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Results of Identification of Trawl Catchability by Underwater Methods in Relation to Some Fish Species of the Northwest Atlantic

by

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Introduction

Fishing efficiency (FE) of the trawl implies the ratio of the number of fish caught to the number present in the bottom area fished off or number of fish in the filtered water volume (Baranov, 1918). This concept characterizes the retaining capability of trawl system in toto, including not only all its details, but also the physical fields created by the system; therefore, it is rather wider than the concept "selectivity", usually concerned only the netting. In some papers (Zasosov, 1970) the "fishing efficiency" means the ratio of the single catch to the total fish stocks, but it seemed to us that in this case the concept "catchability" suggested by W.E.Ricker (1979) is better fitted.

Determination and studies of FE allow to judge about the perfection degree of fishing gears and possibilities for their development, to obtain an assessment of fish abundance due to the results of trawl surveys, but, mainly, to ensure the fish resources investigations with precised initial data on populations structure and fishery effect upon it. Probable models of interaction between the fishing object and trawl are considered in some theoretical papers (Ionas, 1967; Chestnoy, 1977; Lukashov, 1972; Rosenshtein, 1976; Treshchev, 1983).

Attempts of direct identification of FE were repeatedly undertaken, the methods applied could be divided into three groups: the fishing of the artificially formed tagged fish concentrations of certain density; the repeated fishing of the species escaped the trawl; direct identification of density, size composition and abundance of the concentration under natural conditions on trawl's way.

Artificial concentrations are formed by tagged fish releases from the net container between boards and trawl wings (Treshchev, Efanov, 1976). As the size composition of the concentration fished off is known in advance, the method gives an opportunity to differentiate FE by fish length groups. The use of acoustic tags instead of the common ones and the control of spatial location of fish and trawl by means of hydrolocator with the indication on display represents the development of the method (Harden et al., 1977). However, similar methods hardly can give the reliable identification of FE, because, firstly, it is impossible to create an artificial concentration of sufficient abundance (some thousands of fish) for each trawling aimed at statistical confidence of the results, and, secondly, it is impossible to guarantee the identity of behaviour of tagged and intact fish and equal probability of their catchability.

The method of repeated fishing, aimed at determination of the number of fish escaped the fishing gear, was applied for FE estimate of valid lampara nets (Maisky, 1940) and scrapers. While studying the trawls operation this method is only used for selectivity assessment of the netting with covers of different designs (Treshchev, 1974). To determine by this way the FE of trawl it would be necessary to tow the second trawl in such a short distance, at which the other fish could not be in the fishing zone of the second trawl, except those fish escaped the first trawl. The practical use of this method would be extraordinary complicated. Besides, similar location of the trawls undoubtedly can change their hydrodynamic characteristics and interaction with the fishing object, therefore, these methods as well as the former ones are of little use for FE identification.

The most reliable estimates of FE can be obtained if the process of the natural concentration fishing is investigated and there are no any changes and additions in the fishing gear design. But in this case, it is necessary to identify the natural concentration density independently of their fishing with trawl. There were taken the attempts to use for this purpose special fishing gears with FE close to 100%, for example, ring traps (Kuipers, 1975), but these were suitable only for not mobile flounders. The hydroacoustic methods can not be also universal (Artemov et al., 1978; Stromme et al., 1982): these are applicable only for pelagic concentrations of homogeneous species and size compositions and do not represent any information on fish behaviour and their sizes, that can give the erroneous results.

Methods

Significant possibilities of the trawl FE identification for any concentrations of fish and invertebrates were open due to application of equipment for underwater observations, in particular, of submersibles. The identification of the density of natural concentration in front of the trawl was carried out in accordance with the visual-geodesic methods (Zaferman, 1978). The submersible passed through the concentration before trawling, the observers identified the extents of the water volume or ground area investigated, taking into account visual angles, the range from the submersible to the ground, submersible's speed, which were kept to be constant, and registered the fish on the route by means of magnetic type. After lifting of submersible the recordings were deciphered, the number of each species was counted, the density of their concentrations over the observed area was estimated. When the diametrical dimensions of trawl, speed and duration of trawling are known, the ground square trawled or water volume and number of fish on trawl's course were estimated. FE was obtained by comparison between this value and catch.

The method of density identification by means of submersibles allows to investigate mixed concentrations consisted of some species of fish and invertebrates, the density of each species is independently estimated. To control the submersible effect upon the fish behaviour, two criteria were used: character of fish orientation to submersible and distance of their response. If the fish orientation did not show any relation to the direction of submersible run, but response distance was considerably less than visibility distance, then the fish behaviour in concentration was considered to be not disturbed and the estimated density - to be true. By these criteria the estimates of concentration density of majority of the species observed (about 30) were considered to be reliable. Only blue whiting in the summer feeding period and herring had evident negative response to submersible, that did not allow to identify the true density of their concentrations.

First experimental studies on FE identification were carried out in 1973-1975 by means of submersible "Sever-I" from board the RV "Tunets" in the Barents Sea and RV "Persey III" in the Northwest Atlantic (Zaferman, 1976). As the parameters of submersible drifted with vessel (direction, speed and range above the ground) were unstable and could not be estimated with reasonable accuracy, the observations were conducted in polygon, where series of submersions and trawlings were carried out. FE was identified by averaged values of density and catch measured, aimed at reduction in errors.

In 1976-1978, the photogrammetric method, at which the camera was installed on special false line (Fig. 1), stretched between trawl boards (Serebrov, 1980) was applied for identification of concentration density of demersal fish in front of the trawl. The height of photocamera above the bottom, and, consequently, the square photographed were determined by means of stereo survey or special device projecting the light spot on the ground (Serebrov, 1980a). The density was determined by division of the number of fish photographed into overall bottom square in all the pictures. In these experiments the confidence interval and probable error in FE assessment were possible to be estimated. Data on fishing efficiency were used for the first time for assessment of abundance and biomass of commercial fish in the area investigated (Chumakov, 1979). The comparison between photogrammetric and acoustic estimates of near bottom concentrations density showed that because of masking of fish by reflection from the ground, the acoustic methods always gave underestimation with high random error, that made them unsuitable for similar investigations.

In 1983, the underwater TV was used for the first time for identification of the trawl FE for beaked redfish on the Flemish Cap Bank (Serebrov, 1985). The underwater block of TV-station "Kaiman-2" (Shimyansky, 1983) was towed above the ground (Fig. 2) in front of the vessel towing the trawl. The distance from the transmitted camera to the ground was measured by echo sounder, the vibrator of which was on the underwater block. This allowed to determine the scale of the image, the true length of the fish visible on the screen, width and square of ground patch observed. On the basis of the results of the TV observations it was possible to determine not only the average, but also differentiated by size groups, trawl FE in relation to beaked redfish on the Flemish Cap Bank.

The total error and confidence interval of the underwater observations results were estimated with allowance for possible errors in determination of the area observed, number of fish and their lengths (Table 1).

While estimating the confidence of FE values, the average random error in trawl catch amount was also taken into account. Aimed at determining this error, the simultaneous fishing of the same concentration by similar trawls from two vessels sailing by parallel courses in close distance between them was carried out.

Results

The results of identification of average FE of trawls (for fish of given species and size composition) in relation to cod, halibut, redfish and grenadier of the Northwest Atlantic are represented in Table 2. As it is seen from the data obtained the trawl catches only a comparatively small number of fish from the area trawled. The FE value is fairly unstable and depends upon many factors, in particular, upon the size composition of the concentration.

The comparison of the trawl FE by size groups of the beaked redfish shows (Table 3), that with length growth the FE values firstly increase from 0 to maximum equal to about 70% at 35 cm long and then decrease again up to 0. The size composition of the catch both in right and left sides of the frequency principally differs from size composition of the concentration fished off (Fig. 3). The most numerous small specimens of redfish in the population are represented in the catch by extremely insignificant amount.

The trawl FE in relation to the Greenland halibut of various length was also sufficiently different (Fig. 4). Visual observations from the submersible "Sever-1" showed that even in the areas of the commercial concentrations the distances between the single individuals of halibut, lying on the ground constituted from 10 to 50 m and longer. Photographic survey of similar scattered concentrations by means of automatic camera, installed on false line (Fig. 2) did not allow to obtain sufficient data on their density and size composition. In particular, the halibut specimens of over 70 cm long were completely absent in the pictures. Due to the same reason the data on the trawl catchability in relation to halibut of different length, given in Fig. 4, are not sufficiently indicative of their variations tendencies. To obtain more complete data concerning this problem it is necessary to apply deepwater manned submersibles or TV systems.

The response of cod, redfish, grenadier and Greenland halibut to light of projectors and moving of submersibles was, as a rule, rather passive and sometimes it was absolutely absent. In the moment of meeting with the submersible no any disturbance features were expressed by fish. In some cases the large specimens of cod and flounders tried to retain over the area lighted by projectors and moved for some time accompanying the submersible. Roundnose grenadier usually always passive expressed obvious negative response to bright light of projectors and tried to move away into less lighted area. On the whole, the lack of well-expressed wish to leave the observed zone in all the fishes analysed is an evidence of the fact that the availability of submersible does not disturb the natural character, behaviour and distribution of fish inhabiting on the ground and near it. Respectively, the data, obtained during the underwater observations, on density and structure of populations are probably considered to be quite representative.

Discussions

The obtained results can be explained by the interaction between fish and trawl. Taking fright of boards, cables and turbidity, the fishes concentrate off the axial line of a trawl and then while approaching the net mouth they turned into trawling derection and swim in front of the trawl, trying to escape the fishing zone. Due to V.V.Shuleikin (1968) the speed of fish swimming is directly related to their sizes.

Low trawl catchability in relation to fish of small sizes (younger age groups) is probably caused not only by their escapement through the mesh, but also by their low swimming speed because of which they are insufficiently effectively concentrated by boards, cables and turbidity. The fish of average sizes have the swimming speed sufficient for effective concentration to the trawl mouth from boards and cables, but not for active escapement from the trawl, therefore, FE for them are of maximum value. Large fish of elder age groups have high swimming speeds allowing them to overrun the trawl and to leave the fishing zone, that causes the reduction in FE for large fish. An analogous relationship between the value of differentiated FE and fish length was earlier revealed (Serebrov, Popkov, 1982) for the Barents Sea cod and long rough dab.

The behaviour type while fishing described, is typical for demersal and near-bottom fishes not forming the shoals with ordered structure. Each individual of these species interacts with trawl independently from the others and the catch is determined as a result of a great number of individual or similarly running acts of such interaction. In this case FE is reliably identified and the more so statistically reliable when greater number of fish in the fishing zone is observed.

A great number of specimens is related by unity of behaviour among the pelagic fish and they form ordered shoals responding to trawl as a single whole. Here the catch consists of the results of fishing the comparatively small number of such shoals, that leads to great variations both in catch and FE estimate. Probably, spread of results of the FE identification for roundnose grenadier is explained by this fact (Table 1).

The results of FE identification are indicative of sufficient reserves for trawl design development available. So far the trawl capability was tried to raise, mainly, by their sizes increase. At present it is reasonable to pay more attention to problems of the fish behaviour features use for their fishing efficiency increase.

The data on average and differentiated by size groups trawl FE can have a sufficient importance for those conclusions, which are usually made on the basis of analysis of data about scientific and commercial catches. In particular, the average density of concentrations of fish of different species can be found from the catches with use of data on average FE for species. However, similar assessment in any case would be rather approximated because of inconstancy of size composition of concentrations fished off and random variations in trawls catchability.

For instance, mean error of identification of concentration density by single cod catch constituted approximately $\pm$ 57.2%, and by beaked redfish catch - $\pm$ 87.3%, that was significantly higher than total error of analogous estimates by means of underwater methods (Table 1).

If concentration density is determined not by single catch but by mean catch, estimated on the basis of series of N of trawlings, then the error in final result would be by $\sqrt{N}$ times less than the error in single assessment. It makes possible to use the trawl surveys method for approximate estimates of abundance and biomass of populations under condition, if the mean value of FE of trawl is known for fish of a given species.

As it is seen from Fig. 3 and Table 3 the valid trawl with fine meshed (12 mm) netting in the codend catches the redfish of various length, with fairly different probability. Size composition of the catch absolutely differs from size composition of the concentration fished off. This result is necessary to take into account while studying the population structure and distribution of redfish by catches taken with scientific valid trawls.

Conclusions

The conducted investigations showed that the problem of identification of the average for species and differentiated by length groups FE of trawls is entirely solved by means of underwater equipment. The data collected can be applied to different aspects of investigation and exploitation of fish resources. Aimed at practical use of obtained results it is necessary to widen them and to make more accurate on the basis of collection of greater amount of data by means of more developed methods and technical devices.

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Table 1 Average errors in single assessment of concentration density and object size by underwater methods

Methods	Errors in assessments, ± %			Intervals of reliable estimates of density, spec/thou m^2
	Area observed	Density	Object length	
Visual-geodesic	9.5	12-14	18.5	0.5-200
TV	15.6	17-21	36.7	1.7-100
Photogrammetric	6.0-22.5	8.8-29.5	3-14.4	74-15000

Table 2 Results of identification of mean FE of trawls in relation to fish in the Northwestern Atlantic

Species	Trawl sizes, m	Mesh size in cod-end, mm	Years	Method and submersible for observations	Number of observations	Mean FE, %	Notes
Cod	3I,2/ /27,3	30	I975	Visual-geodesic "Sever - 1"	I	23,8	
		30	I976	Photogrammetric	9	6,4	
		30	I977	Photogrammetric	2	9,6	
Greenland halibut	3I,2/ 27,3	I20	I976	Photogrammetric	7	I7,0	Mean error ±3,5
		I20	I977	-"-	4	20,0	
		I20	I978	-"-	I	I3,4	
	4I,7/ 39,6	I20	I976	Visual-geodesic "Sever - 1"	3	2I,7	
		I20	I977	Photogrammetric	2	8,5	
Roundnose grenadier	3I,2/ 27,3	30	I975	Visual-geodesic "Sever - 1"	I	45,0	
		I20	I976	Photogrammetric	3	4,6	
		I20	I977	-"-	2	20,5	
		30	I978	-"-	I	II,4	
Beaked redfish	3I,2/ 27,3	30	I975	Visual-geodesic "Sever - 1"	I	I0,0	
		30	I978	Photogrammetric	I	4,5	
		I2	I983	TV	4	I9,5	Mean error ±I0,3

Table 3 Fishing efficiency of valid trawl in relation to beaked redfish of different length

Indices	Size classes, cm: 5–9	10–14	15–19	20–24	25–29	30–34	35–39	40–44	45–49	Total	Mean
Number of fish observed, spec.	20	21	21	16	12	9	6	4		109	
Abundance in fishing zone, spec.	1686	1770	1770	1349	1012	759	506	337		9189	
Catch, spec.	13	177	359	165	450	527	82	14	3	1790	
Fishing efficiency (FE), %	0,8	10,0	20,3	12,2	44,5	69,4	16,2	4,1			19,5
Expected error of FE in % of its value	19,4	24,2	26,0	25,7	25,7	27,8	31,3	35,6			27,2
Confidence estimate of difference between FE values (t due to Student)		3,8	1,78	1,31	3,7	1,11	2,7	2,3			

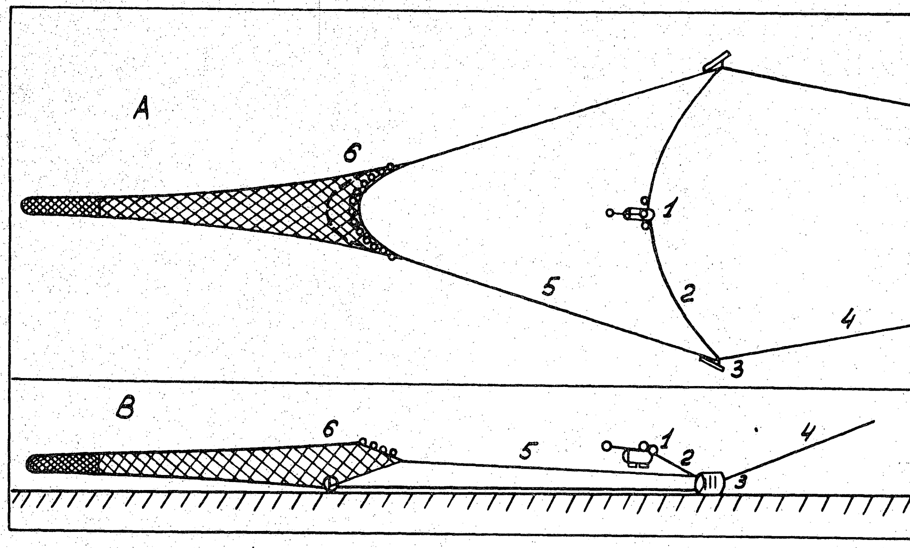

Fig. 1 Scheme of automatic photocamera tow on false line in front of the trawl
A - upper view, B - side view,
1 - photocamera, 2 - false line, 3 - board,
4 - wire, 5 - cable, 6 - trawl.

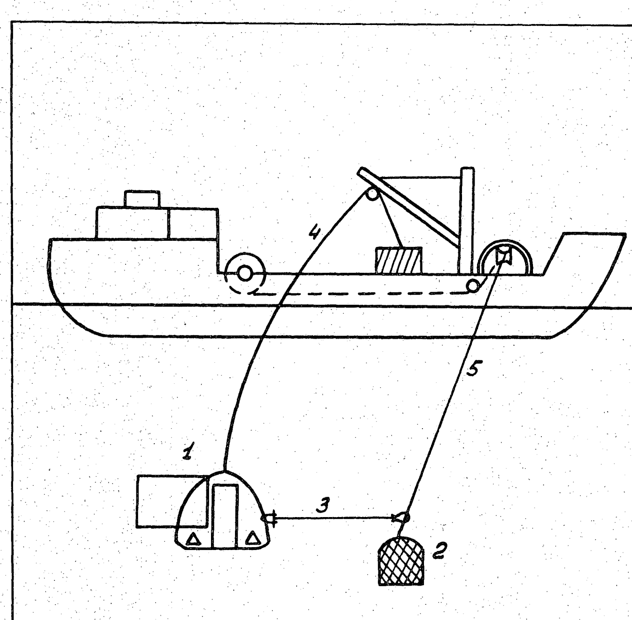

Fig. 2 Scheme of transmitted TV camera tow
1 - camera, 2 - 450 kg cargo-depressor,
3 - antenna with figured bracket slipping along the wire, 4 - cable, 5 - wire.

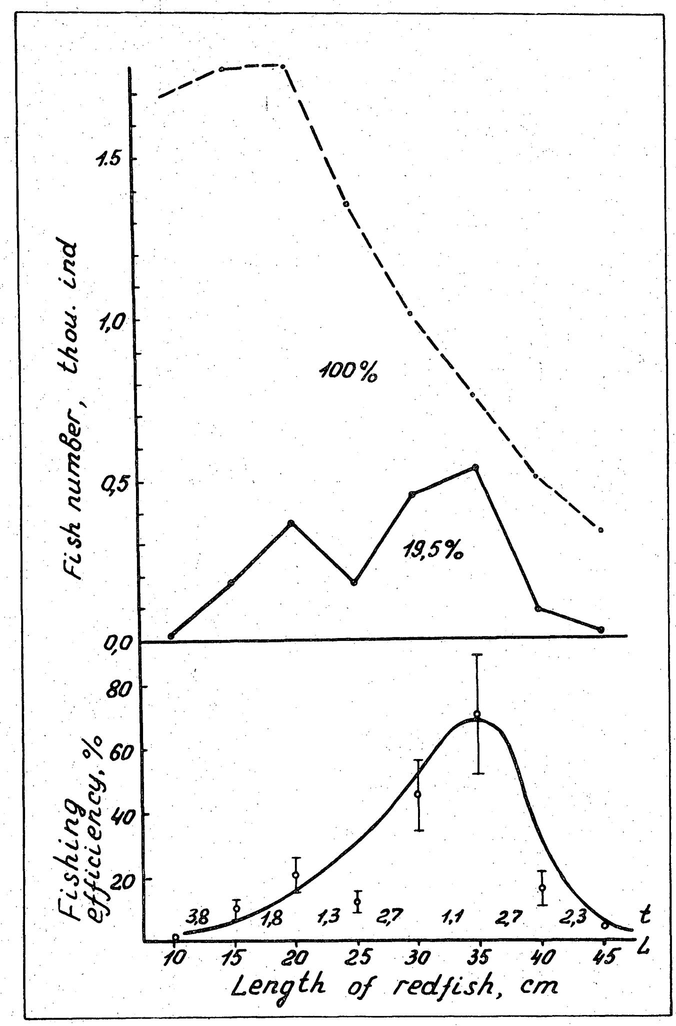

Fig. 3 Size composition of beaked redfish in the fishing zone (dotted line), catch (solid line) and FE of trawl with 12 mm mesh size in the codend in relation to beaked redfish of different length. Vertical lines with dashes - range of possible random errors in FE values.

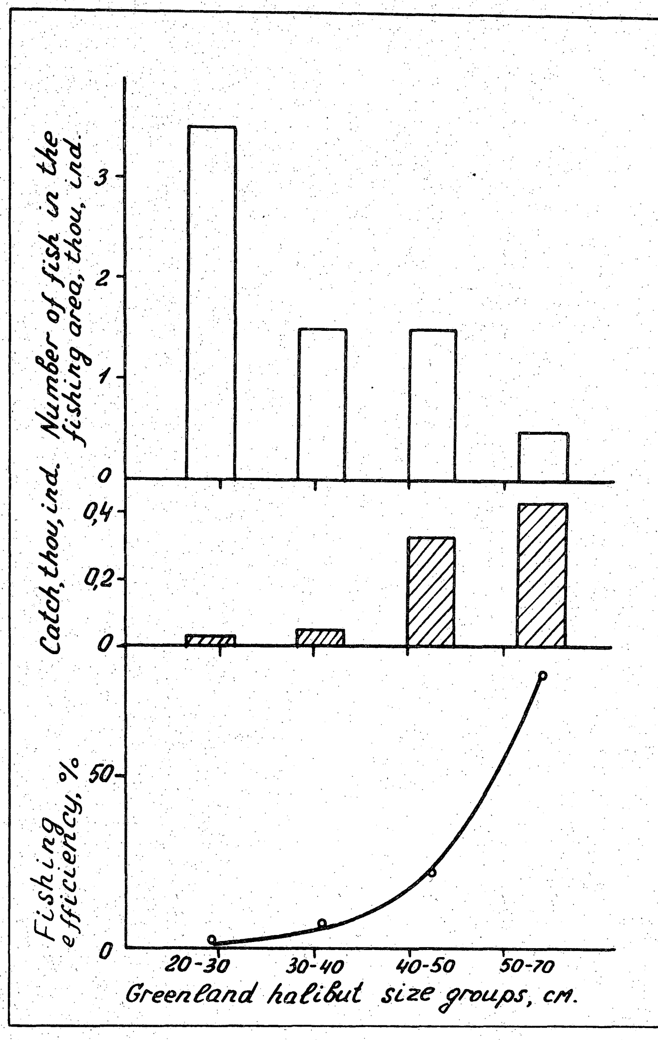

Fig. 4 Abundance of halibut of different length in the fishing zone (light rectangles), catch (shading) and approximate FE of valid trawl in relation to halibut of different length (curve).