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ABUNDANCE AND MORTALITY OF HERRING (*Clupea harengus* L.)  
ON GEORGES BANK ACCORDING TO THE RESULTS OF EGGS CALCULATION  
IN SPAWNING AREAS IN 1964-1966

The USSR. AtlantNRO

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ABSTRACT

In September 1964 investigations began in order to calculate the abundance of spawning population of herring on Georges Bank, according to the quantity of eggs in spawning areas. These studies were continued in 1965-1966 as well. The results of egg calculation confirmed, that the major part of herring spawned on northern slopes of Georges Bank. The areas, terms and conditions of spawning have been defined more accurately; the area of spawning region and abundance of herring spawning population on Georges Bank have also been defined. The latter composed 1.180 thousand tons in 1964, in 1965 it was 580 thousand tons.

In comparing absolute abundance of herring generations in different years the total mortality has been defined which averaged 63-75%; the fishing mortality appeared to be 3-20% and the natural mortality - 55-63%.

INTRODUCTION

The resources of herring population, inhabiting Georges Bank and adjacent areas are, evidently, the richest in comparing with resources of other herring populations of North-

Eastern Atlantics.

Till 1961 fishing of this population had been conducted in inshore waters of the Gulf of Maine, where small immature herring had been fished. From 1961 Soviet ships have begun fishing of adult herring on Georges Bank. Beginning from summer 1961 the Soviet research vessels have regularly been conducting observations on length and age composition and distribution of herring catches. In 1964 and the following two years in September and beginning of October the egg calculation was made in herring spawning areas on the northern part of Georges Bank.

Similar studies in North-Western Atlantics have been conducted in St. Lawrence Gulf in spring of 1962 by Tibbo and others (7), Mckenzie in 1961 along South-Western coast of Nova Scotia (4).

In the Soviet Union the definition of herring abundance according to the count of eggs are being conducted annually from 1958 along the coast of Kamchatka (2). On the basis of comparing the abundance and amount of catches from herring shoal the investigators came to a conclusion about the necessity of establishment of annual limits on fishing.

In this paper the results of investigations on definition of spawning population abundance and of total, fishing and natural mortality on Georges Bank are given.

#### MATERIALS AND METHODS

After observations on distribution of ichthyoplankton in 1956-1958 in the Gulf of Maine and on Georges Bank the american investigators have found dense concentration of just hatched larvae of herring on the northern slopes of Georges Bank. On the basis of those observations the conclusion has been reached, that Georges Bank slopes are the principal areas of herring spawning (3).

The analyses of dislocation and catches of the USSR fishing fleet on Georges Bank in 1961-1966 has also shown that from the end of August to the beginning of October annually dense pre-spawning and spawning concentrations of herring have been observed. However, till 1964 no direct observations on the terms and conditions of spawning, on egg calculation and abundance of spawning population had conducted. In 1964-1966 special observations on herring spawning were undertaken.

The areas and terms of spawning were preliminarily defined by appearing of dense herring concentrations with sexual products in pre-spawning and spawning condition (8).

Pre-spawning and spawning herring concentrations can be easily found on the basis of echo-sounder readings and control and commercial catches, because herring at this time keeps in dense and not mobile concentrations.

The end of the spawning was defined by the time of leaving the spawning areas and appearing of spawned herring in catches from the districts next to spawning areas. The time and area of spawning and the calculation of the eggs spawned have been defined by means of conducting the periodical survey together with taking of core samples at the stations in supposed spawning area.

Core and egg samples were taken by the drag "Ocean-50" with the capacity of  $0.25 \text{ m}^2$ . The stations at the period of survey were marked so as to cover the whole district of supposed spawning area.

In order to establish the terms of spawning the surveys have been made more than once, so in 1964 they were made four times (see table 1). In the herring spawning areas a detailed survey was conducted after the end of spawning.

For this purpose in the area where the eggs had been spawned a proving ground was arranged by means of buoys. The distance between buoys was estimated by doubled course of the ship at constant rate of engine working with regard for drift

of the ship. It was supposed to plan a network of the stations in the area of spawning. The stations were generally made every 0.5 mile, but occasionally a distance between stations turned actually to be greater, as a result of drift of the vessel under the influence of wind and currents.

Three egg samples were taken at each station, they were weighed and the average weight of the eggs from the three samples was distributed on the area of  $1 \text{ m}^2$ . Simultaneously the water temperature was measured by means of bathythermograph.

Data on the number of eggs at stations in kg on  $1 \text{ m}^2$  were recorded on the charts. Then by interpolation the isolines were made and by means of planimeter the areas of zones with the identical density of eggs were defined. Generally three zones with high, average and low number of eggs were singled out.

3 samples each 1 g were taken at each station. The eggs in samples were recounted and from the sum of samples at all the stations the mean number of eggs in a part of the sample weighting 1 g was defined.

In August annually when the female gonads were in pre-spawning condition the samples for definition of fertility were taken. For this purpose 10-15 female gonads each length group with the interval of 1 cm were obtained in the following way. From the front, middle and back parts of a gonad a piece was taken from each, a total weight of 100 mgr, then the number of eggs in the weighted part of sample was calculated. In order to reach a more faultless result the egg calculation was made two or three times running. On the basis of those calculations a mean number of eggs in the weighted part of the sample was counted and with regard for gonads weight a total number of eggs for an individual was calculated. Joint data on individual fertility by length groups made a basis for an average fertility for each length group and its dependence on the

Table 1.

The terms of obtaining the surveys by the drag in the spawning areas during pre-spawning, spawning and post-spawning periods.

Years	The terms of obtaining of benthos surveys.	A Number of Stations.	The spawning period (determ. of terms by the rate of egg development).
1964	5 - 6 September	12	
	17 - 18 -"-	21	
	27 - 28 -"-	28	28-29 September
	5 October	42 <sup>x</sup>	
I spawning area			
1965	23 - 24 September	25 <sup>x</sup>	
	25 - 26 -"-	21	11-12 September
	8 - 9 October	12	
II spawning area			
1966	3 October	42 <sup>x</sup>	23-25 September
	6 - 7 -"-	18	
	8 - 9 -"-	10	
	I spawning area		
1966	9 September	4	
	14 -"-	33	19-20 September
	16-18 -"-	47	
	20-21 -"-	35	
	24-30 -"-	214 <sup>x</sup>	
II spawning area			
1966	8-10 October	108 <sup>x</sup>	28-29 September
	14 -"-	21	in the area Nuntucket

<sup>x</sup> The egg was found and calculated.

length of body (Fig.1).

On using the data on occurrence frequency, obtained from mass measurements of herring in catches of pre-spawning and spawning periods, as well as on using the data on mean fertility for each length group, mean fertility of all the spawning population was defined by formula,

$$C = \frac{\sum f \cdot n}{100} \quad \text{where}$$

n - is a number of individuals in catches of a given length in %;

f - is a mean fertility of length group in pieces

$$N = \frac{q \cdot A \cdot B}{c \cdot 10^9} \quad \text{of eggs.}$$

The stock of spawning population was defined by formula, where:

N - the stock of spawning population in thousand tons ;

A - number of eggs in spawning areas in pieces ;

B - mean weight of a herring in gr.

c - mean fertility in pieces of eggs ;

q - coefficient, taking account of males at sexual correlation 1 : 1.

In its turn  $A = \sum aSz$ , where :

S - the area of spawning zones in  $m^2$  ;

a - mean number of eggs in zone  $kg/m^2$  ;

z - mean number of eggs in 1 kg in pieces = 480 000 pcs.

On the basis of determination of age composition of catches during the period of spawning the abundance of every generation of spawning population in million pcs was calculated. As in catches during the spawning period immature herring constituted about 2%, the abundance of generations of spawning individuals following the calculation was a little bit lowered. On the basis of herring catches by months and age composition the catch by generations in million pcs. was determined

at the periods between conducting the calculations, that is from October of a certain year to September inclusive the next year.

By difference of abundance of identical generations of two successive years a total relative mortality was defined.

Fishing mortality was defined by difference in generation abundance in spawning population and catches during periods between two evaluations of stocks. Relative natural mortality was defined by difference between total and fishing mortalities.

#### Areas, terms and conditions of spawning.

The spawning areas of herring were found on the northern part of Georges Bank (Fig.2). This part of the bank is characterized by even relief of the bottom. The grounds overlaid by eggs consist of gravel, pebbles mixed with broken shells (mainly *Pecten* sp.) (Fig.3). Occasionally in egg samples some algae was found (*Rhodomela* sp.) However, the quantity of algae is not large and they do not play an important part as spawning substratum. The depths in the spawning areas used to be 40-50 m.

The contours of spawning areas show, that the latter are stretched in latitudinal direction.

Localization of spawning areas, as seen from Fig.2, somewhat changes from year to year. The examination of egg samples taken from the drag showed, that the eggs lie on the substrate in several rows. The thickness of an egg layer in samples was from 0.2 - 0.5 cm to 4-6 cm. The layer of eggs on large pebbles and boulders was from 0.2 to 1.5 cm, and on small pebbles, gravel and broken shells from 2 to 4-6 cm (Fig.4).

The eggs were laid like bunches of grapes, so that there was a spare room between the eggs (Fig.5). Annually the zones with eggs, laid in several rows, were marked in spawning areas. The maximum weight reached in these cases was 20-23 kg/m<sup>2</sup>. To the outlying districts of the spawning area

the density of eggs gradually decreases so that in samples only separate eggs were observed (Fig.6). In 1965 and especially in 1966 in contrast to 1964 some samples with negligible quantity of eggs were obtained in the central parts of spawning areas as well. This leads to the conclusion that the eggs cover the bottom of spawning area by a solid layer of different thickness.

The temperature regime within the limits of spawning area is affected by two water masses - the surface layer with the depth of 50 m and the underlying one of Labrador origin (1). These water masses of Labrador origin approach the northern part of Georges Bank, and bottom water temperature while spawning is  $5-6^{\circ}$ ; more southern and shallower waters of the spawning areas (40-45 m) are characterized by temperature of  $11-12^{\circ}\text{C}$ . The distribution of water masses is rather stable on the northern slopes of Georges Bank within the fall. Thus, the growth of eggs in different parts of spawning area takes place at temperature from  $5-6^{\circ}$  to  $11-12^{\circ}\text{C}$ .

The mass spawning in 1964 was observed about 28-29 September, in 1965 in the first spawning area on 11-12 of September, in the second one on 23-25 of September, in 1966 on 19-20 and 28-29 of September. Judging from the fact, that the eggs in samples were of identical or near stages of growth, one can suppose that the spawning indeed takes place in short terms of 2-3 days.

The survival of eggs is very high. In the majority of samples dead eggs were occasionally found, whereas in multilayered eggs, the lower ones contained a considerable number of dead eggs. After the spawning was over, dense concentrations of haddock were observed in the spawning areas in 1964 and 1965, and in 1966 those were replaced by concentrations of alewife. Haddock and alewife were intensively feeding on herring eggs. Flatfish was also found in spawning areas in small number; as to invertebrates - starfish, sea-urchin and polychaete frequented those areas.



The Abundance of Eggs and Spawning Population.

The results of egg calculation are given in table 2. As seen from the data of the table the spawning area in 1964 reached 38,8 mln. m<sup>2</sup> (38.8 km<sup>2</sup>), in 1965 it reduced to 24,3 mln. m<sup>2</sup> and in 1966 it was 19,1 mln. m<sup>2</sup> all in all. According to reducing of spawning area, the total of eggs and abundance of spawning population also decreased.

T a b l e 2.

Results of Calculation of Herring Spawning  
Population Stocks on Georges Bank in 1964-  
1966.

Date of Calculation	Spawning Area in mln. m <sup>2</sup>	Quantity of spawned eggs in mln. kg	Fertility in thousand pieces of eggs	Mean weight of 1 specimen of herring	Number of female spawners in mln. pcs	Stock of spawning population in thousand pcs.
October 5, 1964.	38.8	427.8	79.1	226	3018	1180
September 23, October 3-8 1965	24.3	299.5	114.2	231	1261	580
September 29-30, October 9-10, 1966.	19.1	76.7	116.3	240	317	150

Thus, annually the abundance of spawning population was reduced from 1180 thousand tons in 1964 to 580 thousand tons in 1965 and to 150 thousand tons in 1966. It is explained by decrease of herring stocks on Georges Bank, since the abundance of strong generation of 1960 and the average one of 1961 has considerably reduced at present as a result of natural mortality, and year-classes of 1962 and 1963 turned to be not strong. Whether the herring stocks have really so strongly reduced the further observations on catches and abundance of spawning populations would show.

MORTALITY

Total relative mortality, defined on the basis of comparing the abundance of year-classes in spawning populations of 1964 and 1965, was from 39 % of three-four years ~~old~~<sup>old</sup> specimens to 79 % of six-seven years old ones. (tables 3,4).

Total mortality in average from four to seven years old specimens was 66 % in 1964-1965. In 1965 and 1966 total mortality from three to four years old specimens increased to about 64 %, from six to seven years old ones to 94 %, and from four to seven years old ones in average to 75 %. The increase of total mortality within the period of 1965-1966 as comparing with 1964-1965 is explained by increased fishing mortality following the growth of catches at simultaneous reducing of total herring resources.

Table 3.

Abundance of Spawning Population and Herring Catches of the USSR on Georges Bank in 1964-65 (in mln. pcs.)

A G E	Spawning Population Stocks in mln. pcs.			Catches from October to September	
	1964	1965	1966	1964/65	1965/66
2	6	-	3	0.4	1.8
3	1020	131	9	17.7	4.1
4	3160	621	47	69.5	23.2
5	1080	1131	277	82.1	137.4
6	740	475	270	39.3	255.1
7	30	152	29	11.5	68.8
8	-	12	-	-	17.8
9	-	-	-	-	0.1
<b>TOTAL</b>	<b>6036</b>	<b>2522</b>	<b>635</b>	<b>220.5</b>	<b>508.3</b>

Total relative mortality, defined by abundance of spawning population year-classes, by meaning turned to be relative to total mortality, defined by other methods. Thus, Noskov A.S. on the basis of age composition of catches per drift net in

1961-1963 has defined that total instant mortality (z) of specimens from five to eight years old constituted 1.17 and on the basis of age composition of catches per hauling hour of BMRT the  $z = 1.25(5)$ .

Table 4

Recruitment and Decrease of Stocks,  
Relative Total, Fishing and Natural Mortality of Herring on Georges Bank in 1964-1965 (in %).

Years		Age groups						
		2-3	3-4	4-5	5-6	6-7	7-8	4-7
1964-1965	Recruitment and Decrease	2183	61	36	44	21	40	
	- total mortality		39	64	56	79	60	66
	- fishing mortality		7	3	4	2		3
	- natural mortality		32	61	52	77		63
1965-1966	Recruitment and Decrease		36	44	24	6		
	- total mortality		64	56	76	94		75
	- fishing mortality		18	22	23	15		20
	- natural mortality		46	34	53	79		55

The instant mortality equal to 1.17-1.25 corresponds approximately to 60% of relative mortality. Relative fishing mortality in 1964-1965 from four to seven years old specimens was 2-7%, average 3%, and in 1965-1966 from four to seven years old ones it was 15-23%, average 20%. The increase of fishing mortality, as already mentioned, was entailed by increase of catches in 1966 as compared with 1965. Thus, from October 1964 to September 1965 the catch of herring constituted 43.2 thousand tons, at the same period of 1965-1966 it was 116,6 thousand tons.

By difference of total and fishing mortality natural mortality was defined. In 1964-1965 total mortality from four to seven years old specimens averaged 63%, in 1965-1966 it was 55 %.

Thus, till 1966 the fishing of adult herring on Georges Bank did not much affect the stocks and only in 1966 when the herring stocks decreased and the catches increased fishing mortality averaged 20%.

In future in order to the reliability of stocks and mortality calculations it is necessary to improve the methods of sampling the eggs and to study more thoroughly the character of laying the eggs by means of underwater television or observation from bathyscaf.

### S U M M A R Y

1. The spawning of herring shoal, inhabiting Georges Bank and adjacent areas, takes place on its northern part during the second and third decade of September. The spawning actually takes place in short terms (2-3 days).

2. Herring eggs are spawned by solid layer, from 0.2-0.5 cm to 4-6 cm thick. Maximum quantity on 1 m<sup>2</sup> reaches 20-23 kgs.

3. The abundance of spawning population, which constituted in 1964 1180 thousand tons, in 1965 - 580 thousand tons and in 1966 - 150 thousand tons was defined as a result of eggs calculation.

4. Total mortality of herring in 1964-1965 from four to seven years old specimens constituted 66 %, natural-63 % and fishing - 3.0%. In 1965-1966 the total, natural and fishing mortalities were 75%, 55% and 20% respectively.

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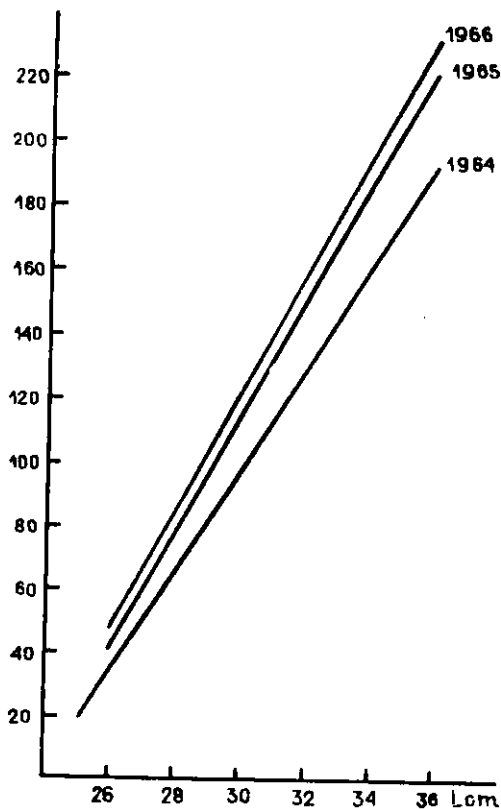


Fig.1. The length of the body (in cm) and the fertility of herring on Georges Bank (in thousand pcs. of eggs).

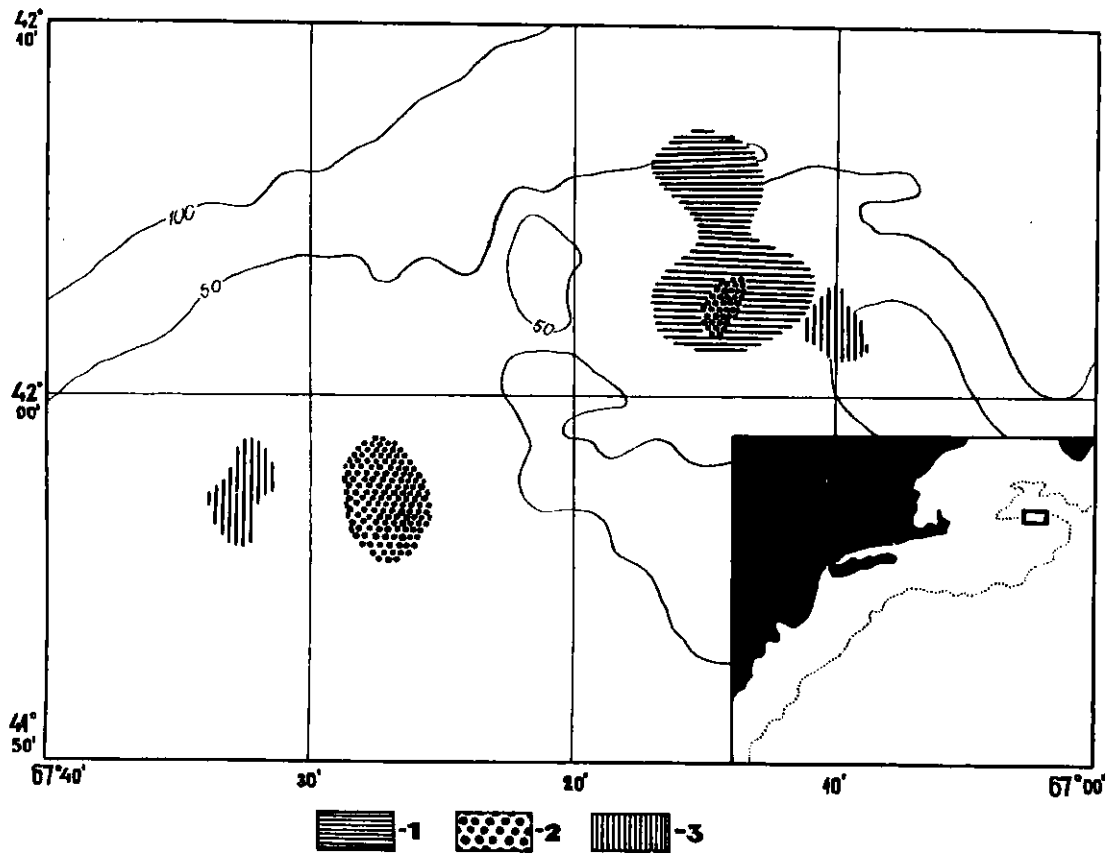


Fig. 2. Spawning areas of herring on the northern slopes of Georges Bank: 1 - in 1964, 2 - in 1965, 3 - in 1966.



Fig. 3. Pre-bottom concentration of herring in typical spawning area. (Plate of Chesny V.N.)

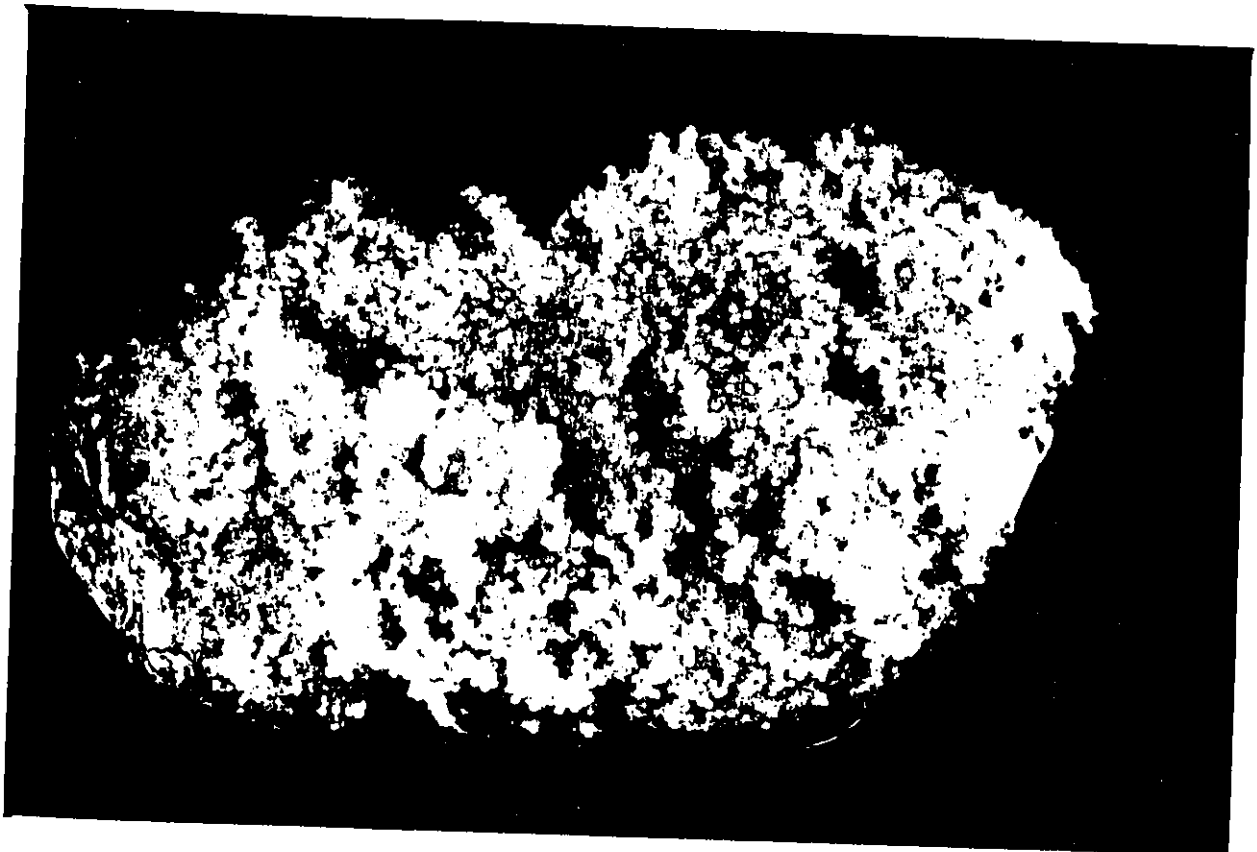


Fig. 4. Herring eggs taken on trawels.

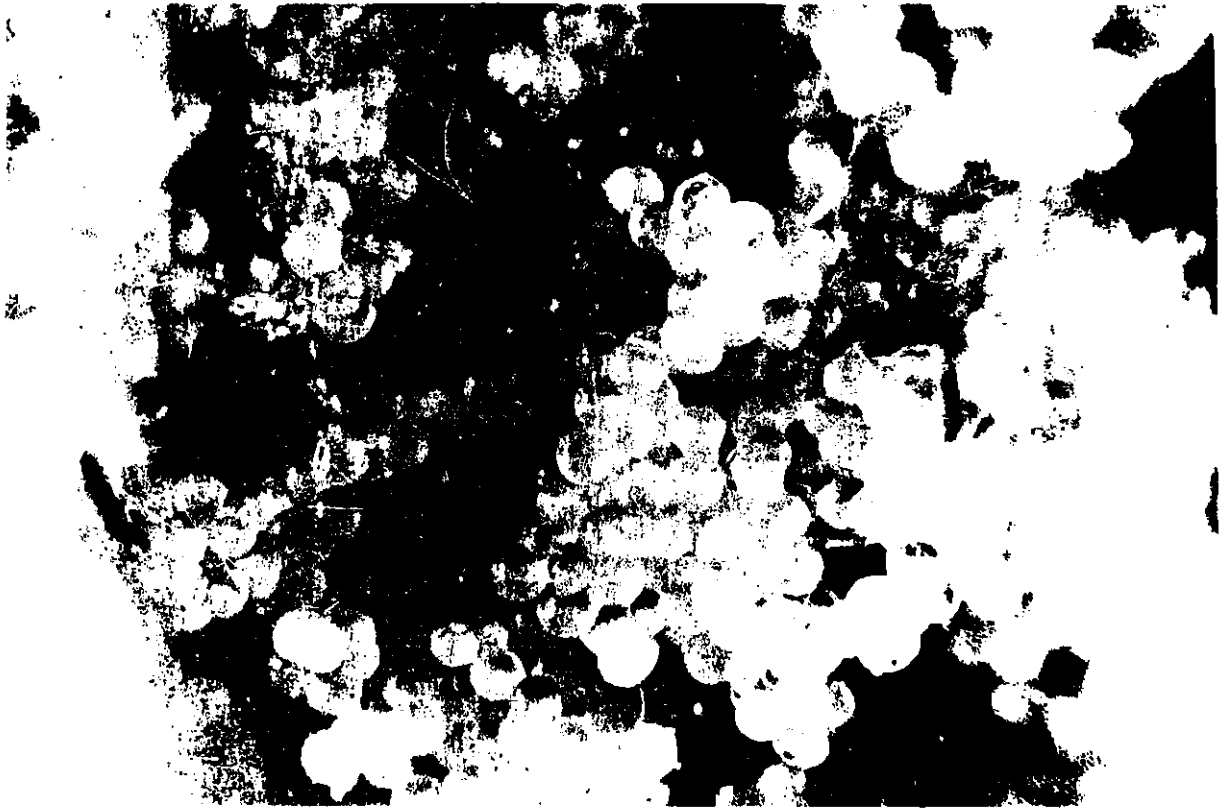


Fig. 5. The character of eggs distribution in a laying.

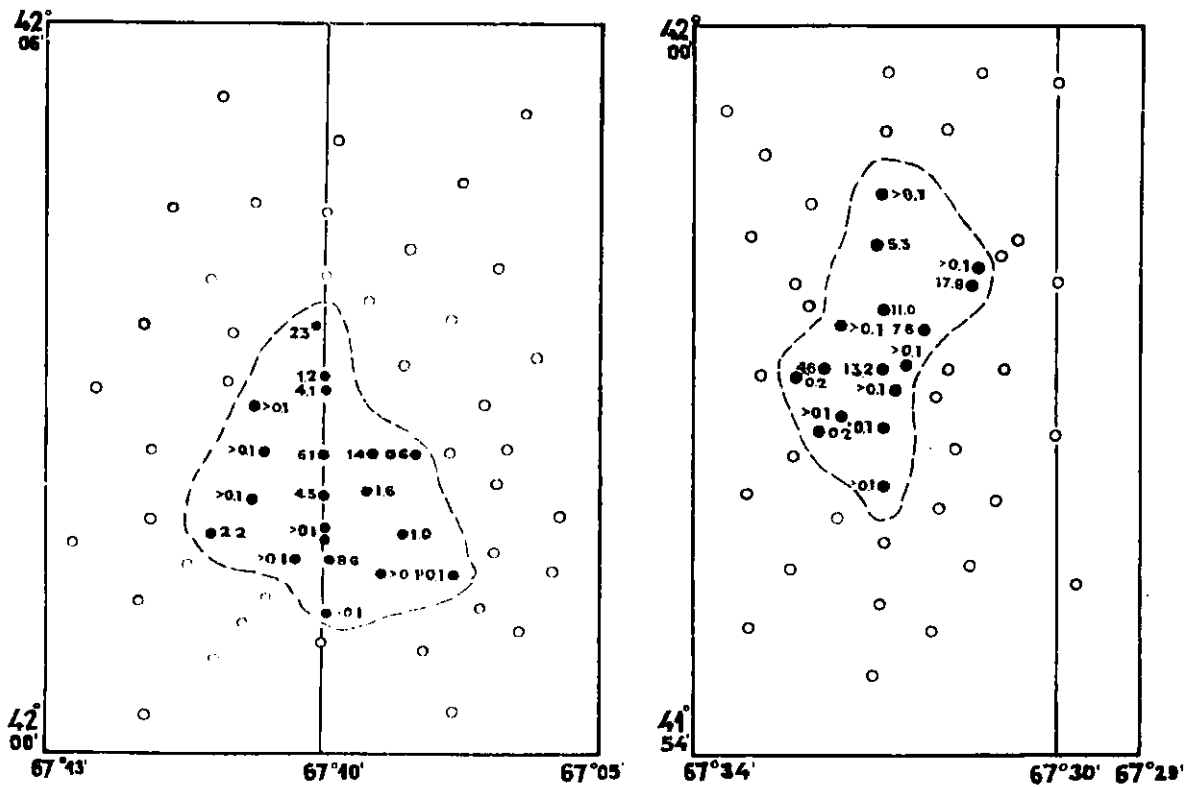


Fig. 6. The quantity of eggs in  $\text{kgs}/\text{m}^2$  in different parts of spawning areas in 1966.