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Fishing unit measures
(The second supplemented and revised report)

by

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PREFACE

Due to the inclusion in the Agenda of the Standing Committee on Research and Statistics (STACRES) of an item on the principles of fishing effort regulations, the Soviet delegation submit its proposals on the method of defining fishing effort. These proposals were earlier considered and approved by ICES, were discussed in 1973 at the Special ICNAF Meeting of Experts on Effort Limitation at Woods Hole, Massachusetts, USA and at the ICES Gear and Behaviour Engineering and Statistics Workings Groups at IJmuiden, Netherlands, with a participation of the ICES, ICNAF and FAO representatives. The IJmuiden Working Group has recognized this method as a fundamental approach to solution of the problem of the fishing effort evaluation and recommended to the participating countries to study results of its implementation in their fisheries.

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The analysis of the system of the fishing unit measures worked out in 1969 for trawl, purse seine and drift net fisheries showed that the system of measuring where the same units are used for all fishing methods will have very great advantages. Based on this conclusion, we tried to work out and to apply the same units of fishing power, fishing effort, efficiency and intensity for beach seine, set gill net, long line and others used within the modern fishery, as for the three methods of fishing considered earlier. With this aim we divide all fishing gears into the following three groups:-

1. Gears the fishing power of which is defined directly;
2. Gears the fishing power of which is defined experimentally;
3. Gears the fishing power of which is defined by comparison of catches.

The value of fishing power is the same for all fishing gears, i.e. the volume of water swept per unit of time.

The first group, in addition to trawls, purse seines and drift nets already considered, includes all dragged fishing gears. The characteristic feature of the fishing gears of this group lies in the fact that the volume of water swept by them can be directly counted by their dimensions and parameters of the fishing exploitation.

The second group includes the fishing gears within which the volume of the water swept depends considerably on the radius of action of the devices or factors employed for the attraction of fish to the fishing area. The attraction of fish to fishing gears by means of electric light has been studied intensively, and this method is now widely used in combination with lifting nets (veranda traps) and fish pumps. For different items of fishing and sources of electric light the radius of the sphere of fish attraction is determined experimentally. Thus, for example, it was found that this radius at the sources of electric light used in the Caspian kilka fishery equals 20 m, and amounts to 25-35 m in the Far East saury fishery.

The fishing power of the fishing gears employed in conjunction with the devices for the attraction of fish in the fishing area provided the radius of action of the attractive factor is known, can be defined by the product of the water volume contained in the sphere of attraction, by the coefficient of fishing continuity.

The coefficient of the fishing continuity is assumed to be the relation of the time of action of the attractive factor in the course of a given fishing period (for example, a night) to the general duration of the period.

The third group comprises the fishing gears that according to present knowledge can neither be related to the first nor to the second group, because the actual volume of water swept by them has not, for some reason or other, yielded a precise definition. It is proposed to determine the fishing power of these gears in an indirect way, i.e. by comparing the catches made by those fishing gears with the catches taken by the other fishing gears for which the volume of water swept is known. Thus, for example, if the catch of a drift net = x, the volume of water swept per unit of time = Vx, and the catch by the same set single-walled gill net when fishing the same items is y, then there are good reasons to believe that the unknown water volume (V_y), swept by a set gill net equals:

$$V_y = \frac{Y\,Vx}{x}$$

In other words, we assume that the fishing power of the set gill nets will differ from the fishing power of drift nets so many times as the average catches of the former gears are more or less than the latter gears.

It is evidently possible with this method to define not only the fishing power of the same type of fishing gears, as in the example above, but also of all other secondary fishing gears founded on different principles of fishing, for instance, nets in comparison with hooks, nets in comparison with traps etc. It is only necessary to remember that in this case not the actual volume of the water swept is taken into consideration, but a certain conventional value is needed to express the fishing power of all fishing gears in commensurable units.

Examples of the estimation of the fishing power for all fishing gears of the third group are given below.

A. Set gill nets

In order to determine fishing power of a set gill net we compare its catches with the catches of the same drift net: the annual catch in centners per drift net averaged over the USSR (by years) is as follows:

1965	1966	1967	1968	1969	Average for 5 years
7.03	7.07	6.83	7.26	8.02	7.24

The average catch per set single-walled gill net of the same dimensions q_x makes up 1.78 centners.

A drift net 30 m by 12 m per 1 000 m drift sweeps the volume of water: V_y equal to:

$$V_y = 30 \times 12 \times 1\ 000 = 36\ 000\ m^3.$$

Hence, the equivalent volume of water swept by a set gill net, Vx, can be determined according to the formula:

$$Vx = \frac{q_x \cdot V_y}{q_y} = \frac{1.78 \times 36\ 000}{7.24} = 8\ 830.$$

This volume equals approximately the cylinder volume, the base of which is a circle with a diameter equal to the length of the net and the height equal to its height, i.e.:

$$V = \frac{\Pi\ l^2\ a}{4} = \frac{3.14 \times 30^2 \times 12}{4} = 8\ 478$$

Thus, proceeding from the ratio of catches, the following formula can be used for the definition of the fishing power of set gill nets:

$$V = \frac{\Pi\ l^2\ na}{4t} \qquad \text{..............} \qquad (1)$$

where

l = length (m)

a = height (m)

n = number of nets

t = time of fishing (days).

B. Traps

In a number of cases we can find examples of simultaneous application of traps and set gill nets when fishing the same items. Thus, for instance, in the Don area of the Azov Sea set traps and set gill nets were used in the bass and bream fishery for a long period. The nets measure 20 m in length and 3 m in height.

There are three categories of set traps, the length of a guiding wing being 30, 80 and 150 m, respectively, the average height being 3 m.

Both fishing gears are used annually at the same places and at the same time: in spring from 15 March to 20 April, and in autumn from 1 October to 20 December.

In the years from 1946 to 1955, i.e. in the period of the most intensive use of these fishing gears in the Don area of the Azov Sea, the annual catch amounted to:

I.	Per net, 20 x 30 m	3 c
II.	Per trap (having a single heart), the length of the wing being 30 m	20 c
III.	Per trap (having a single heart), the length of the wing being 80 m	50 c
IV.	Per trap (having two hearts), the length of the wing being 150 m	160 c

Provided that the lengths of orders of set gill nets are equal to the lengths of sea guiding wings of traps, the ratio of their catches is as follows:-

$$\frac{II}{I} = \frac{20}{4.5} = 4.4; \quad \frac{III}{I} = \frac{50}{12} = 4.2; \quad \frac{IV}{I} = \frac{160}{22.5} = 7.1$$

The volume of water swept when estimated according to the formulas:-

$$V = \frac{\Pi\, l^2\, na}{4} \qquad \text{(for nets)}$$

$$V = \frac{\Pi\, l^2\, a}{4} \qquad \text{(for traps) comes to the following:}$$

$$\frac{II}{I} = \frac{2\,120}{480} = 4.4; \quad \frac{III}{I} = \frac{15\,072}{3\,768} = 4.0; \quad \frac{IV}{I} = \frac{52\,987}{7\,065} = 7.5$$

As is seen, the corresponding ratios of the catches and the volumes of water swept by traps and set gill nets are close to each other. Proceeding from this we may assume that the fishing power of traps with a precision sufficient for practical estimations can be expressed by the following formula:

$$V\ (trap) = \frac{q\ (trap)\ \cdot\ V\ cm.c}{q\ cm.c\quad t} \approx \frac{\Pi l^2\ a}{4t} \quad \ldots\ldots\ldots\ldots \quad (2)$$

C. Hooked fishing gears

In the 30's set gill nets and long-lines were rather widely used in the cod fishery at the Murman coast of the Barents Sea.

Till now, the fishery of spring spawning cod (skrey) in Norway has been made by set gill nets and hooked fishing gears (lines and long-lines). In 1961, for example, 53.1% of the total catch of those fish were caught by nets, and 36.9% by hooked fishing gears. Recently, the specific weight of nets and hooks in the skrey fishery has decreased somewhat, but, nevertheless, these gears remain the essential ones up till now. Skrey catch per fisherman amounted to:

by nets in 1959 -	62.4 c;	by nets in 1961 -	47.0 c
by hooks in 1959 -	53.6 c;	by hooks in 1961 -	64.2 c x)

According to previous data, the catch in 1969 per fisherman engaged in the line and long-line fishery was approximately 5 centners higher than the catch taken in the net fishery. Thus, if we take an average of many-year figures, it appears that the catches per fisherman in net, line and long-line fisheries respectively are about the same.

A Norwegian set gill net for cod fishing is 28 m long, height in setting being 5 m. xx) The fishing power of such a net is:

$$V = \frac{\Pi\ l^2\ na}{4} = \frac{3.14\ \times\ 28^2\ \times\ I\ \times\ 3}{4} = 1\ 846\ m^3.$$

If we try to determine the fishing power of long-lines, we suppose in the first instance that the distance between the hooks of long-lines proceeding from their catchability has been properly selected. Then each hook may be considered as a centre, and a ganging as a radius of the water volume swept, i.e.:-

$$V\ hook = \frac{4}{3}\ \Pi\ R^3 \quad \ldots\ldots\ldots\ldots \quad (3)$$

The length of gangings in the Norwegian cod long-lines (R) is 0.46 m. Substituting this value in the formula we then see that one hook of such a long-line has to sweep a volume of water equal to:

$$V\ hook = \frac{4\ \Pi \times 0.46^3}{3}\ 0.41\ m^3$$

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x) KUZMICHEV, A. B., 1964. Fishing industry of Norway. Ed. by VNIRO.

xx) FAO Catalogue of Fishing Gear Designs, No.408, Rome, 1965.

Having divided the volume of water swept by one set gill net by 0.41, we then get:-

$$\frac{1\ 840}{0.41} = 4\ 488$$

i.e., one net corresponds to approximately 4 500 hooks.

The Norwegian cod long-line consists of 16 200 hooks and is served by five fishermen, and consequently each fisherman serves:

16 200 hooks : 5 = 3 240 hooks

The number of nets per one fisherman averages 7.

At the same time the catches per one fisherman in the net and hook fishery, as shown above, are approximately equal. This means that the radius of the spherical volume of water swept by one hook approximately is not equal to the length of the ganging, but somewhat longer.

Let us determine this radius on the assumption that the catches and the volumes of water swept remain the same, and at the same time taking into account the number of fishing gears served by one fisherman:

$$V_{\text{set gill net}} = V_{\text{long-lines}},$$

hence,

$$7\ V_{\text{set gill net}} = \frac{4}{3}\ \Pi\ R^3\ \ 3\ 240$$

or

$$R = \sqrt[3]{\frac{3 \times 7\ V\ \text{set gill net}}{4 \times 3\ 240}}$$

Then, using constant numerical values we got:

$$R = \sqrt[3]{\frac{3 \times 1\,846 \times 7}{4 \times 3.14 \times 3\,240}} = 0.984 \text{ m}$$

Having placed the thus obtained value of R in the formula (3), we find that one hook of long-lines and lines in the skrey fishery swoops a volume of water equal to:

$$V_{hook} = \frac{4}{3} \Pi R^3 = \frac{4}{3} 3.14 \times 0.9526 = 3.9882 \approx 4.0 \text{ m}^3$$

Therefore, proceeding from the ratio of catches, one may assume that the fishing power of hooked fishing gears can be defined according to the following formula:

$$V_{hook} = \frac{4}{3} \frac{\Pi R^3 n}{t}$$

where,

R = radius of the fishing sphere found by the above-mentioned method, and

n = number of hooks.

In this estimation we used catches per fisherman. The task might obviously have been solved in a much simpler way if the direct data on catches per net, long-line or hook had been available.

Since set gill nets are very widely distributed and easily accessible fishing gears, the determination of the fishing power of any coastal fishing gear by comparison of catches offers no difficulty.

As to the reduction of fishing power in various kinds of fisheries to the common index, we shall not only define the total fishing effort in the socalled 'mixed fishery', but also differentiate it according to the kind of fishery.

As a result of dividing all fishing gears into three groups and expressing the fishing power by the above-mentioned methods, we managed to perfect considerably the system of the units worked out in 1969 and to use it for all kinds of fishery with no exception. The summary table of the methods on the definition of the fishing power of different fishing gears is shown in Figures 1 and 2.

As a common unit for the fishing power for all fishing gears the power at which 1.000.000 m^3 of water is swept per unit of time is assumed. The establishment of this value of fishing power unit was based on the estimation given below.

The fishing power of the most widely distributed modern trawl (horizontal opening 37.5 m, vertical mouth 3.9 m, speed of trawling 4 knots, i.e. approximately 2 m per second) per hour of trawling (3 600 seconds) makes up:

$$37.5 \times 3.9 \times 2 \times 3\,600 = 1053000 = 10^6 \ m^3$$

This is the value that has been assumed as a unit.

The determinations of the fishing power, fishing efficiency and the intensity for all this remained as previously (see 1970, Special Meeting on Measurement of Fishing Effort, Doc.No.2), with the only difference that these indices in all kinds of fishery were also measured by the same units.

A unit of the fishing effort is the product of the fishing power by the time of fishing during a 24-hour period; the time of fishing in all cases in the period within which a fishing gear is actively fishing. For the different fishing gears this time is defined in the following way:-

Trawls - $\dfrac{\text{number of hours trawling}}{\text{24 hours}}$

Purse seines - $\dfrac{\text{Time from the beginning of shooting till the end of pursing in hours} \times \text{Number of shootings}}{\text{24 hours}}$

Traps and other stationary fishing gears - number of days fished

Drift fishing gears $\dfrac{\text{Number of drifts} \times \text{Average duration of a drift (hour)}}{\text{24 hours}}$

Fish pumps and lifting fishing gears applied with fish attracting devices to a fishing area $\dfrac{\text{time of action of fish attracting devices per cycle (hour)} \times \text{Number of fishing cycles}}{\text{24 hours}}$

Other fishing gears - time of active fishing per day

The fishing efficiency, as found earlier, is the ratio of the catch for a period of fishing to the fishing effort for the same period. Hence, a unit of fishing efficiency would be expressed as follows:-

$$\frac{\text{Tons}}{10^6 \ m^3}$$

If the catch is averaged over a sufficiently long period of time, the unit of fishing efficiency for each class (group) of gear will accumulate all the peculiarities of the fishing process, including fish behaviour and the organisation, technique and tactics of fishing. Unlike the measures used, such as catch per unit time, catch per unit tonnage, etc., which are not connected with the principle of fishing, the new measure of fishing efficiency will incorporate both the effect of fishing and the degree of perfection of the fishing technique. With unchanged fishing technique, the fishing power remains the same and the fishing efficiency of the gear will change proportionately with the changes in the stock. Considering that the fishing efficiency is based on actual catch data over a long period of time, it is also more accurate than other estimates arrived at theoretically on the basis of various assumptions concerning fish behaviour.

When changing (perfecting) the designs of fishing gears or the methods of their application, and provided the fishing power remains constant, then the average efficiency for a rather long period of time will permit to judge as to the efficiency of the innovations. Thus, such perfections in the trawl fishery, for example, as the use of cables, electric current, concentrating the fish in the trawl mouth, as well as the towing of a trawl from two vessels, the use of hydroacoustics etc. in the given system do not relate to the means of increasing the fishing power, as was sometimes noticed in the past, but relate to the methods increasing their efficiency.

When proceeding from fishing effort and fishing efficiency it is possible to determine for practical purposes, and with a quite sufficient accuracy, the fishing intensity, differently called "the intensity of fishing".[x)]

So far there has been no clear definition of the notion "the intensity of fishing", as well as of other fishing parameters. The fishing intensity was understood by some to be the ratio of the square swept to the square of the surface or the bottom of the waterbody (geometrical intensity of fishing), while others characterized the fishing intensity as being the number of vessels participating in the fishery, fishing gears, time etc. The lack of an agreed viewpoint as to the understanding of such an important term as "the fishing intensity" creates great difficulties in the analyses of the fishing effect on the stock, as well as in the solution of many operative problems of fishery regulations.

In the given system of units, fishing intensity means the ratio of the water volume swept to the general/volume of ~~area~~ of distribution of the species fished. Therefore, the fishing intensity is a sizeless value.

For the species, on which fishing intensity is rather high, and of which the fishing areas are clearly restricted (for instance, flounders of all areas, the species fished on the Great Newfoundland Bank, cod off Lofoten Islands and Iceland, sea bass on the Kopytov Bank etc.), both values are commensurable, and it presents no difficulty to determine the fishing intensity. For the species on which the fishery is only slightly developed, and of which the areas of distribution are either unknown or too vast, it is still difficult to define the true fishing intensity by means of the above-mentioned method. The fishing intensity in these areas can be roughly expressed by the product of the fishing effort by the sizeless coefficient of catchability (in cases where the coefficient of the catchability of fishing gears is unknown). The value characterizing the fishing intensity will in this case be expressed in units of the fishing effort.

If the coefficient of the catchability of fishing gears is unknown and cannot be determined, the fishing intensity can be characterized by the product of the fishing effort by the dimensional value - the fishing efficiency. This product, as we can see, is expressed in units of weight, i.e. is nothing more than a catch.

In order to characterize the fishing intensity of the items dispersed over vast areas, the method of comparison of the actual catches with the value of the optimal catch may also be employed, provided that this value is known or can be defined. In this case, the fishing intensity, as in the case of the volumes relation, will be expressed by sizeless values.

In future, however, it is necessary, with the development of the fishery, to aim at using the only method for determination of the fishing intensity, namely the true intensity of fishing that is the relation of the water volume swept to the volume of the distribution of the fishing items.

When turning from the fishing indices (power, effort, efficiency, intensity) of certain fishing gears to the summary indices of the work of the fishing fleet and flotillas, the above units for measuring the fishing would be too small; therefore, in addition to the initial unit of the fishing power equal to 10^6 and the units for measuring other parameters corresponding to it, it is advisable to have also units which are 10, 100 and 1 000 times as much. Then, if we take specific nominations and designations, we will get the measuring system of the indices mentioned as shown in Table 1 below.

Table 1. Scale of fishing unit measures.

Name	Purpose	Abbreviation	Dimension	Fraction of basic unit
Promm	Measure	pm	$\frac{10^9\ m^3}{24\ hours}$	1
Decipromm	of	dpm	$\frac{10^8\ m^3}{24\ hours}$	1:10
Centipromm	fishing	cpm	$\frac{10^7\ m^3}{24\ hours}$	1:100
Millipromm	power	mpm	$\frac{10^6\ m^3}{24\ hours}$	1: 1000
Promus	Measure	pu	$10^9\ m^3$	1
Decipromus	of	dpy	$10^8\ m^3$	1:10
Centipromus	fishing	cpy	$10^7\ m^3$	1:100
Millipromus	effort	mpu	$10^6\ m^3$	1: 1000
Promef	Measure	pe	$\frac{t}{10^9\ m^3}$	1
Decipromef	of	dpe	$\frac{t}{10^8\ m^3}$	1:10
Centipromef	fishing	cpe	$\frac{t}{10^7\ m^3}$	1:100
Millipromef	efficiency	mpe	$\frac{t}{10^6\ m^3}$	1:1 000
Promin	Measure	pi	$\frac{10^9\ m^3}{10^9\ m^3}$ =sizeless	1
Decipromin	of	dpi	$\frac{10^8\ m^3}{10^8\ m^3}$ = sizeless	1:10
Centipromin	fishing	cpi	$\frac{10^7\ m^3}{10^7\ m^3}$ = sizeless	1:100
Millipromin	intensity	mpi	$\frac{10^6\ m^3}{10^6\ m^3}$ = sizeless	1:1 000

The general assessment of the fishing power becomes much simpler with such a selection of the units scale.

For the full and uniform assessment of all kinds of fishery made by the various modern devices the following data must be available:-

1. The fishing power of the fishing gears

For each fishing gear of the industrial fishery the fishing power should be established by one of the above-mentioned methods and should be indicated in its 'passport' (for the industrial methods of fishing) or directly in the nomination. For example; trap mpm - 7.2, i.e. the trap that fishes 7.2×10^6 m^3 water per 24 hours of continuous fishing.

2. The number of fishing gears, and 3. The number of days fished

For trawl fishing gears it is more convenient to carry out the collection of data in hours of trawling and then to convert them into days.

For pursing, drift fishing gears and gears applied with the devices for attraction of fish to the fishing area, as well as for trawl gears, it is necessary to introduce the count of the active working time of the fishing gears measured in hours and to registrate it in the boat logs. The summary number of fishing hours divided by 24 will characterize, in this case, the number of fishing days.

For the approximate count of the fishing time by these fishing gears the product of the average duration of their active work per cycle by the number of cycles can be used.

In the first case it is sufficient to collect the data only on the number of fishing hours, while in the second case, the data on the average duration of fishing per cycle in hours and on the number of cycles will be needed.

For the stationary fishing gears the data on the number of days spent in fishing are sufficient.

For all other fishing gears the data on the time of active fishing per day will suffice.

4. The catch

The catch for all fishing gears should be represented by species of fish in tons with an indication of the time and place to which this catch relates. In order to facilitate the collection of data and to increase the precision of the fishery data, it would be advisable to elaborate and to have in the fishing vessels the automatic devices for the registration of the following parameters:

1. Number of hours' trawling

2. Time of active operation of purse seines
3. Duration and length of drifts of the vessels with fishing gears
4. Duration of the action of the fishing stimulators (light, electric current and so on).

All these devices can apparently be very simple and cheap; however, their application will allow to increase greatly the quality of the count in the fishery and to bring it to a really scientific base.

This, in turn, opens the possibility of the more concrete management of fishing efforts in the fishery, creates the conditions for the considerable simplification of the scientific fishery statistics and for the wider application of computing technique.

Besides, obtaining the united quantitative assessment of the species, all together and each one separately, under modern conditions is very important for the study of the interrelation between the stock and the fishery. It is also of great importance for the elaboration of the theory of the optimal catch and for the solution of other scientific problems.

This method allows the determination in comparable units of the fishing power and other characteristics of fishing in earlier years. The use of this method is of special interest as to the estimation of the dynamics of fishing efficiency in relation to the dynamics of fishing effort in the most important fishing areas.

An important advantage of the proposed system of units for measuring fishing lies in the fact that it may be used to provide the basis for the quantitative characteristics of the operation of a fleet in working out future plans on the basis of the rational exploitation of the stock and fishing technique.

The unification of fishing unit measures is at present equally important both for technical and for biological purposes.

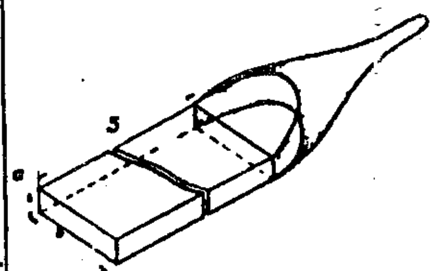
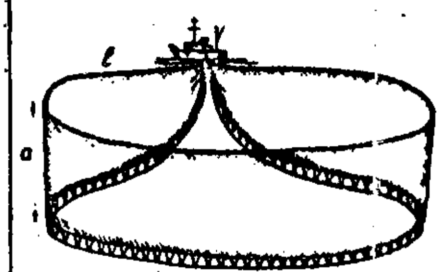
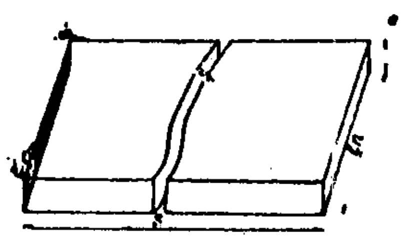
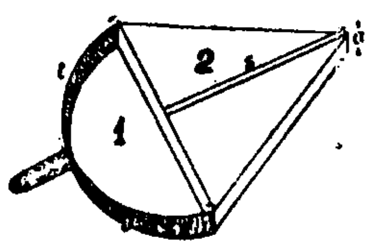
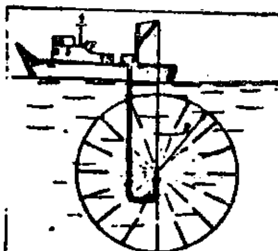
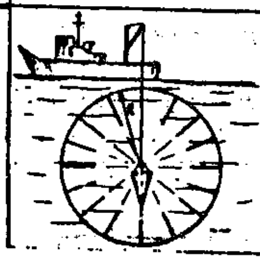
Fishing gear	Diagram	Formula
TRAWLS		$V = abS$
PURSE SEINES		$V = \dfrac{l^2 a}{4\pi}$
DRIFT NETS		$V = alnS$
DRAGGED FISHING GEARS		1. $V = \dfrac{al^2}{\pi}$ 2. $V = \dfrac{al^2}{\pi} + \dfrac{alS}{\pi}$

Figure 1. The gears the fishing power of which is defined directly.

Fishing gear	Fishing power		Determined parameters	
	DIAGRAM	FORMULA	Radius of attraction	Coefficient of fishing continuity
FISH PUMPS		$V=\frac{4}{3}\pi R^3$	R	$K=1$
LIFTING NETS		$V=K\frac{4}{3}\pi R^3$	R_1	$K=\frac{t_1}{t}$ xx) при: $R=R_1$

x) T and t_I - The period of time during a day when the lamp is switched on and fish pumps and nets are respectively used.

x) Duration of the cycle from [illegible] to lift

Figure 2. The gears the fishing power of which is defined experimentally.

Fishing gear	Fishing power		
	Diagram	Formula	Basis
SET GILL NETS		$V = \frac{\pi (l)^2 n}{4} a$	$\frac{\pi l^2 n a}{4} \simeq \frac{q_{CT.C} V_{A.P.C}}{q_{A.P.C}}$
TRAPS		$V = \frac{\pi l^2}{4} a$	$\frac{\pi l^2 a}{4} \simeq \frac{q_A V_{CT.C.}}{q_{CT.C.}}$
HOOKED FISHING GEARS		$V = \frac{4}{3} \pi R^3 n$	$\frac{4}{3} \pi R^3 n \simeq \frac{\pi l^2 n a}{4}$

Figure 3. The gears the fishing power of which is defined by comparison of catches.

FISHERY PARAMETERS ASSESSMENT METHOD (ADDITIONAL COMMENTS AND CLARIFICATIONS*)

by

Dr. A.I. Treschev

International Council for the Exploration of the Sea at its 60th Session (C.Res 1972/2:8/c/) decided to hold in IJmuiden (Holland), May 3 through 8, 1973, a Meeting on Engineering Aspects of Fishing Gear, Vessels and Equipment and on Statistical Problems of Measuring Fishing Efforts. Among the Meeting's objectives, it is pointed out that

"in pursuance of the issues raised by S.A. Studenetsky (Doc.C.M. 1972/D:5, referring to A.I. Treschev, Doc.C.M. 1971/B:9, Dr. A.I. Treschev be asked to submit to the Meeting of the Working Group a paper illustrating by means of worked examples referring to USSR fisheries the application of his proposed new method of measuring fishing effort, and that other countries evaluate the merits of the method applied to their own fisheries and report their findings to the Working Group".

1. Essence and Representativity of Method Proposed.

The method relies on the following basic assumptions: Fishing gear capacity (power) W (in conjunction with a certain class of vessel, crew and equipment) is described by the water volume (V_s) fished per unit of time (T_1), i.e.

$$W = \frac{V_s}{T_1}$$

where V_s - is established for different gear classes by the methods indicated in Doc. C.M. 1971/B:9, and measured in volumetric units;

T_1 - is the time when a gear is in active (fishing) state and is measured in 24-hour periods and registered either in ship-log or by special-purpose instrumentation.

Fishing effort (U) - is the product of the fishing gear capacity (W) multiplied by its active fishing time, for any period

$$U = WT_2$$

Here the time T_2 is measured in the same units as are accepted for fishing capacity, i.e. 24-hour periods.

*) Fishing unit Measures by A.I. Treschev (Doc.ICES.C.M.1971/B:9).

Fishery Efficiency (E_f) - is the catch (c) per unit of fishing effort, viz.

$$E_f = \frac{C}{U}$$

where C - is the catch in metric tons,

U - is the fishing effort in volumetric units.

Since the fishing effort in terms of the accepted measuring system represents:

$$U = \frac{V_s}{T_1} \cdot T_2$$

that is the volume of water fished, then the fishery efficiency indicates the catch per unit of the volume fished.

This indicator is essential because, the fishing effort being constant, it describes the productivity of fishing areas, in the same way as the harvest per unit of agricultural land provides an index of land fertility in agriculture. Its changes give a measure of evaluating the validity of the quotas set out for catches and efforts.

Under mixed fishery, i.e. with the same object being fished by different gears, the application of the proposed method presents no problem because the fishing effort of different gear classes is measured in the same units and, therefore, may be analysed and limited for all the gears and for each one in particular.

Representativity of Method

For the purpose of cheching on the method's representativity, the correlation has been investigated between the catch and the following parameters: volume of the water fished, the length and displacement of vessel and capacity of the main engine.

The degree of interrelation was assessed using correlation ratios (See Appendix). The calculation data used were those of the Soviet fisheries in subareas 2,3,4,5, and 6 north-west Atlantic. Because there was a marked difference in the fishing situation between subareas 2 and 3 , on the one hand, and subareas 4,5 and 6, on another, all calculations were made in relative figures x).

The findings were as follows:

Relations	Correlation ratio:
Catch per hour - total displacement	- 0.82
Catch per hour - vessel length	- 0.79
Catch per hour - master engine capacity	- 0.88
Catch per hour - fishing capacity	- 0.97

It follows from these data that the technical parameters of fishing vessels (length, displacement, H.P., etc.) are not related through close functional dependence to the results of fishery. It is usually confirmed by the fact that the same vessels operating at the same time in the same area, subject to the type of trawl, show a variation of per hour catches in a great limits (for data considered up to 300 percent). It indicates that the technical parameters of vessels, if applied as the assessment criteria of fishing effort, are not enough representative. The fact that the correlation ratio of catch per hour of trawling and fishing capacity is close to unite (0.97) points to their closest functional dependence.

x) For every area, the mean per hour catch with a bottom trawl of a BMRT-type vessel was assumed for unity (OTST-7).

This is one of the reasons why the author has selected this criterion as the initial value for measuring fishing efforts. Besides, volume fished as the chosen measure of fishing capacity in comparison with all other methods, have the following advantages:

1. It permits to obtain the most accurate assessment of the effects of fishery on the stocks.

2. At a certain productivity of the fishing area (with an established optimal permissible catch per unit of water volume) it permits permanently to observe the relationship between the stocks and fishery which may serve as an important criterion to assess the validity of the quotas set out for catches.

3. Where there has been a preliminary evaluation of the fishing capacity of fishing gear, it will be easy to determine from only two indicators, namely, the number of gears and their time on active duty.

4. It is universal for all fishing gear classes.

5. It lends itself to accurate control and distribution between countries, areas and fishing gears.

6. Under mixed fishery it permits to obtain a differential assessment of fishing efficiency with respect to every particular object.

7. Because fishing capacity and fishing effort stand in no relation to the catch but represent, in effect, no more than technical and operational parameters, no uncertainty is admitted to determining the latter's values, as being dependent on the patterns of fish distribution and behaviour, weather, etc.

8. It is no londer necessary to apply any conventional values and salibrated gears, which involves always great errors because of large variations in the conditions of fishery, efficiency of fishing gears and equipment, and skill of the crew.

2. Method as applied to Stocks and Fishery Analysis

The use of the method for stock and fishery analysis cannot be explained unless we have defined first the concept of "the intensity of fishery". The latter comprises two values: intensity of yield and intensity of fishing.

Yield intensity (ν) is understood as the ratio of the catch of a certain species (N_c) to its stocks (N):

$$\nu = \frac{N_c}{N}$$

Under the fishing intensity we understand in this system of measuring fishery parameters, the ratio of the water volume fished (V_f) to the volume of the fishing area (V)

$$J = \frac{V_f}{V}$$

Under rational fishery, the fishing intensity is to be not only known but properly controlled. To do this one may use the concept of relative fising intensity.

Relative fishing intensity (j) is the ratio of the actual fishing intensity rate (I), as defined from fishery data, to its optimal value(I_{opt}) deriving from the condition of rational relationship between stocks and fishery, i.e. from the biologically determined value of the possible harvest per one cubic kilometer of water volume in the given area:

$$j = \frac{I}{I_{opt}}$$

From this expression one can infer that with j less than unity the fishing intensity is insufficient and should be enhanced, while j more than unity indicated that the fishing intensity has reached its limit and should be reduced accordingly.

Method as Applied to Regulation Practices

Let us assume that the fishing effort of the country A in area n for the time t is equal to U_1; the fishing effort of the country B in area n for the time t is equal to U_2 ; the fishing effort of the country C in area n for the time t is equal to U_3 the summary effort of these three countries $\Sigma U = U_1 + U_2 + U_3$; and the countries' catch in the same area for the same time was ΣC ; then the catch per effort has the form:

$$\frac{\Sigma C}{\Sigma U}$$

Let us assume further that it has been found analytically that the given time period (one year, for example) is such that the summary value of the fishing effort in area n has been optimal, i.e. in full accordance with the stock . Also, x tons of fish has been taken per unit of the water volume fished (e.g. per one cubic kilometer). Let us assume finally that the general yield quota for a particular fish species - C_q tons - was determined for the same area for the next year using stock assessment.

As a result, the total quota of the effort in the given year may be defined as:

$$\frac{C_q}{X} = U \text{ cub. kilometer}$$

Approximately, the total quota of the effort can be allocated between the countries in the same proportions in which catch quotas are usually distributed. Yet it can be distributed with greater accuracy, i.e. proportionate with the actual fishing effort of every country, using the Swept Volume Method. Then the countries with less advanced fishing technology will receive a relatively higher quota of fishing effort per unit of the catch quota than the countries with advanced technology. This requires that each country should make preliminary estimates of the fishing capacity of her fishing gear, as provided in Doc. C.M.1971/B:9 and there after enter these into the fishing gear certificates to be kept on board the ships.
Example: calculation of fishing capacity as it is shown in Table 1. Whether or not the estimates are accurate can be verified at any time by the International Inspection for fishing gear parameters and operation mode.

4. Control and Statistics

Control of the fishing effort under using of the Swept Volume Method is to be undertaken, in the main, on the national basis. Each country, as it directs its vessels off into the sea, should supply them with an assignment specifying the value of fishing effort within the bounds of the limit it has established.

The captains are duty-bound to register in the ship logs the actual operation time of a fishing gear and note toward the end of each day the add-up total of fishing effort consumption (expenditure).

An international inspector, as he pays a routine call to the ship, compares the fishing effort limit issued for the ship against its total consumption as of a certain date.

In order to make it impossible for any particular country to issue more limits than it is entitled to issuing, the limit cards are to carry a stamp of the Fishery Control Commission (Convention) for the given area.

For the purpose of more exact control of the fishing effort consumption in the future use can be made of elementary instruments to record on a sealed film the time of gears operation in the fishing mode (for example, the time when a trawl is at stopper). The list of the necessary instruments is given in Doc.C.M.1971/B:9.

Application of the Swept Volume Method of fishery parameter evaluation will cause if only a minor change in statistics, such as is being currently submitted by the Conventions Commission countries. Thus, in Table 4 (Statistics of fishing effort and nominal catch by division, month, gear and country) of the ICNAF Statistical Bulletin, under the heading "gear", besides the type of gear, there must be an indication of the latter's fishing capacity in proms, i.e. in the units equal to $\frac{10^9 m^3}{24\ hr}$.

Thus, instead of "OTST" there should be "OTST - 035" where 035 signifies that a given gear as applied from a given ship during 24 hours of continued fishery is capable of fishing a water volume of 0.035×10^9 cub.m.

The column "days fished" should contain data on the time of the active gear operation over a year. The column "hours fished" is to be ruled out. All other statistics shall be presented in the same form as before.

TABLE 1

EXAMPLE: Calculation of Fishing Capacity and Annual Fishing Effort Developed by a Fleet (real data for a USSR Fishing Fleet, 1968).

essel type	Trawl	Trawl opening area m^2 x)	Trawl coverage per hour m	Fish. cap. of gear in conj. with vessel $10^9 m^3/24^h$	Hours of trawl. per annum	Fish. effort of vessel $10^9 m^3$	Number of vsls	Fish. cap. of fleet $10^9 m^3/24^h$	Fleet's fish. effort $10^9 m^3$
OTST-7) PR	n 396	200	7400	0.03552	2446	3.619	16	0.568	57,904
OTST-7) BMRT	n 352	150	7400	0.02664	2300	2.552	83	2.211	211,816
OTSI-5) RT	n 25	94	5926	0.01337	2000	1.114	180	2.407	200,520
OTSI-4) SRT	n 23	66	5926	0.00939	540	0.211	189	1.175	39,879
								6.961	510,119

x) Trawl opening area for vessels:
- PR - 43m x 4.6m = 200 m^2;
- BMRT - 37.5m x 3.9m = 150m^2;
- RT - 24.7m x 3.8m = 94m^2;
- SRT - 17.5m x 3.8m = 66m^2;

OTSI - otter trawler with side trawling
OTST - otter trawler with stern trawling
OT - otter trawler
RT - pair trawler (twin fishing)
RS - with purse-seine

Categories of Vessel Tonnage

2 - 0 - 51 t
3 - 51 - 150 t
4 - 151 - 500 t
5 - 501 - 900 t
6 - 901 - 1800 t
7 - more than 1800 t

ANNEX

Study of Correlation between Catch per Hour of Trawling and the Following Parameters: Displacement and Length of Ship, Capacity of Main Engine, and Volume of Water Fished (Fishing Capacity).

Determination of Correlation Ratios

Correlation ratio is determined on the formula:

$$\eta_{y/x} = \sqrt{\frac{\sum_{j=1}^{l} m_j (\bar{y}_{/x_j} - \bar{y})^2}{\sum_{i=1}^{n} (y_i - \bar{y})^2}} \quad ; \quad \bar{y}_{/x_j} = \frac{1}{m_j} \sum_{i=1}^{m_j} y_{ij}$$

where:
- l - interval number of value x;
- j - ordinal number of interval of value x;
- $\bar{x}_j$ - interval centre of value x;
- $\bar{y}/x_j$ - mean value of y for the x-th interval;
- m_j - number of points whose (x_{ij}, y_{ij}) x-coordinates are found in j interval;

a) Computation of Correlation Ratio catch per hour - length of vessel $[L, m]$

Length of vessel, m (x_i)	Catch per hour (relative units) (y_i)
84,7	1,0; 1,21; 1,0; 1,05
82,2	0,98; 1,57; 1,95
79,2	0,9; 1,3; 0,6
54,2	0,26; 2,03; 0,74
50,8	0,24;
43,6	0,21; 0,17;

Correlation Grid

Interval	j	I	2	3	4 + 7	8	9
	L	40-45	45-50	50-55	55-+75	75-80	80-85
Catches y_j	x_j	42,5	47,5	52,5	57,5+72,5	77,5	82,5
0,1-0,3	0,2	0,21 0,17		0,24 0,26 0,23			
0,3-0,5	0,4						
0,5-0,7	0,6					0,6	
0,7-0,9	0,8			0,74		0,9	
0,9-1,1	1,0						0,98 1,0 1,0 1,05
1,1-1,3	1,2					1,3	1,21
1,3-1,5	1,4						
1,5-1,7	1,6						1,57
1,7-1,9	1,8						
1,9-2,1	2,0						1,95
$\sum_{i=1}^{m_j} y_{ij}$		0,38	0	1,47	0	2,8	5,21
m_j		2	0	4	0	3	7
$\bar{y}_{/x_j} = \frac{1}{m_j}\sum_{i=1}^{m_j} y_{ij}$		0,19	0	0,37	0	0,93	1,25

Computation: $\sum_{j=1}^{l} m_j (\bar{y}_{/x_j} - \bar{y})^2$

$\bar{y}_{/x_j}$	$\bar{y}_{/x_j} - \bar{y}$	$(\bar{y}_{/x_j} - \bar{y})^2$	m_j	$m_j(\bar{y}_{/x_j} - \bar{y})^2$
0,19	-0,65	0,4225	2	0,8450
0	-0,84	0,7056	0	0
0,37	-0,47	0,1369	4	0,5476
0	-0,84	0,7056	0	0
0,93	0,09	0,0081	3	0,0243
1,25	0,41	0,1681	7	1,1767

$\sum = 2,5936$

Computation: $\sum_{i=1}^{n} (y_i - \bar{y})^2$

y_i	$y_i - \bar{y}$	$(y_i - \bar{y})^2$
0,17	-0,67	0,4489
0,21	-0,63	0,3969
0,23	-0,61	0,3721
0,24	-0,60	0,3600
0,26	-0,58	0,3364
0,60	-0,24	0,0576
0,74	-0,10	0,0100
0,90	0,06	0,0036
0,98	0,14	0,0196
1,0	0,16	0,0256
1,0	0,16	0,0256
1,05	0,21	0,0441
1,21	0,37	0,1369
1,30	0,46	0,2116
1,57	0,73	0,5329
1,95	1,11	1,2321

$\bar{y} = 0,84$ $\sum = 4,2139$

$$\eta = \sqrt{\frac{2,5936}{4,2139}} = 0,79$$

b. Calculation of Correlation Ratio Catch per Hour - Displacement (D,T)

Table 3.

Displacement (x_i)	Catch per hour (relative units) (y_i)			
3800	1,0 ;	1,0 ;	1,21;	1,05
3362	0,98;	1,57;	1,95	
3275	0,9 ;	0,6 ;	1,3	
912	0,26;	0,23;	0,74	
737	0,24			
545	0,21;	0,17		

Correlation Grid:

Interval	j	I	2	3	4-13	14	15	16	
	D	400-600	600-800	800-1000	1000-3200	3200-3400	3400-3600	3600-3800	
Catches	$y_i \backslash x_i$	500	700	900	1100-3100	3300	3500	3700	
0,1-0,3	0,2	0,21	0,24	0,26					
		0,17		0,23					
0,3-0,5	0,4								
0,5-0,7	0,6					0,6			
0,7-0,9	0,8			0,74					
0,9-1,1	1,0					0,9		1,0	1,05
						0,98		1,0	
1,1-1,3	1,2					1,3		1,21	
1,3-1,5	1,4								
1,5-1,7	1,6					1,57			
1,7-1,9	1,8								
1,9-2,1	2,0					1,95			
	$\sum_{i=1}^{m_j} y_{ij}$	0,38	0,24	1,23	0	5,95		4,26	
	m_j	2	1	3	0	6	0	4	
$\bar{y}_{\mid x_j} = \frac{1}{m_j} \sum_{i=1}^{m_j} y_{ij}$		0,19	0,24	0,41	0	1,22	0	1,06	

E1

Computation: $\sum_{j=1}^{\ell} m_j (\bar{y}_{/x_j} - \bar{y})^2$

$\bar{y}_{/x_j}$	$\bar{y}_{/x_j} - \bar{y}$	$(\bar{y}_{/x_j} - \bar{y})^2$	m_j	$m_j(\bar{y}_{/x_j} - \bar{y})^2$
0,19	-0,65	0,4225	2	0,8450
0,24	-0,6	0,3600	1	0,3600
0,41	-0,43	0,1849	3	0,5547
0	0,84	0,7056	0	0
1,22	0,38	0,1444	6	9,8664
0	0,84	0,7056	0	0
1,06	0,22	0,0484	4	0,1936
				2,8179

$$\eta = \sqrt{\frac{2,8179}{4,2139}} = 0,82$$

c) computation of Correlation Ratio:
catch per hour - main engine capacity (N, h.p.)

Table 4

Main engine capacity, h.p. (x_i)	Catch per hour (relative units) (y_i)			
2000	1,0;	1,0;	1,21;	1,05
2320	0,98;	1,57;	1,95;	
1340	0,9;	0,6;	1,3;	
800	0,26;	0,23;	0,74;	
540	0,24;			
400	0,21;	0,17;		

Correlation Grid:

Interval	j	1	2	3	4+5	6	7+8	9	10	11
	N	300-500	500-700	700-900	900-1300	1300-1500	1500-1900	1900-2100	2100-2300	2300-2500
Catches	y_j \ x_j	400	600	800	1000-1200	1400	1600-1800	2000	2200	2400
0,1-0,3	0,2	0,21	0,24	0,26						
		0,17		0,23						
0,3-0,5	0,4									
0,5-0,7	0,6					0,6				
0,7-0,9	0,8			0,74		0,9				
0,9-1,1	1,0							1,0		0,98
								1,0		
								1,05		
1,1-1,3	1,2					1,3		1,21		
1,3-1,5	1,4									
1,5-1,7	1,6									1,57
1,7-1,9	1,8									
1,9-2,1	2,0									1,95
	$\sum_{i=1}^{m} y_{ij}$	0,38	0,24	1,23	0	2,8	0	4,26	0	4,5
	m_j	2	1	3	0	3	0	4	0	3
$\bar{y}/x_j = \frac{1}{m_j}\sum_{i=1}^{m} y_{ij}$		0,19	0,24	0,41	0	0,93	0	1,06	0	1,50

E 3

Computation: $\sum_{j=1}^{l} m_j (\bar{y}/_{x_j} - \bar{y})^2$

$\bar{y}/_{x_j}$	$\bar{y}/_{x_j} - \bar{y}$	$(\bar{y}/_{x_j} - \bar{y})^2$	m_j	$m_j(\bar{y}/_{x_j} - \bar{y})^2$
0,19	-0,65	0,4225	2	0,8450
0,24	-0,60	0,3600	1	0,3600
0,41	-0,43	0,1849	3	0,5547
0	-0,84	0,7056	0	0
0,93	0,09	0,0081	3	0,0243
0	-0,84	0,7056	0	0
1,06	0,22	0,0484	4	0,1936
0	-0,84	0,7056	0	0
1,50	0,66	0,4356	3	1,3068

$\sum$ = 3,2844

$$\eta = \sqrt{\frac{3,2844}{4,2139}} = 0,88$$

d) Computation of Correlation Ratio catch per hour - fishing capacity $\left[10^9 \frac{\text{cub.m.}}{\text{24 hr.}}\right]$

Table 5

Fishing capacity $\left[10^9 \frac{\text{cub.m.}}{\text{24 hr.}}\right]$ (x_i)	Catch per hour (relative units) (y_i)
0,0173	1,0; 1,0
0,0958	1,21; 1,05
0,0162	0,98;
0,2570	1,57; 1,95
0,0152	0,9; 0,6
0,0986	1,3;
0,0098	0,26; 0,23
0,0352	0,74;
0,0072	0,24;
0,0068	0,21; 0,17

E 4

Correlation Grid:

Interval	j	1	2	3	4	5+8	9	10+24	25
	w	0-0,010	0,010-0,020	0,02-0,03	0,030-0,040	0,04-0,090	0,090-1,00	0,100-0,250	0,250-0,260
Catches	$y_i \diagdown x_i$	0,005	0,0015	0,025	0,035	0,045-0,085	0,095	0,105-0,0245	0,255
0,1-0,3	0,2	0,21 0,17 0,24 0,26 0,23							
0,3-0,5	0,4								
0,5-0,7	0,6		0,6						
0,7-0,9	0,8		0,9		0,74				
0,9-1,1	1,0		0,98 1,0 1,0				1,05		
1,1-1,3	1,2						1,3 1,21		
1,3-1,5	1,4								
1,5-1,7	1,6								1,57
1,7-1,9	1,8								
1,9-2,1	",0								1,95
	$\sum_{i=1}^{m_j} y_{ij}$	1,11	4,48	0	0,74	0	3,56	0	3,52
	m_j	5	5	0	1	0	3	0	2
$\bar{y}/x_j = \frac{1}{m_j}\sum_{i=1}^{m_j} y_{ij}$		0,22	0,90	0	0,74	0	1,19	0	1,76

Computation: $\sum_{j=1}^{\ell} m_j (\bar{y}_{/x_j} - \bar{y})^2$

$\bar{y}_{/x_j}$	$\bar{y}_{/x_j} - \bar{y}$	$(\bar{y}_{/x_j} - \bar{y})^2$	m_j	$m_j(\bar{y}_{/x_j} - \bar{y})^2$
0,22	-0,62	0,3844	5	1,9220
0,90	0,06	0,0036	5	0,0180
0	-0,84	0,7056	0	0
0,74	-0,10	0,0010	1	0,0010
0	-0,84	0,7056	0	0
1,19	0,35	0,1225	3	0,3675
0	-0,84	0,7056	0	0
1,76	0,92	0,8464	2	1,6928

$\sum = 4,0013$

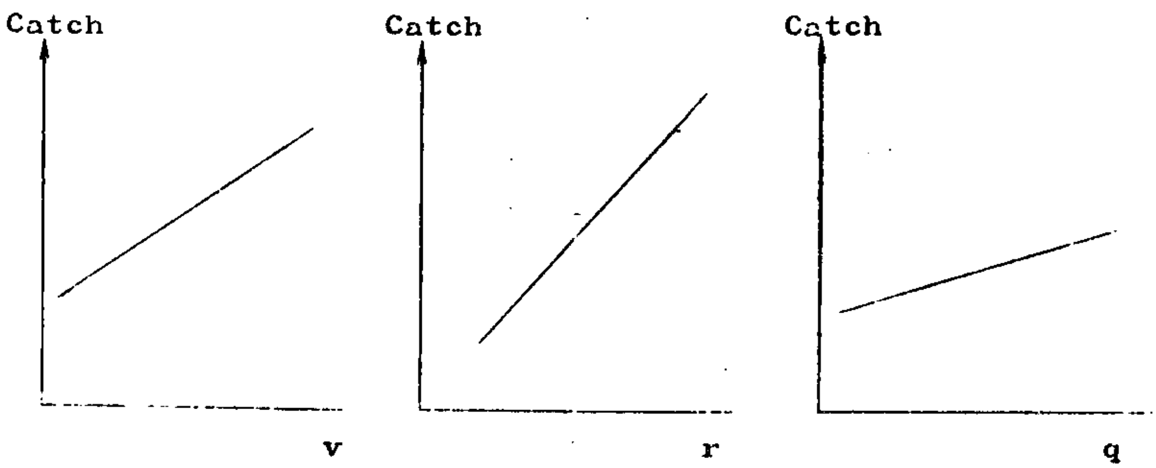
$$\eta = \sqrt{\frac{4,0013}{4,2139}} = 0,97$$

ENGINEERING ASPECTS OF SWEPT VOLUME METHOD (SVM) DEFENITION PARAMETERS OF FISHERY

by
Dr. A.I. Treschev

Fishing effectivity (E) depends upon three factors:

1. Swept volume (V). It charactorises the degree of area covered which is fished;
2. Degree of fish finding (r);
3. Catchability of fishing gear (q):



$$E = f_1(v, r, q)$$

S.V.M. shows us how these factors should be considered.

V - depends on the square of the mouth of the gear opening - S, Speed - γ and fishing time - t,
In other words:

$$V = f_2(S, \gamma, t)$$

From another side:

$$V = f_3(HP, \frac{B}{L}\lambda, Kw)$$

HP = horse power of engine;

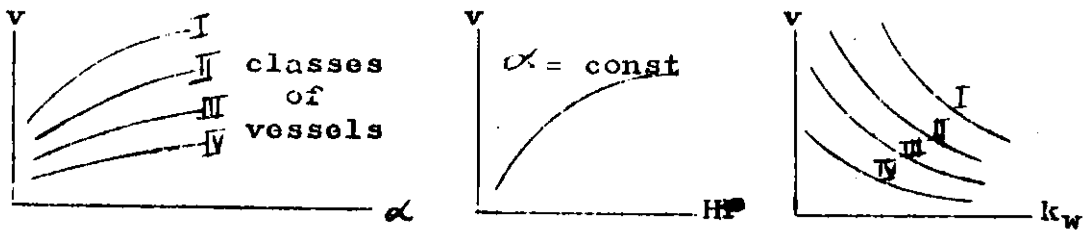
$\frac{B}{L}\lambda = \alpha$ - hydrodymamic data (B - breadth of vessel, L - Length of vessel over all)

λ - coefficient which depends on form of vessel, propellor and gear).

E 8

K_w - is a coeficient which characterises the influence of weather. It can be the Beaufort's scale of the sea state.

In results of investigations of these factors, we can obtain:



When we have that we will be able to know the influence of all those parameters to fishing efficiency

2). Degree of fish findings

$$r = \frac{Nv}{Nfa}$$

Nv = the number of fish discovered in the fishing area (N - fish in swept volume)

Nfa = total number of fish in the area during fishing time

3). Catchability of fishing gear - q - is

$$q = \frac{Nc}{Nv}$$

ratio of numbers of fish in catch (Nc) to number of fish in swept volume (Nv).

As we can see in this analysis there is no Gross Tonnage because it has no direct influance on the fishing efficiency. Sometimes we find the connection between Gross Tonnage and catches. It only means that in these cases Gross Tonnage is proportional to HP and speed of vessels.

This brief analysis shows us how many components should be included in the determination of fishing efficiency and why we cannot take the time on the fishing grounds, HP, Gross Tonnage, standard gear and so on.

Swept volume is much more representative because it includes all real influent factors and it can be determined in a very simple way.

/JT