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Size and density of mackerel schools measured by echo sounders and catches

by

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Introduction

Hydroacoustic measurements of mackerel schools were carried out on board the m.t."Kantar" during a commercial cruise which took place from 17.12.1972 to 25.2.1973 in the region of George's Bank /40°58'N to 39°52'N and 072°48'W to 068°39'W/.

"ELAC" apparatus was used in the measurements. An LAZ 17 ADT 3 vertical echo sounder equipped with an LSR 23 type transducer, operating on a frequency of 30 kHz, and a net sonde with an identical graphic recorder and NES-2 type float, were used.

Measurements of the schools were carried out during hauls to ensure accuracy as to fish species in the schools measured. Hauls were taken with a WP 64/112 x 61/92 type trawl with vertical and horizontal spread are 24x30 m. During the cruise, 42 successful hauls were taken, these containing over 95% mackerel. Measurements were taken of 342 mackerel schools.

Methods

The following data were recorded during the investigations:

1/ serial data /haul number, data, position, hour/,

2/ school parameters from the vertical echo sounder /depth, breadth, height, degree of reddening/,

3/ school parameters from the net sonde /entrance into the trawl by the school, degree of reddening/,

4/ hydrological-meteorological data /cloud coverage, precipitation, air temperature, water temperature,direction and force of wind/,

5/ data on the fishing grounds /depth, bottom topography/,

6/ trawl set parameters /type of trawl,warp length, direction and speed of trawling, trawling depth, distance of trawl from bottom, vertical spread of trawl opening, distance between otter boards/,

7/ catch results /result of catch, catch composition in percentages, state of gonads acc. Mayer's scale/.

The following were recorded direct onto the vertical echo-sounder and net sonde echograms: range, amplification, haul number, commencement and completion of trawling, catch result and percentage data on catch species composition.

Based on the above data, the geometrical parameters of fish schools were calculated. The school length equal to a section of the ship's path over the school, was calculated using the formula given in "FAO Fisheries Technical Paper No. 83/1969". Using this formula the length of school was calculated for such case when the horizontal section of the echo sounder beam at the school level is less than its surface.

$$B_s = B - 2\,h\,tg\,\frac{\theta_e}{2}$$

where: B_s = length of school /m/,

B = length of school measured on the echogram /m/,

h = mean depth of school /m/,

θ_e = effective angle of echo sounder transmitter--receiver beam.

Where the horizontal section at the depth of the school is greater than its surface, when the above formula is applied, negative lengths of schools are obtained. In order to calculate the length of schools in this situation, the following formula is applied which is true for small schools.

$$B_w = B - \frac{\pi}{2} \cdot h \cdot tg\,\frac{\theta_e}{2}$$

In cases where the surface area of the school is much greater than the area of the beam section and the shape of the school is unknown, the school length measured by sounding is a random value. It may happen that the will steam either over the edge of the school, or through the centre. It is impossible to determine the ratio of the measured length of the school to the true one by means of a vertical echo sounder. In view of this, measurements of the length of schools are completely random sections of the ship's track over them. For schools with a horizontal section approximate in shape to a circle or ellipse, the measured values should be increased $\pi/4$ times.

The coefficient $\pi/4$ results from the statistical dependency existing between the mean length of schools measured by echo sunder and their true length. The true length of the schools will thus be calculated from the formula:

$$B_r = B_s \cdot \frac{4}{\pi}$$

The height of schools is calculated by means of the following formula:

$$\Delta h = \cos \frac{\theta_e}{2} \; /h - H - V_{dz} \cdot T_n/ - h$$

Where: Δh = height of school /m./,

H = height of school measured on the echogram /m./,

V_{dz} = speed of sound in water /m/s/,

T_n = length of echo sounder transmitting pulse /s/,

Based on observations of mackerel schools, using a vertical echo sunder and sonar, it was found that they formed bodies similar in shape to ellipsoids or ellipsoids of revolution. The volume of the schools was therefore calculated from the following formula:

$$V = \frac{\pi}{6} \cdot B_s^2 \cdot h$$

During the cruise, attempts were made to determine the density of fish in schools from the catches. By writing the track of the trawl with the head and ground lines into the echogram from the vertical echo sounder and marking out the schools fished on the basis of the net sonde indications, the volume of the parts of the schools caught were determined.

When the length of the school was less than the horizontal spread of the trawl, the volume of the part of the school caught was calculated from the following formula:

$$V_1 = 0.5 \cdot B_w^2 \cdot \Delta h_z$$

Where: V_1 = volume of the part of the school caught, when the length was less than the horizontal spread of the trawl /m^3/,

B_w = length of a small school /m./,

Δh_z = height of the part of the school caught /m./.

When the length of the school was greater than the horizontal spread of the trawl, then the volume of the part of the school caught was calculated from:

$$V_2 = B_s \cdot \Delta h_z \cdot R$$

where: V_2 = volume of the part of the school caught, when the length was greater than the horizontal trawl spread /m^3/,

B_s = length of a large school /m./,

R = horizontal trawl spread /m./.

The mean density of fish in the schools met during trawling was calculated from:

$$\bar{G} = \frac{1}{k} \cdot \frac{W_p}{\sum_1^n V_1 + \sum_1^m V_2} \cdot \frac{1}{\bar{C}}$$

where: $\bar{G}$ = mean density of fish in schools for a given haul /fish/m^3/,

k = trawl catch efficiency coefficient,

W_p = catch yield /kg./,

$\sum_1^n V_1$ = sum of volumes of the parts of schools caught, where the length of the schools is less than the horizontal trawl spread /m^3/,

$\sum_1^m V_2$ = sum of volumes of the parts of schools caught, where the length of the schools is greater than the horizontal trawl spread /m^3/,

$\bar{C}$ = mean unit weight of fish /kg./.

Knowing the volumes of the schools sounded and the number of schools present in a haul, the mean volumes of schools were calculated, these corresponding to the mean densities of fish in the schools calculated from the above formula.

Results

Calculations of the lengths of all mackerel schools occurrung in hauls, were carried out. The length of the mackerel schools fluctuated between 0.5 m and 962 m., the mean length being 148 m. Fig. 1 gives the frequency of schools of various lengths and their percentage participation in individual length classes.

The height of mackerel schools fluctuated between 0.1 m. and 71.6 m., the mean height being 13.5. Fig.2 gives the numerical and percentage participation of schools of different heights.

The relatiopship between the height and length of schools is given in Fig. 3 with the help of a simple equation, $h = 0.038\ B_s + 8.3$. The crorrelation coefficient is 0.39. The volume of mackerel schools varied greatly, from 0.01 thousand m^3 to 26,569 thousand m^3. Table 1 gives both numerical and percentage participation of schools of various volumes.

An analysis was made of the relationship between the catch yield and the parameters of schools met during hauls. The relationship between the number of schools recorded on the vertical echo sounder and the catch yields is given in Fig.4, but that between number of schools recorded on the net sonde and the yield is given in Fig.5.

In both cases very low correlation coefficient values of about 0.4 were obtained. Better relationships can be expected between the overall volume of schools fished and catch yield. This is presented in the form of the following linear equation:

$$W_p = 0.58\ V + 6.251$$

where: W_p = catch yield /kg./,

V = overall volume of schools /m^3/.

The correlation coefficient for the above equation was 0.58. The relatively low value of the correlation coefficient indicates relatively large differences in the density of fish in schools, and also the varying reaction of fish to trawls.

To investigate the changes in density of fish in schools in the function of volume of schools, the coefficient of trawl efficiency was assumed to be 1, which meant that the fish did not react to the trawl. In such assumptions, diurnal changes in the reaction of fish to trawls are not taken into account and these may be substantial. The mean volume and density of fish schools were calculated for each haul. Fig.6 gives the relationships between the mean density of fish in schools and the mean volume of the schools. The mean density of fish in schools, calculated by this method, varies between 0.1 fish/m^3 and 6.5 fish/m^3, the density dropping with the increase in volume. It should be remembered that density was obtained with the assumption of lack of reaction to the trawl. In actual fact, the densities of fish in the schools will be greater.

Table 1.

Specification of schools classified acc. to volume.

Volume of schools (thous.m^3)	No.of schools	Percentage of schools of various volume	Mean volume of schools (thous.m^3)	Total volume of schools (thous.m^3)
0-0,5	34	9,94	0,14	4,931
0,5-1,0	9	2,63	0,70	6,37
1,0-10,0	53	15,49	3,1	216,12
10 -20	25	7,30	15,75	393,83
20 -30	24	7,01	24,48	587,64
30 -40	17	4,97	34,53	586,99
40 -50	10	2,92	45,49	454,98
50 -60	6	1,75	54,96	329,76
60 -70	4	1,16	62,91	251,67
70 -80	4	1,16	73,01	292,07
80 -90	3	0,87	84,12	242,36
90 -100	9	2,63	95,14	856,3
100 -200	27	7,89	137,46	3701,15
200 -300	16	4.67	248,8	3980,70
300 -400	10	2,92	345,37	3453,74
400 -500	7	2,04	454,62	3182.36
500 -600	9	2,63	543,32	4889,87
600 -700	4	1,16	626,9	2507,6
700 -800	7	2,04	744,73	4214,1
800 -900	3	0,87	856,48	2569,46
900-1000	3	0,87	957,67	2873,01
1000-2000	20	5.84	1377,0	27539,0
2000-3000	11	3,21	2364,0	26004,0
3000-4000	8	2,33	3410,8	27286,0
4000-5000	6	1,75	4331,85	25991,0
5000-6000	1	0,29	5400,64	5400,64
6000-7000	1	0,29	6447,0	6447,0
8000-9000	1	0,89	8339,79	8339,79
1000-11000	1	0,29	10015,36	10015,36
11000-12000	1	0,29	11624,0	11621,0
powyżej 12000	5	1,46	17266,0	86330,0

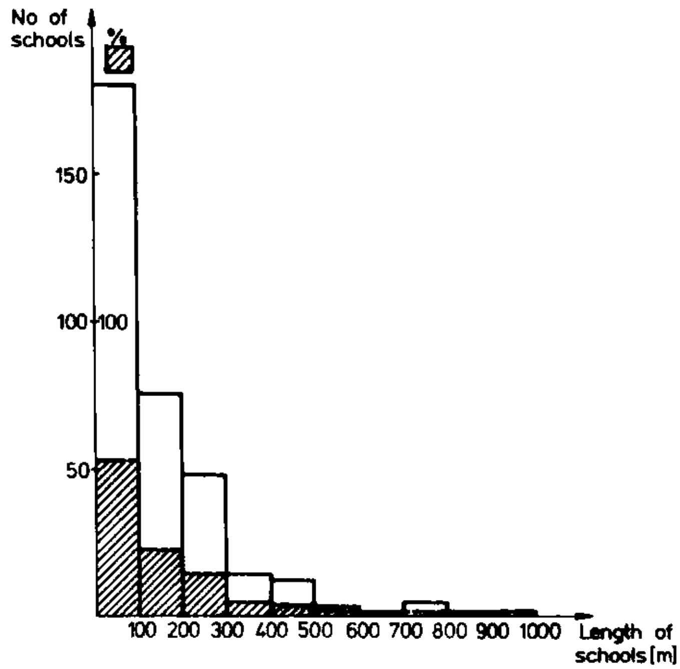

Fig.1. Frequency with which schools of various lengths occur.

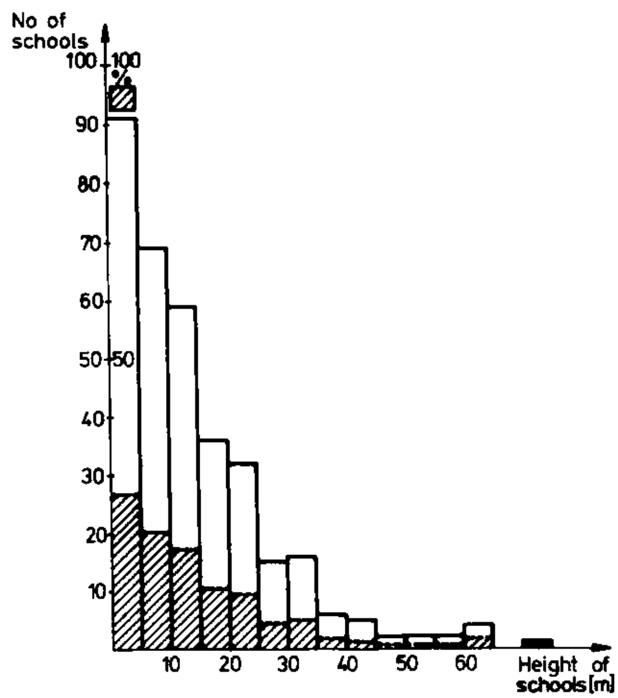

Fig.2. Number and percentage of schools of different heights.

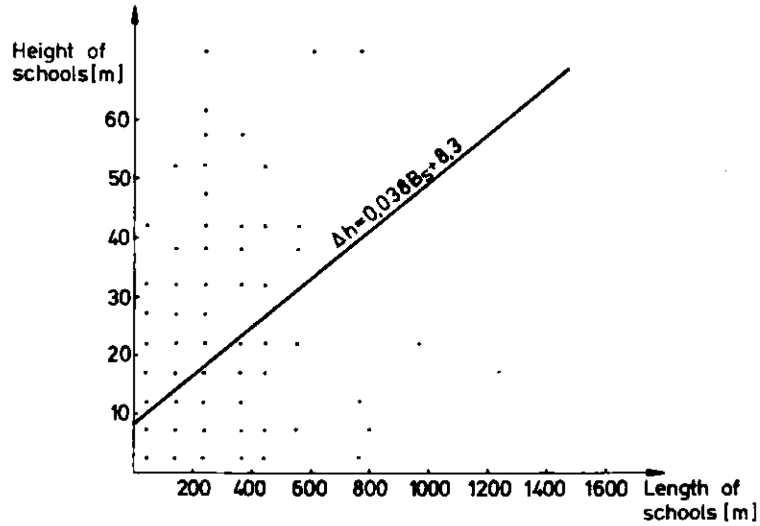

Fig.3. Relationship between the height and length of schools.

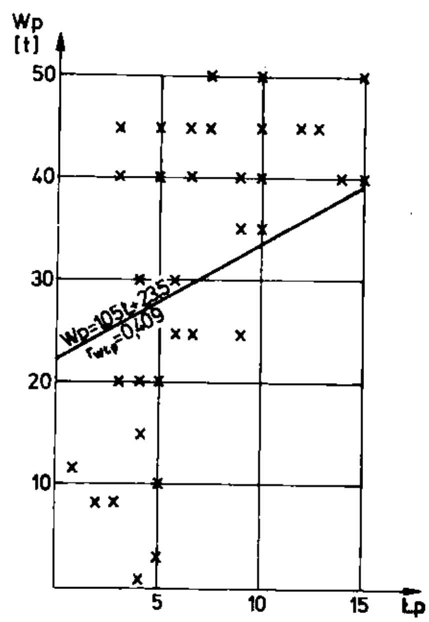

Fig.4. Relationship between the number of schools recorded on the vertical echo sounder /L_p/ and catch yields /W_p/.

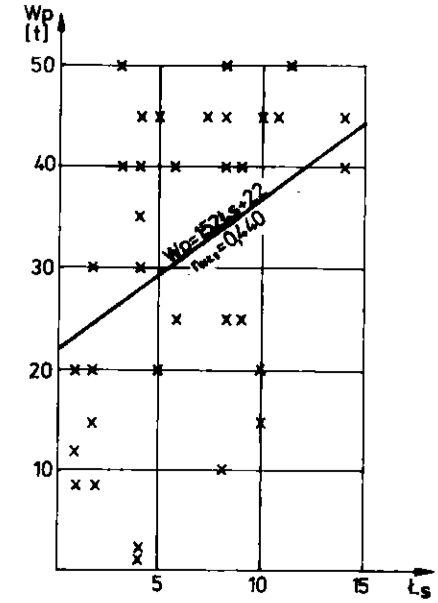

Fig.5. Relationship between the number of schools recorded on the net sonde /Ł$_s$/ and catch yields /W_p/.

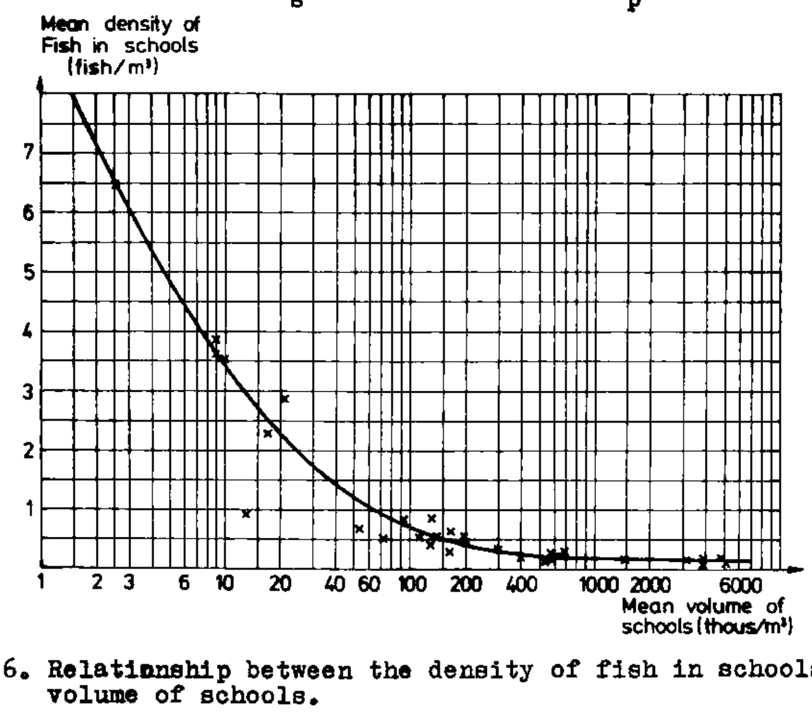

Fig.6. Relationship between the density of fish in schools and volume of schools.