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# Modelling of Fish Schools for Calibration of the Echo-integrator

by

V. A. Ermolchev, S. M. Kovavlev, and V. S. Mamylov
Polar Research Institute of Marine Fisheries and Oceanography (PINRO)
Murmansk, USSR

## Abstract

The paper deals with the method of echo-integrator calibration on the models of dead fish schools of different density. This method was used when conducting echometric survey on capelin stocks on the Grand Newfoundland Bank in spring/summer 1979. The survey was carried out by RV "Poisk".

## Introduction

Hydroacoustic method of the assessment of fish concentrations based on measuring the energy of echo-signals from concentrations M with the help of echo-integrator connected to the echo sounder with TVG - 20 lgr permits to measure indirectly the concentration density in accordance with the formula (Forbes, Nakken, 1972):

$$\rho_s = CM + d; \quad \rho_s = \rho_v \cdot \Delta r \cdot 3{,}43 \cdot 10^6;$$
$$C = C_y\, C_f\,; \quad C_f = C_s L^{-\varepsilon}, \quad C = C_n L^{-\varepsilon}, \qquad (1)$$

where

$\rho_s$ - number of fish per square mile in the layer $\Delta r$, sp./sq.m.;

$\rho_v$ - density of fish concentration in the layer $\Delta r$, sp./$m^3$;

$C$ - coefficient of absolute calibration of echo-integrator, sp./sq.m./unit of echo-intensity M;

$M$ - total echo-intensity from the fish concentration in the layer $\Delta r$, per unit value;

$L$ - fish length, cm;

$C_y, C_f$ - constituents of coefficient C.

The total echo-intensity M is measured with echo-integrator during the echometric survey. Value $C_J$ is called "instrumental" constant and calculated after determining the echo sounder specifications ( directional diagram of antenna, gain of the receiving channel, duration of the emitted signal and its power). Value $C_f$ is determined from target strength measurements of fish of different species and length. Special instruments should be installed on board the vessel to determine $C_J$ and $C_f$ but it is rather difficult to conduct such measurements in the open sea. This resulted in working out new methods of echo-integrator calibration: by means of echo-counting system with separate recording of echo-signals from single fish and groups of fish (Dowd, Bakken, Nakken, 1970; Ermolchev, 1979; Ermolchev, Kovalev, Seliverstov, 1979); by means of underwater photographing ( Zaferman, 1976; Ermolchev, 1978); with the help of tanks with living fish placed under the echo sounder antenna (Johannesson, Losse, 1973). The first two methods are indirect, they in turn require preliminary calibration of echo-counting system and camera. The third method is a direct one ( the number of fish and tank volume are known), but rather laborious when being implemented in the sea. Besides, the distribution of fish in the tank is not always even or they die quickly and sink on the tank bottom.

The direct calibration becomes easier when a school model of different density and consisting of dead fish is used. The method is described below.

## Methods and results.

A school model should be constructed in the following way. First of all two similar frames are to be made: the upper and lower ones. An external antenna of the echo sounder is installed in the centre of the upper frame (Fig.1). A weight is attached to the lower frame. Corners of the frames are interconnected by means of four carrying wires. 5-6 similar nettings made of thin filament are used, their mesh size being somewhat smaller than the fish length. Dead fish evenly distributed over the nettings are tied by their heads and tails to the corners of the mesh. A netting should be smaller in size than a frame. Placed one over another the nettings with fish are connected to the wires. The lower frame and weight stretch the wires which in turn keep the nettings in a horizontal position. As a result a school model preserves its geometric form in water, and fish in it distribute evenly.

A distance between the upper frame and the model $r_1$, model dimensions ( $a, b, h_K$ ) are chosen with regard to the following: operation zone of the echo sounder transducer should not exceed the school volume; school model should be outside the antenna nearest zone and within the operation range of TVG of the echo sounder. For echo signals from the lower frame and the model not to overlap each other a proper distance $r_2$ between these two elements should be kept. These requirements may be presented as follows:

$$r_1 > r_{min}\ ; \quad a > 2(r_1 + h_K)\, tg\frac{\theta}{2}; \quad r_2 > \frac{c\tau}{2}\ , \qquad (2)$$

where $r_{min}$ - distance from the antenna where echo sounder TVG starts working.

In echo sounders value $r_{min}$ is usually set outside the nearest zone ( for example, in EK echo sounders $r_{min}$ = 3 m). From (2) it is clear that lateral dimensions of the school should be the greater, the further it is from the antenna and the wider the antenna directional diagram is.

In accordance with (2) a nomogram for determining the lateral dimensions of the school model depending on the distance to antenna and its directional diagram ($h_K$ being equal to 1 m) is given on Fig.2. As the echometric survey was conducted with the help of underkeel antenna (13° x 21°) of EK-38 and external antenna with the same directional diagram installed on the upper frame at the distance of $r_1$ = 3m above the model, the lateral dimensions of the nettings were taken: a=1,5 m, b=1,0 m (Fig.2), vertical dimension being $h_K$ =1 m(5 nettings separated from each other by a distance of 0,25 m). The distance from the school to the lower frame is $r_1 = r_2 = 3$ m. Lateral dimensions of frames are by 0,2 m larger than those of nettings.Three school models were used when taking measurements: two of them were made up of capelin of different length (Fig.3, "A","B"), one - of sand eel (Fig.3,"C"). The following coefficients of absolute calibration of the echo-integrator were calculated (a transfer factor between the under-keel antenna and external antenna is taken into account):

$$C_1 = 3{,}04 \cdot 10^6 \text{sp./sq.m./1 deflec.M}$$
$$C_2 = 1{,}95 \cdot 10^6 \text{sp./sq.m./1 deflec.M}$$
$$C_e = 4{,}3 \cdot 10^6 \text{sp./sq.m./1 deflec.M}$$

$C_1$ was calculated for capelin of mean length $\bar{L}_1$=15,52 cm, $C_2$ - for $\bar{L}_2$= 16,52 cm, $C_e$- for sand eel with mean length $\bar{L}_e$= 21,1 cm (Fig.3,"E")

The analysis of instantaneous values of echointensities from the school model (at each sounding) showed (Fig.3,"D") that this method of calibration permits to calculate coefficients $C_1$, $C_2$ and $C_e$ with an error less than 10%.

In accordance with (1) coefficients of absolute calibration may be presented in a standard form using $\varepsilon$ = 1,91 obtained for capelin by norwegian scientists (Dalen, Rakness, Rottingen, 1976). Then the coefficient of absolute calibration for the first model will be as follows:

$$C_1 = C_n L^{-\varepsilon} = 5{,}65 \cdot 10^8 \cdot L^{-1{,}91} \qquad (3)$$

and for the second model

$$C_2 = 4{,}13 \cdot 10^8 L^{-1{,}91} \qquad (4)$$

The calibration of echo-integrating system of RV"Poisk" was carried out during the joint Soviet-Norwegian survey on the assessment of capelin stocks in the Barents Sea in autumn 1979. The coefficient of absolute calibration was determined through calculations based on the data from intercalibration of echo-integrating systems on RVs"Poisk" and "G.O.Sars" and on measurements of capelin target strength carried out by norwegian scientists in laboratory, it was equal to

$$C = 5{,}8 \cdot 10^8 L^{-1{,}91} \qquad (5)$$

The comparison of coefficients C obtained through two different methods shows that their values are very close, especially for the first model ( expressions (3) and (5) ). To ensure a high accuracy of absolute calibration with the help of school modelling and to make the measurements easier it is necessary for each model to choose fish of the same length as well as to reveal the difference in target strength of dead and living fish, and to take this into account when processing the results of echometric surveys.

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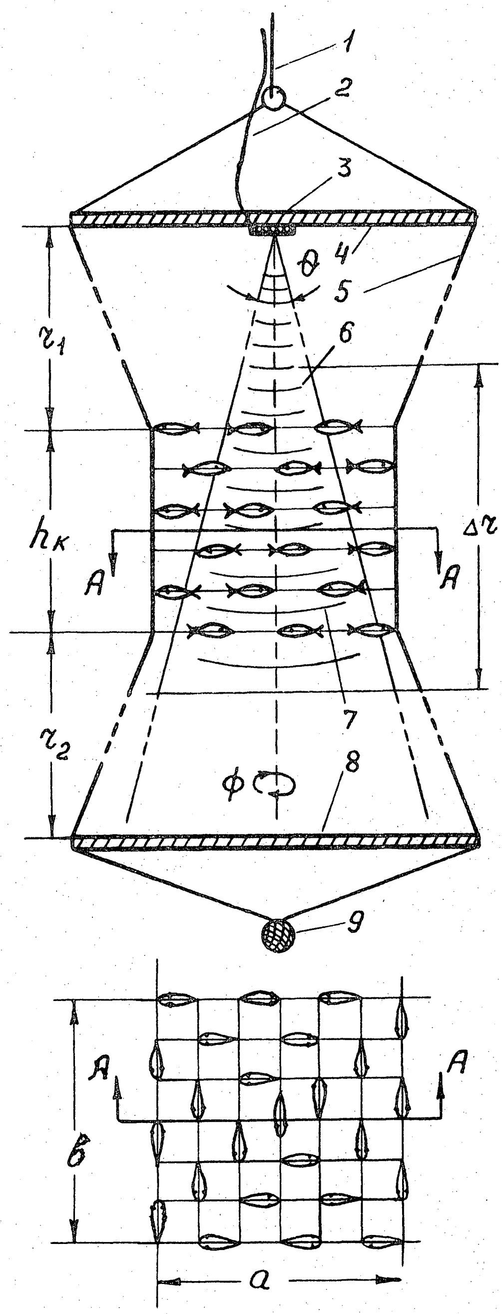


Fig. 1. Model of capelin school.

1 - rope; 2 - cabel from external transducer; 3 - echo sounder; 4 - upper frame; 5 - wire; 6 - operation zone of transducer; 7 - nettings with fish; 8 - lower frame; 9 - weight.

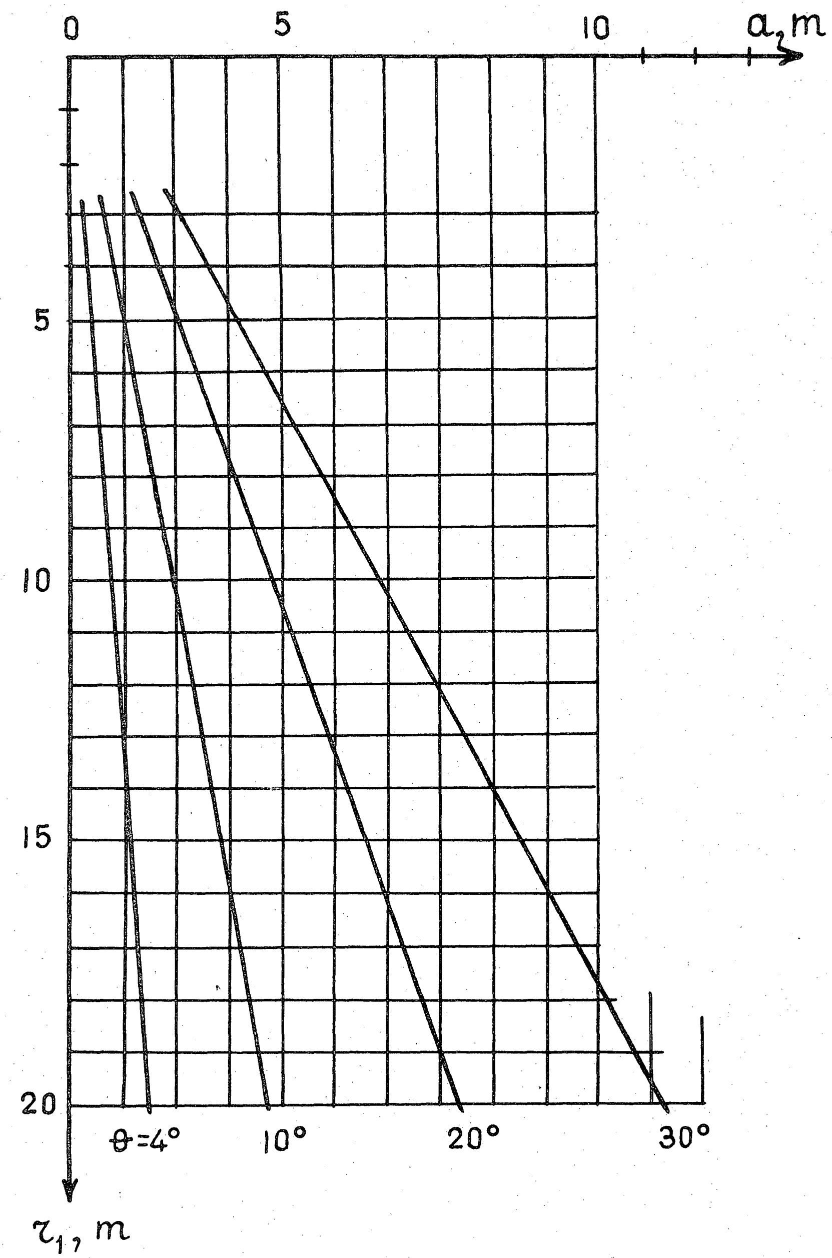


Fig. 2 Nomogram for determination of geometric dimensions of the school model.

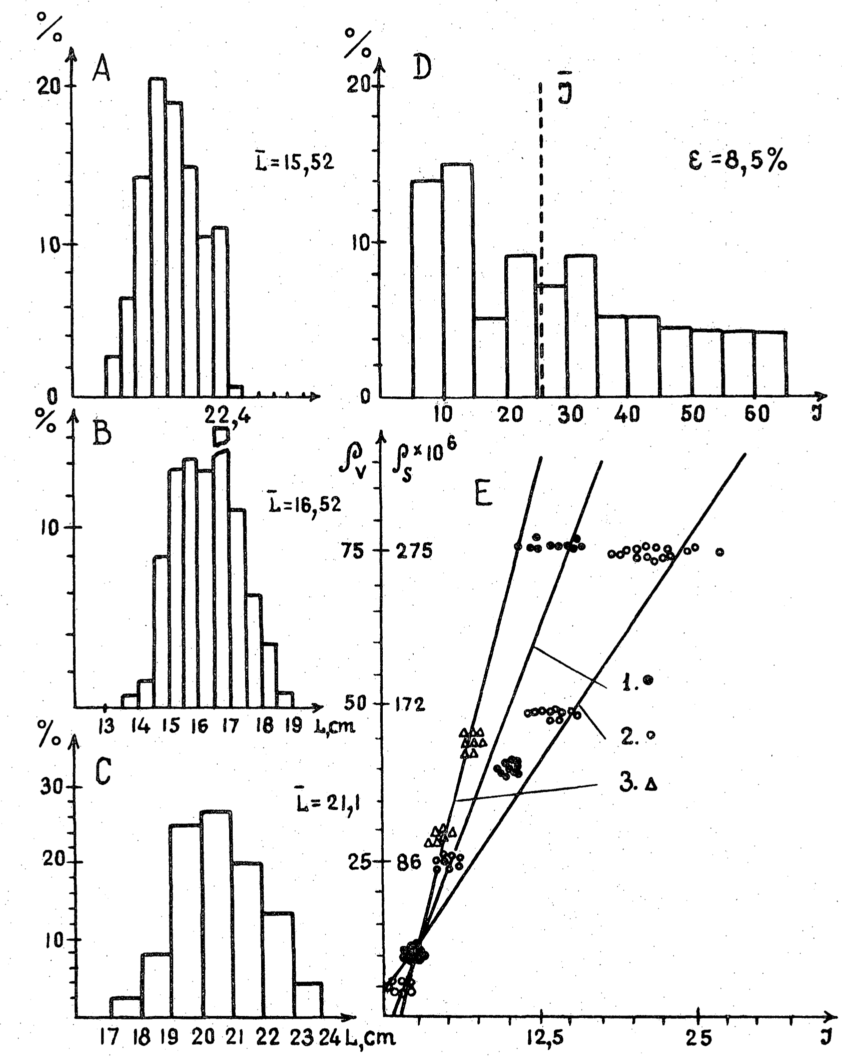


Fig. 3. Results of measuring of echo-intensities from the models of capelin and sand eel schools.

A - length frequency of the first model of capelin school;

B - length frequency of the second model of capelin school;

C - length frequency of the model of sand eel school;

D - distribution of instantaneous values of echo-intensities from capelin school;

E - statistical relationships between echo-intensities and the number of fish in school models ( 1 - capelin, $\bar{L}$ = 15,52 cm; 2 - capelin, $\bar{L}$ = 16,52 cm; 3 - sand eel, $\bar{L}$ = 21,1 cm ).