannot be determined so easily. An example is shown in Fig. 103, which shows a catch of herring, Clupeonella brashnicovi made on April 3, 1913 during the Caspian Expedition. In this case, an attempt to smooth the curves in order to find the points of intersection will be too subjective. A method which permits the solution of such problems in a more objective way is indicated by the theory of the probabilities. An example of its application can be found in a paper by the author entitled "Fishing of herring with stationary nets".

Figs. 102 and 103 show how much catches obtained at the same time and at the same place but, by means of the nets having different mesh, can differ one from another. There are described in literature, cases of distinct underfishing (such as English herring fishing in 1927) which occur because the mesh of the gear does not correspond to the size of the fish which constitute the main mass of fish population. Therefore, it is obvious that a profound study of the interrelationship between the size of the fish and the size of the mesh is of great practical interest. This correlation undoubtedly varies even in fish of the same species, depending on the general condition and appearance of the fish (which depends on the feeding conditions in the body of water, etc.), on the sex of fish, and on the time of the year (which determines the condition of the gonads and the

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[4] Clupeonella brashnicovi = Clupea harengus

stoutness of the fish). Therefore, the data described in S46 can serve only the purpose of an initial orientation to the problem.

The theory which has been described above indicates the necessity of considering not only qualitative but also quantitative correlation between the catches made with the nets of different mesh. Therefore, special accuracy is required in construction of the nets and in the actual method of the fishing. Only under such conditions can the analysis of the material obtained lead to reliable results. First of all, the nets must be of a very uniform bar which must be measured very accurately; it is desirable that the twine in those nets is of the same material, and thickness corresponds to the size of the bar. The difference in the bar of the nets which have to be compared must be neither too great nor too small. In the first case, the difference in the composition of the catches made by the nets will be too great, and the comparison of the results will have to be based upon the least reliable sections of the catch curves, that is, on those sections which correspond to the small numbers of the fish whose length differs much from the mean value. In the second case, the catch curves differ very little from one another, in which case, the influence of various secondary circumstances may acquire a great importance.

It appears that it is quite suitable if the bar of the nets taken for a comparison differ by 15%.

The setting of the nets has to be quite the same; for more reliable results, it is desirable that the nets with different mesh are set alternately, although this way of setting the nets makes sorting of catches difficult. When the nets are lifted, it is necessary to note whether the nets were set correctly and whether, while staying in the water, they did not get entangled, etc. The results of faulty catches must be rejected. All the same, the peculiarities in the run of the fish can lead to certain defects which cannot easily be accounted for.

1. For instance, heterogenous distribution of schools of fish in time may be of a great importance. Suppose a school of small fish was the first to pass certain gillnets. Then later, a school of a bigger fish passed the same nets. The fish of the first school will get stuck in the net of the small mesh size, and if those small fish are pretty numerous, they twist the webbing and make the nets badly entangled. Owing to this, at the moment when the second school of bigger fish come to the nets, the nets of small mesh netting will already be less efficient and will capture a much smaller number of fish than they originally could have. At the same time, the nets of bigger mesh, which captured a smaller number of the small fish, will be able to capture a normal quantity of bigger fish. Thus, a consequitive passing of several schools of fish of different length through the nets will lead to an abnormal distribution of fish in catches made with experimental nets and to erroneous conclusions.
2. Finally, let us suppose that a fairly large school of fish approaches the nets, and that the composition of the school remains the same all the time. At first, the fish will be caught in maximal numbers in those nets, the bar measure of which is the most suitable for the length composition of the fish in the school. Later, these nets will become clogged with the fish twisted and their efficiency will be reduced. The fish will then begin to be entangled in the webbing of

the nets of other mesh sizes. If the fishing is of a rather long duration, those nets also will get twisted, etc. Thus, under certain conditions, if the nets remain in the water for too long a time, the results of the catch will become unsuitable for the analysis. Unlike the previous case, here the correlation between the size of the catches will be incorrect, while the length distribution of fish in the catches will be normal.

All foregoing considerations indicate that various catches may be of quite different values and, in their analysis, it is necessary by means of various correlations to select the most reliable ones which must be regarded as the most significant. That is why the pooling of the results of various catches is quite undesirable although, at the first glance, it appears to be permissible to do so. This pooling leads to a devaluation of the results of the most successful experimental catches, since their data are mixed with the data of quite unreliable catches. Thus, in order to have a large number of data for analysis, it is necessary to set a number of nets of each mesh size.[5] In addition, in a study of the problem of capture of fish in different nets from the standpoint of the mechanical similarity, it appears logical to extend the requirement of similarity of the external measurements of the nets to their length and width, and the way the nets are set (depth in the place of fishing) and, finally, to the

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[5] A theoretical analysis of the problem (F. Baranov, "On biological basis of fisheries management", 2. 1919) comes to a conclusion that, in the catch of each kind of net, there must be not less than 500 fish of each species studied.

dimensions of the schools of fish. Failing to do so, and considering the conditions of similarity only in the process of the actual capture of each fish, one will be forced to compare the catches of the nets of same size on the basis of the fact that the number of fish caught is small in comparison to the number of meshes in the net. It would seem possible to obtain comparable data for nets of different sizes by means of estimating, for example, the catch per unit area of the net. However, here the following objection arises. It is not possible to state that different sections of the net have the same efficiency. Thus, if the net is set across the current, the force of the moving water arches it and it can be presumed that the efficiency of its middle portion will differ from that of its end portion. Still, more difference can be expected if the efficiencies of the lower and upper parts of the net are compared. If the fish run at the bottom, the increase in the depth of the net and, consequently, the area of the net does not increase the size of the catch. Consequently, in order to avoid all doubts, it is necessary to use the nets of exactly the same length and height and, still better, to do experimental fishing at such depth where the nets reach from the surface to the bottom. Fishing under such conditions excludes the possibility of difference in the position of the nets with regard to the depth.

S46 Optimal correlation between the bar measure of the netting, length and weight of the fish

Until now, this dependency was determined for roach ($a = 0.15L$) and for Caspian herring ($a = 0.125L$) only. In order to get at least approximate values for other fishes, it is possible to begin with the following considerations.

It is obvious that considering a fish which is caught in the webbing of the net, it is possible to mentally disregard those parts of its body which are located in front and behind the cross-section of the fish at the place where the twine of the mesh became stuck on its body. In doing so, one can just consider the effort done by the fish and the force which makes the section stay in the mesh of the net. The latter depends on the correlation between the perimeter of the mesh and the perimeter of the body at the point where it is caught. Therefore, having found out the details of the capture of fish of one species by experiment, it is possible, on the basis of the data obtained, to pass by means calculations to the cases of capture of the other species of fish, provided the integuments of those species are similar in strength and elasticity to those of the species studied experimentally.

The work on the direct study of the actual interrelationship between the perimeter of the mesh and the perimeter of the section of the body of the fish caught was carried out by a student, A.N. Ivanov, at Krugloozernoi Fisheries Station in 1924. Perimeters of the body of perch, roach and pike were measured at intervals of 1 cm. To facilitate the comparison of the results obtained, the data were brought to one conditional length = 10 cm. That was done because the fish captured in the experiment were of different sizes. The data are shown in Figs. 104 and 105. On the horizontal axis, the length of fish (divided into 10 parts) was plotted, and on the vertical, the corresponding perimeters of the cross-sections, the body of the fish were plotted. Each figure represents average data of several measurements.

Observations on the way in which the fish is caught in the webb of the net were also carried out. It was found that when the fish gets stuck in the webb, it puts 5-10, or even more, meshes upon its body in succession. By taking them off the fish in succession, it was possible to find the first mesh which led to the capture of the fish. This first mesh was cut out (together with the fish stuck in it) for further study in the laboratory. Then the fish was measured, one of the threads of the mesh was cut and the perimeter of the mesh was measured (4a). The results of the measurements are shown in Fig. 105 as vertical lines, each line representing one fish. The distance between the line and the vertical axis corresponds to the position of the section across the body at the place where the mesh stuck on the captured fish. The length of each line is the perimeter of the mesh (4a) and illustrates the strength of the compression of the body of the fish by the twine of the mesh.

Detailed studies of the mechanism of the capture of the fish of different species and sizes, with nets made of different netting in different seasons of the year, can provide many valuable data for the selection of the netting for the nets. Although the above described data are insufficient, they nevertheless show that the fish examined were actually caught in the mesh whose perimeter was about 60% of the length of the body (from 57 to 64% of the length). This confirms the dependency $a = 0.15\ L$, which was found for roach and perch.

Further, if it is known that in roach the greatest perimeter of the body is about 75% of the length of the body, then the relationship between the greatest perimeter of the roach and the perimeter of the mesh for an optimal catch is:

$$0.75L/4a = 0.75L/4(0.15L) = 1.25$$

Similarly, the results of the Caspian Expedition give the same value (1.25) on the average for herring.

Regarding this ratio as a starting point, and using the values obtained for different species of the fish from measurements of fish in collections of the Fisheries Section of the Academy of Agriculture at Timiziazev, it is possible, by means of a simple calculation, to find the dependency between the bar measure of the net and optimal length of fish of different species.

However, in commercial fishing, usually the weight of 1000 specimens, but not the actual length of fish, is available. Since the principle of similarity is the basis of the reasoning, it is obvious that the weight of the fish, which is proportional to its volume, is proportional to the third power of its length. Therefore, the cube root of the weight is proportional to the length of the fish and, consequently, to the bar measure, a. Thus, the dependency between the fish and the mesh of the net is expressed by the formula:

$$a = K_1L$$

$$a = K_2(P)^{0.333}$$

where P = the weight of the fish; L = the length.

According to the value of the coefficients K_1 and K_2, the fish can be divided into 3 groups:

1. Carp, bream, goldfish
   (fish of large height) .... - $a = 0.20L$ or: $a = 7.0(P)0.333$
2. Roach, whitefish .... - $a = 0.15L$ or: $a = 6.0(P)0.333$

3. Pickerel, mackerel, mullet

(fish of small height)................ - $a = 0.10L$ or: $a = 5.0(P)0.333$

a = optimal bar measure (in mm)

L = length of fish (in mm)

P = weight of fish (in g)

Suppose, for example, that it is necessary to determine the optimal size of the mesh for fishing of bream whose average weight is 1000 g (1000 fish = 1000 kg). Therefore,

$a = 7.0\ (1000)^{\text{[illegible]}} = 70$ mm

for pickerel of the same weight, it will be:

$a = 5.0\ (1000)^{0.3\text{[illegible]}} = 50$ mm

Fig. 106 presents a graphical picture of the same dependency, where the weight of the fish in hundreds of grams is shown on the abscissa and the bar measure in mm on the ordinate. The numbers on the diagonal lines are coefficients of the formulae given above.

To determine the size of the bar in Fig. 106, which corresponds to the fish of certain weight (for instance pickerel, whose weight is 1000 g), it is necessary to go from the horizontal axis upwards to the point of the intersection with the corresponding diagonal line (which, in this particular case = 5.0), and from that point of intersection go horizontally towards the vertical axis. The corresponding point on vertical axis is 50 mm.

To determine the weight of bream, which corresponds to the net of 30 mm bar, it is necessary to go from point 30 on vertical axis of the diagram horizontally away from the vertical axis until intersection with line 7.00, and then down to the horizontal axis; the point on horizontal axis is 80 g.

It should be stressed once more that the coefficients given above can serve the purpose of only the initial orientation, and require a detailed additional study in different areas and in different species of the fish.

Thus, for Caspian herrings, they are as follows:

<u>Casprialosa brashnikov</u>........... Ki = 0.12, K2 = 5.8

<u>Nyzanok</u> sp. (shad)............... K_1 = 0.13, K2 = 5.5

S47 <u>The curve of relative efficiency</u>

In passing to the determination of the curve of efficiency, it must be mentioned here that if a school of fish, which is of uniform composition (that is the one in which the number of the fish of various sizes is the same) comes to the net, the curve of the catch will give the curve of the efficiency of the net. It would also be possible to determine the curve of efficiency even if composition of the school were not uniform, provided the composition of this school were known. In case there is a school of unknown composition, it is possible to do the same as in determination of values X1 and X2. Thus, let us turn our attention to X_1B_1 and X_1B_2 in Fig. 101.

X_1 is optimal size for the first net. Therefore, X_1B_1 corresponds to the number of fish of this length in the school. Suppose the same number of fish of length X_1 approached both nets, then out of the same number of fish, a certain number of fish - X1B2 will be caught in the second net.

Thus, relative efficiency of the second net, in relation to fish of length X, is equal to:

$X_1B_2:X_1B_1$

Also, the relative efficiency of the first net, in relation to fish of length X , equals:

$X_2C_1:X_2C_2$

Consequently, comparing the catch curves of two nets, it is possible to find a common point on both of the efficiency curves of those nets. Having done it for a certain series of nets, it is possible to determine the whole curve of the efficiency. However, it is possible even without those data to determine an actual curve of the efficiency of a given net (for a certain species of fish), on the basis of one point on it, if a general form of curve of the efficiency were known. So far, all that is known about such curves is:

1. that the curve of the efficiency has one peak which corresponds to the optimal size of fish;
2. that the farther from the peak the ordinates are, the smaller they become and the greater becomes the deviation;
3. that the curve has a more or less symmetrical form.

In empirical sciences, one rather frequently is confronted with the problem of the distribution of the deviations from the mean of a certain variable. One also finds that these deviations in the most different phenomena obey the very same laws.

On the basis of the latter fact, the theory of probabilities opens the way to the construction of a corresponding normal curve of the distribution of the deviations (the curve of Gauss).

The equation of the gaussian curve is:

$$Y = (n\pi^{-\,\cdot\,-})(e^{-2v2})$$

here, X = deviation of the value from the mean (or in this instance, the deviation of the length of fish from the optimum)

Y = frequency (probability), which corresponds to this value.

This curve is symmetrical in relation to its optimal ordinate (peak), the shape of one half is shown in Fig. 107.

Deviations from the mean are plotted on the abscissa; a unit of the scale is $r = 1/n$. Vertical axis - relative frequency of those deviations expressed as a percentage is plotted on the ordinate; 100% of $Y = n/\pi^{d\cdot s}$. If we assume as a hypothesis (which needs further detailed working upon), that relative efficiency of the net corresponds to the normal law of distribution, then the curve of the efficiency of any net assumes the form shown in Fig. 107, when the appropriate horizontal scale is selected. The problem consequently consists of the determination of the unit of the division of the scale. How this can be done is clear from the discussion above.

Let us use as an example the catches of roach from lake Krugloe (Fig. 102). Optimal length of roach for 22 mm net = 19 cm; for 32 mm net = 21 cm. Fig. 102 shows that 41 fish of 21 cm were caught with 32 mm net, while only 10 fish of the same length were caught with 28 mm net.

Consequently, relative efficiency of 28 mm net, in relation to roach of 21 cm, is:

10:41 = 0.24, or 24%.

According to Fig. 107, a relative efficiency 24% corresponds a point on horizontal axis of value 1.7. Thus, in this case for 28 mm net, the value 1.7r corresponds to the deviation of fish from the optimal length by 21-19 = 2 cm or, 2 cm = 1.7r and r = 2/1.7 = 1.2 cm. In this case, it was found that r = 1.2/19, that is, about 0.06 or 6% of the optimal length of fish.

A determination of the same values for Caspian herring gave 8.5%. Assuming that average value r from length L is 7.5%, let us plot the Gauss curve and indicate the scale in fractions of the length L (considering that 0.075L = one unit of the scale in Fig. 107). This curve shows a decline in the efficiency of the capture of fish by a certain net as their length departs from the optimal length L. From the relation

$$a_1/a_2 = L_1/L_2$$

it follows that

$$(a_1-a_2)/a_2 = (L_1\ L_2)/L_2$$

that is, the deviation of the size of fish from the optimal size by P% is equivalent to the deviation of the bar of net from the optimal bar of mesh by the same P%.

Consequently, the given curve indicates that the greater the deviation of the bar of the net from the optimal value, the smaller is the probability of capture of the fish in the net.

The reduction in the efficiency of the net, shown in the right half of the curve, is due mainly to the number of the fish which were able to escape through the meshes of the net. The decline in the efficiency of the net, shown in the left part of the curve, is due to the fish which did not get entangled in the webbing of the net and were not captured.

As can be seen from the curve, the deviation of the length of fish by 10% from the optimal length (or what is the same, the deviation of the weight of fish by 35% from the optimal), can be regarded as a limit of the efficiency from the standpoint of the commercial fishing. For a fish, the length of which deviates from the optimal one by 20%, relative efficiency constitutes only 2-3%. This means that those fish are practically not captured by the nets in question at all.

S48 The increase in the efficiency of gill nets

Up to now, we have been considering gill nets of the simplest pattern. In large scale commercial fishing, the nets of this simplest pattern are almost exclusively used. The simplicity of the design of such nets leads to a decrease in the cost of their manufacture, and in the quantity of the material required for their construction. It facilitates the process of taking the fish out of the net as well as the repair of the net. However, sometimes, especially in a small commercial fishery, the nets of more complicated design are used. These complications in the design of the nets lead to an increase in their efficiency. A study of these complications is important, not only from the theoretical standpoint, but is necessary also for a determination of the possibility of improvement of the fishing gear in large scale commercial fishing.

The first method (S43), which leads to the increase in the efficiency of the nets, is a decrease in the thickness of the twine of the netting. A second method consists of a decrease in the tension of the netting. A net which is hung rather loose catches fish better - as soon as fish touch it. Also, the fish get entangled more securely and that leaves little chance for fish to escape from the net.

A decrease in the tension of the net can be achieved if head- and foot-lines of the net are tied together by means of a "bridle", the length of which is less than the height of the net. Thus, in nets which are used in sea for halibut fishing, where the height of the net = 1 m, the head and foot-lines are tied together at intervals of 50 cm with "bridles" 40-50 cm long. "Bridles" go on both sides of the net (to prevent pulling of the net by the current); also, sinkers are attached to the foot-line at each bridle. If the net is of greater height, such simple construction is inconvenient because the whole loosened part of the netting sags while the upper part of the netting remains standing as a wall. Therefore, in such cases as a supplement to the "bridles", a line is put along the net at the middle of the height. This line is tied to the "bridles" at the points of intersection and the net is attached to the same knots. In this way, a "frame" net is formed, which is used in the lower part of the river in winter fishing. Such netting is hung according to a coefficient $U_1 = 0.5$ and even somewhat less. Besides this, at each interval of two "ogniva", the head- and foot-lines are tied together with a line. This line has length which is equal to a half of the height of the net and is carefully put through the meshes of the nets. Similar lines are put through the meshes along the net at the same intervals one from another as the vertical ones, and at the points of intersection they are tied up together.

Thus, the net is divided into square "windows" with netting hanging loosely in them.

The efficiency of the "frame" net, as well as of the multi-walled nets, is increased due to: (1) a possibility of using a netting of thinner twine in nets of such type; (2) a decrease in the tension of the netting; (3) a widening of the range of the efficiency ("adjustment" of net to fishing of fish of different sizes). The widening of the range of the efficiency of the net is due to the fact that fish, which do not actually get stuck in the mesh of the net, can get entangled in the webbing and, thus, get captured in the net.

Each "window" of the "frame" net forms a shallow net sac. A big fish can get wrapped in this net sac, pull it into the adjacent window and, thus, get captured independently from the process of the actual sticking in the mesh. Finally, in the one-walled net, some fish can escape even at the moment of lifting the net out of the water; the possibility of this is reduced if the fish is captured in the "windows" of the "frame" net.

Multi-walled (trammel) nets

The most widely used type is the usual three-mesh net. This net consists of a smaller-mesh netting (the size of the mesh and the thickness of the twine correspond to the kind of fish the net is meant for), which is put in between 2 pieces of bigger-mesh netting. All three pieces of netting are attached together to the same head- and foot-lines. The hanging of the netting is rather cumbersome and can be done in different ways. The best and the most economical way of doing it, from the standpoint of the quantity of the material, is the following. The small mesh netting of a three-mesh net is hung and attached to a cord with a definite number of meshes to a certain definite interval - "ognivo". The size of the interval corresponds to the size of one mesh of the coarse mesh netting, which forms the outer walls of the trammel net. In the process of hanging the netting, a certain number of meshes of the inner wall are put on the cord and then the latter is attached to the side-line of the gill net. At the same time, one mesh of both outer walls of the net is tied to the side-line by the same knot. The "hang" of the seaming on line is such that one cord corresponds to one mesh of the coarse mesh netting of the outer walls of the net.

The twine of the outer walls is 3-4 times thicker than the twine of the inner wall. Also, the height of the outer walls of the net is 20-50% smaller than that of the inner wall. That makes the inner wall hang rather loosely.

The principle of capture of the fish in a trammel net is analogous to that of a "frame" net. Having passed through the outer wall of the net, fish get stuck in the mesh of the inner wall. It drags the netting of the inner wall through the mesh of the second outer wall of the net and stays hanging in a pocket from which it cannot escape. Thus, the first outer wall of the net is of no special importance, and is put on for the purpose of symmetry in order that fish could be caught from both sides of the net. It is especially important, for instance, in those cases when fish are driven into the net by the fishermen. Nets are set around bush growth, grass, etc., and the fish are driven out into the net which must be set in a direction which depends on wind, current, etc. Sometimes two-mesh gill nets of the same type are used.

Unfortunately, there are no data on comparative efficiency of the trammel and gill nets. A small number of experiments were carried out in that direction at Fisheries Station on Lake Krugloe by the author. Trammel nets with inner walls of 25 mm mesh made of twine No. 200/6, and gill nets of the same twine were used.

The size of the catches made by both nets as well as the size of fish caught (roach) turned out to be the same. At the same time, the timing of the operation showed that the process of taking the fish out of the trammel net requires twice as much time as out of the gill net. Thus, under these conditions (the fish caught were of small size), the trammel net proved to be plainly unprofitable. However, the results of the experiments, of course, do not solve the problem yet. In some cases, the trammel net is very useful, for example, in capture of pike by driving them toward the net in autumn when pike are moving very quickly and can break through a net made of thin twine. The use of the trammel net ensures the same efficiency of the net, even if a net with inner wall is made of twine 2-3 times thicker than usually used.

Combined nets

A second way of increasing the efficiency. of the net is the construction of a combined net, that is the one which consists of the two normal nets of different mesh put together on the same side-lines. This is done to catch two associated species of fish, for example, such as pickerel and Acipencer stellatus. A combined net consists of two gill nets put together on the same side-lines without any special slack. Fish which approach the net at the side where a bigger mesh net is situated, get stuck in the mesh of the net if their size is suitable. Fish of the smaller size pass through the first, coarse net and get stuck in the other net made of smaller mesh netting. There are some considerations which might prove to be true, that big mesh net facilitates the capture of fish in small mesh net, since big mesh net prevents fish from going backward and escaping. However, this problem has not yet been clarified by exact experiments. For reasons of symmetry, combined nets are sometimes made of 3 gill nets.

Finally, combined nets may have a single wall. In that case, the net consists of 2 halves: the upper one which is made of small mesh netting and lower one made of bigger mesh netting. Such nets are sometimes used in marine fishing (surface drift nets) for mackerel at bigger size. These fish swim at the surface and, when they approach the net and find the small mesh netting in their way, try to go deeper and pass under the net. A similar pattern of combined nets may be used in fishing at the bottom (bottom nets). In this case, however, the upper part is made of a bigger mesh netting.

Combined nets are especially frequently used in river drift net fishing. When there is a run of several species of fish in the same area, a fisherman can use one combined net. In such cases, a complication in the pattern of the net is very useful.

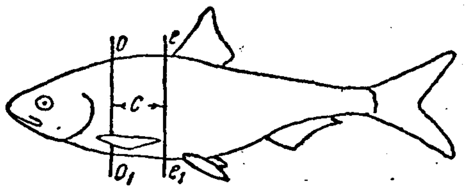


Fig. 95

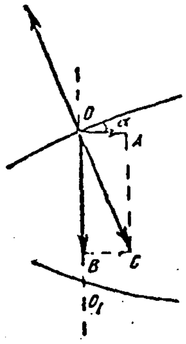


Fig. 96

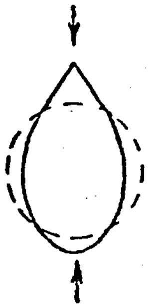


Fig. 97

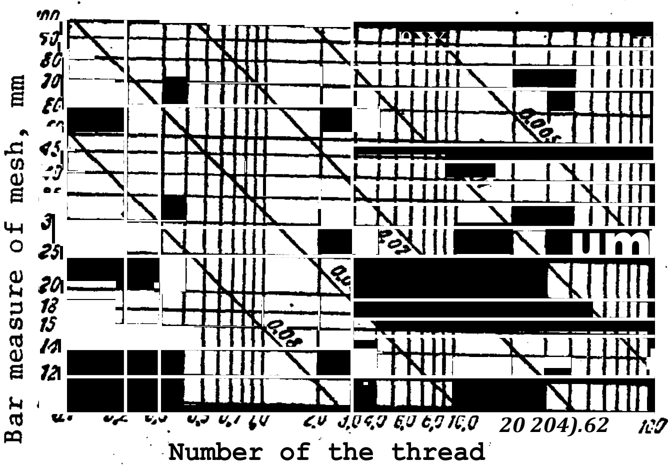
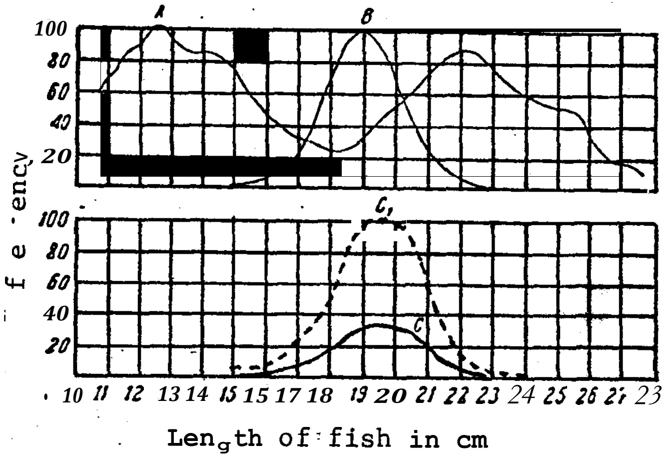


Fig. 98



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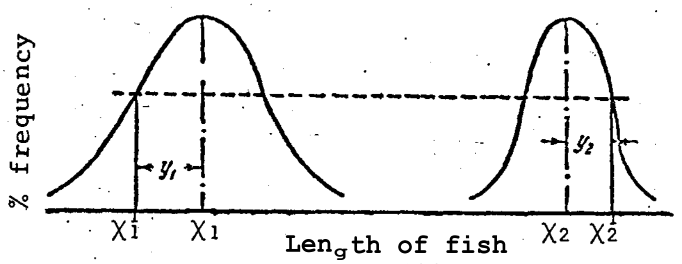


Fig. 100

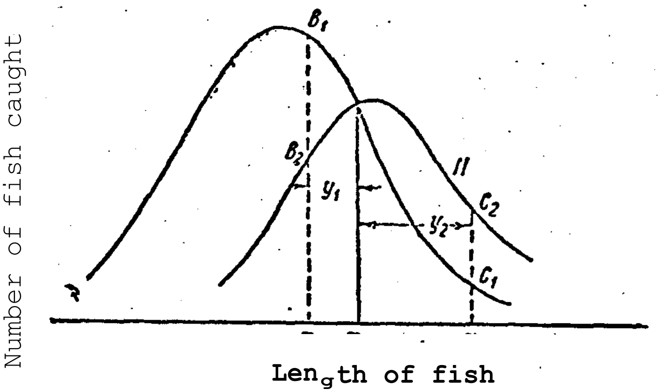


Fig. 101

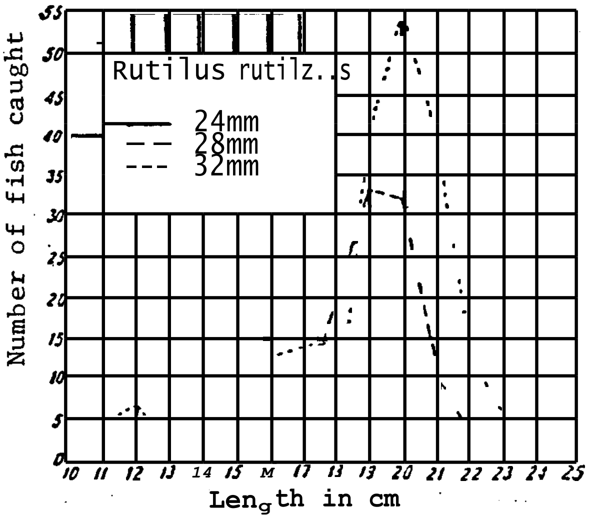


Fig. 102

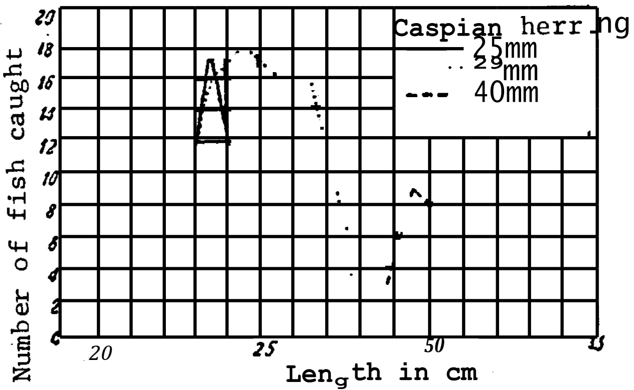


Fig. 103

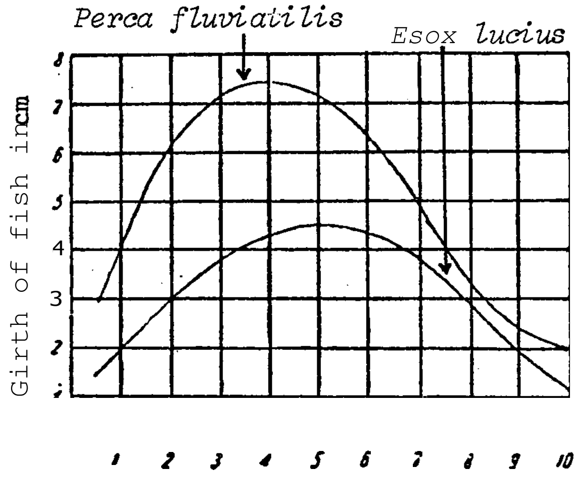
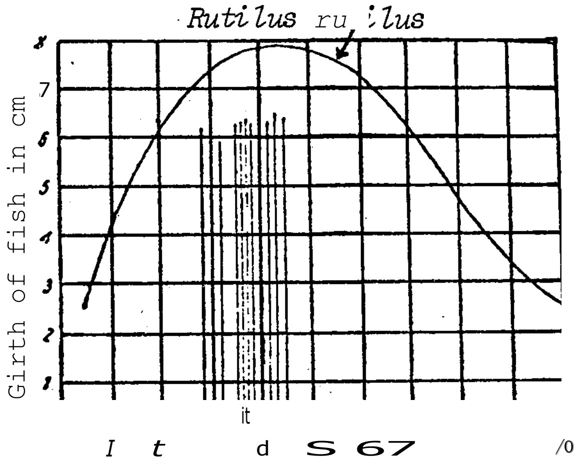


Fig. 104



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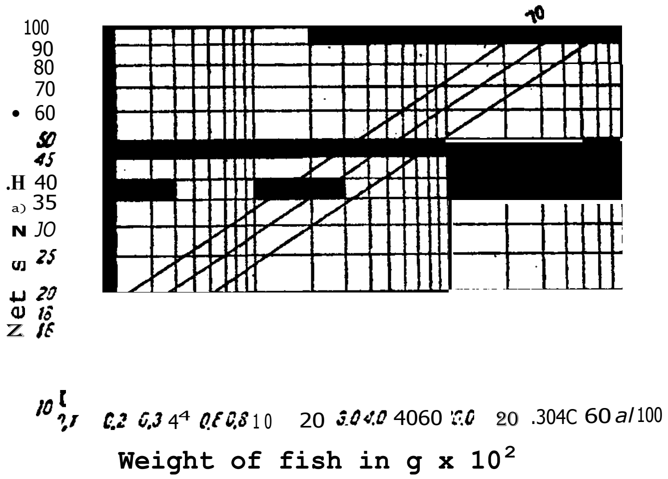

Fig. 106

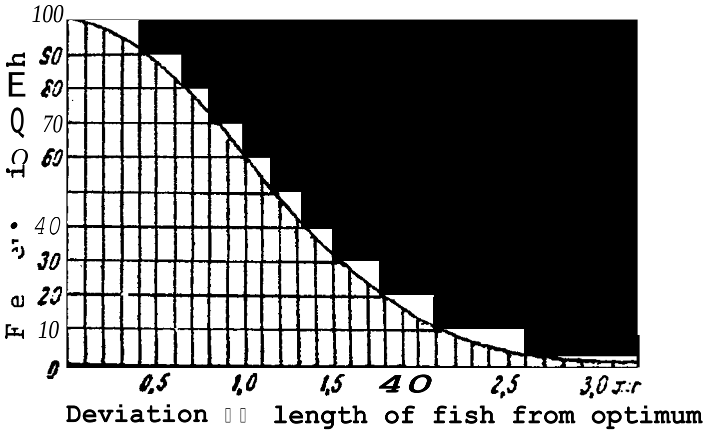

Fig. 107

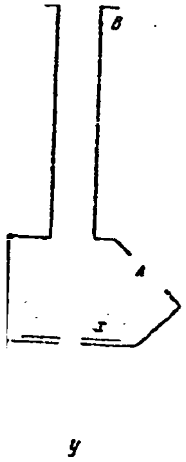

Fig. 108