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Preliminary instrument estimate of abundance and biomass of capelin off South Labrador and the North Newfoundland Bank (divisions 2J and 3K)

by

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Abstract

The paper contains the results of the instrument estimate of abundance and biomass of capelin concentrations off South Labrador and over the North Newfoundland Bank in October 1975.The capelin biomass in these areas is 0.98 million tons.The removal does not exceed 50% (0.4 - 0.45 million tons) of the above biomass.

Introduction

The work was made on the recommendation of the Standing Committee on Research and Statistics (STACRES) of the International Commission for the North West Atlantic Fisheries (ICNAF,Ann.Meet. January,1975).

The instrument estimate of capelin abundance and biomass in divisions 2J and 3K was carried out October 21 - 27 1975 by R/V " Odissey ". During this period the capelin winter slowly moving concentrations are formed up and replenished with recruits.

A similar survey was made in divisions 2J and 3K in the fall 1974.It showed the minimum abundance ,according to the most cautious estimate,to be of the order of 1.33 million tons (Serebrov,

Material and methods

The theory of the methods to carry out the abundance surveys with the use of hydroacoustic equipment and underwater photography and their practical application are to be found in the papers of a number of authors (Zaferman,1972;Kiselev,Truskanov,Shcherbino, 1962; Serebrov,1974;Seliverstov,Zaferman,1974;Serebrov,Bakanev, Kovalev,1975;Truskanov,Shcherbino,1963,1966).

For acoustic investigations echo sounder Simrad EK - 38 was used.

On the basis of the information from the commercial vessels were established the general capelin distribution and relative density of capelin concentrations.Having done that we worked out the route of R/V " Odissey " the tracks of the echo survey running in latitudinal direction at a distance not nearer than 20 miles from the Canadian coast up to depths of 280 - 300 m east of which there were no capelin concentrations.The distance between the tracks over dense concentrations was 10 miles, over scattered concentrations - 30 miles.

The volume of schools was determined from the formula:

$$V_{sch} = (L - Z)\ Dh \text{ , where} \qquad (I)$$

L- horisontal length of a school

Z - beam width alongships at average depth of a school

D - beam width athwartships

h - height of a school

The specific volume of schools per square mile was calculated from the formula:

$$V_{sp} = \frac{V_{sch}}{S} \text{ , where} \qquad (2)$$

S - investigated area per unit time (15 minutes).The area was determined from the formula: $S = c \cdot e$, where c - distance covered by the ship,e - beam width in miles at the depth of a school.

Then the specific density of a fish concentration was found :

$$Q_{sp} = V_{sp} \cdot \rho \text{ , where} \qquad (3)$$

ρ - absolute average density of capelin schools in specimens per cubic metre as determined from photos.

For underwater photography the automatic camera " Triton " was used (Serebrov,1974; Seliverstov,Zaferman,1974).

During the investigations in the fall 1974 the camera was fixed on the trawl (Serebrov,Bakanev,Kovalev,1975).In 1975 it was lowered into the school on a cable with the help of a hydrological winch.

The displacement of the research vessel was what dictated the method of the underwater photography. In 1974 the photography was carried out from R/V "Protsion " of 800 tons displacement. Because of the ship's roll and pitch the camera fixed on a cable made vertical jerks and frightened away the fish. The displacement of R/V " Odissey" (3 000 tons) makes it possible in fair weather to lower the camera into fish schools on a cable.

The scale of photography, the volume of photographed space and the absolute density of fish concentrations were determined by well tested methods (Truskanov, Zaferman, 1973; Truskanov, Shcherbino, 1963, 1966).

The scale of photography was determined from the formula:

$$M = \frac{\varphi}{l} \quad \text{where} \qquad (4)$$

φ - average length of a fish from the catch in mm

l - length of the farthest fish in the negative in mm

The volume of the photographed space was determined from the formula:

$$V = \frac{1}{3} K (F \cdot m \; M)^3 \quad \text{where} \qquad (5)$$

F - camera focal distance equal to 28.5 mm

m - water refraction index equal to 1.34

K - nondimensional coefficient equal to 0.27

The absolute density of the schools is the quotient obtained by deviding the number of fish on the photo (n) by the volume (V)

$$\rho = \frac{n}{V} \qquad (6)$$

The value of ρ was calculated for each photo. The average density of schools was determined separately for the day-time and for the night-time.

The number of fish per unit volume in the day-time and in the night-time was found to be different (table 1). In the day-time the schools of a greater density kept near the bottom but at night they swam up to the surface and scattered partially. To determine a quantitative estimate of the ratio between the densities of schools in the day-time and in the night-time was carried out the survey of the experimental area of 100 square miles. The survey was made: 1) by acoustic method coupled with underwater photography

2) by acoustic method using echo sounder " Simrad EK-38 " with echo integrator.

The second method is not a method to estimate the abundance which was developed by Midttun and Nakken (Midttun and Nakken, 1971) The echo integrator was used only to obtain the total sum of echo signals in the experimental area which then was compared with the data obtained by the first method (table 2).

From table 2 it can be seen that the number of fish registered in the experimental area during the night-time is 2.3 times less than that registered in the day-time. A similar phenomenon was noted also in 1974 (Serebrov, Bakanev, Kovalev, 1975). As the interval between the day and night surveys was only 2 hours, the fish moved relatively slowly (no shift was noted in the position of boundaries of concentrations) and the experimental area was 100 square miles the decrease in the number of fish in the night-time can not be explained by its migration beyond the boundaries of the experimental area. The echo integrator also indicates the decrease in the number of fish in the night-time this decrease being practically that obtained by photogrammetry.

Control trawlings in the surface layer showed that in the night-time a certain part of the fish were distributed at a depth of 0-5 metres and were out of the range of the echo sounders whose transducers were mounted in the bottom of the ship.

Therefore, when processing the data obtained in the night-time the specific abundance of fish determined during 15 minutes was multiplied by a correction coefficient 2.3.

The values of Q_{sp} obtained for 15 minutes were averaged and entered upon the route map and through them were drawn the lines of equal specific density of fish (Fig.1) according to the following gradations:

zone 1 -	< 1	
zone 2 -	1.1 - 10.0	
zone 3 -	10.1 - 25.0	
zone 4 -	25.1 - 50.0	$\times 10^6$ Spec./mile^2
zone 5 -	50.1 - 100.0	
zone 6 -	> 100.1	

For each zone the average specific abundance of fish per sqare mile was calculated ($Q_{av.}$).Then the total abundance of fish in the zone was determined : $N= Q_{av.} \cdot S_z$ where (7)

S_z - area of the zone

By taking a sample of fish from a catch and deviding the weight of the sample by the number of fish in it the average weight of 1 specimen was determined.In divisions 2J and 3K it was found to be 21.5 grams. The total biomass of fish in each zone was calculated from the formula:

$W=N \cdot m$ where (8)

m - average weight of 1 specimen.

The estimates of abundance and biomass are shown in table 3.

Discussion of results and conclusion

In the fall 1974 it was determined that the abundance of capelin in 2J and 3K was of the order of $43681.8 \cdot 10^6$ specimens and the biomass 1.3 million tons (Serebrov,Bakanev,Kovalev,1975).

In the fall 1975 the capelin abundance in these divisions was $45665.7 \cdot 10^6$ specimens and biomass 0.98 million tons.

That the abundance increases while the stock biomass shows a decrease is explained by a mass appearance in divisions 2J and 3K of the recruits of the 1973 year-class which,apparently,is as strong as that of 1969.The 1969 year-class appeared in these divisions at the age 2+ and in the fall 1971 made up more than 50% of the stock. The 1973 year-class in 1975 also comprised more than 50% of the capelin stock.The reduction in average age of the stock both in 1971 and in 1975 has led to the decrease in the average weight of 1 specimen (Fig2)

In 1971 the capelin stock was made up of the fish not older than 3 years (97% - 2J and 96% - 3K).The international capelin fishery in division 2J was initiated only in 1972 when only 18 000 tons were taken and there was no inshore fishery at all.In division 3K up to 1972 existed only a small inshore fishery with the annual catch less than 1 000 tons.In the southern divisions ($3LNOP_s$) up to 1971 the removal did not exceed 2 000 - 3 000 tons (ICNAF,Summ.Doc.75/5). From this it follows that in 1971 the age structure of the stock practically did not suffer the effect of fishing.Therefore,we can think that the chief cause of the decrease of the stock biomass while its abundance increases is natural alternation of strong and poor year-classes.

If we accept the hypothesis that at the end of the winter the capelin migrate from divisions 2J and 3K to spawn off the eastern coast of Labrador and Newfoundland (3 LOP_s) as well as in division 3N (Serebrov,Bakanev,Kovalev,1975) then the estimate of the biomass made in the fall 1974 (1.3 million tons) was a clear cut underestimate.Assuming that the international quota for divisions (3 $LNOP_s$) was taken (200 000 tons) then only in the international waters were 1.25 million tons of the capelin which were migrating from divisions 2J and 3K.From this quantity,after the closure of the fishery,on a comparatively small spawning ground in the Southeast Shoal were 1.05 million tons (Seliverstov,Kovalev,in press).From the fishery literature it is known that main capelin spawning grounds are located off the eastern and south-eastern coast of the Avalon peninsula and the eastern coast of Newfoundland where several local capelin stocks were identified according to seasonal distribution (Templeman,1948;Campbell,Winters,1973;Winters,1975).

Proceeding from this the actual capelin stock in divisions 2J and 3K must be several times greater.The instrument survey with underwater photography gives the underestimated abundance and biomass. The cause of it are peculiarities of capelin vertical diurnal migrations.In the night-time as it has been mentioned above,some part of the fish rise to the surface and above the transducers of echo sounders.As a result,some part of the fish are not registered and the night survey always yields a lesser abundance and biomass than the day-time survey.

In the day-time part of the fish keep in the middle layers and over the bottom while the other part sink directly to the bottom. The latter part of the fish are very poorly registered by the echo sounder.According to reports of R/V " Persey III " and scouting vessels it is not infrequently that in the fall up to 0.5 - 1.5 tons of capelin are taken with a bottom trawl in the areas where no capelin have been recorded in the body of water and near the bottom.

October 21 - 27 1975 R/V " Odissey " carried out the capelin abundance survey, the minimum distance from the Canadian coast being not less than 20 miles.The scouting vessels reported that the dense recordings of capelin concentrations had also occurred west of the surveyed area up to the fishing zone of Canada.Judging by the distribution part of the fish at the time of the survey were also in the fishing zone of Canada.

From the above it follows that 0.98 million tons determined in the fall 1975 are but a part of the stock in divisions 2J and 3K.

The consumption of capelin by predators and the estimates of capelin stocks made by many authors (Campbell,Winters,1973;Dragesund, Monstad,1973;Gulimov,Kovalev,1975;Nakken,Dommasnes,1975; Ponomarenko,V. Ponomarenko,I,1975;Seliverstov,1975;Seliverstov,Kovalev - in press - Serebrov,Bakanev,Kovalev,1975;Winters,1975) both for the Barents Sea and for the Labrador and Newfoundland waters are presented in table 4.

For the Barents Sea the size of the capelin spawning stock as determined in the fall by the acoustic method (Nakken,Dommasnes,1975) in 3 cases out of 4 (table 4) exceeded but little the removal of capelin in pre-spawning and spawning period of the successive year and the annual total removal was often greater than the size of the spawning stock.For example,in the fall 1971 the mature capelin stock was 1.7 million tons.The total catch for the Barents Sea in 1972 was 1.6 million tons (Seliverstov,1975).In the fall 1973 the stock was 1.0 - 1.5 million tons (table 5) but only Norway alone took in 1974 1.03 million tons (Norges fiskerier,1974).

With a such stock:removal ratio when 70% - 80 % of the removal are made up of the pre-spawning and spawning capelin the abundance of the capelin stock in the Barents Sea had to sharply reduce.But nothing of the kind took place.Hence it follows that so far one has not succeeded in obtaining the absolute size of the spawning stock by acoustic methods.

Mathematical models give considerably greater estimates of the mature capelin abundance (table 4).Fishing mortality in 1972 - 1974 calculated on the basis of these estimates did not exceed 15 - 25% and for a species with a monocyclic spawning and a short life span was very low (Prokhorov,1965; Tyurin,1963; Templeman,1948).

The biomass of capelin consumed by predators is calculated for the Barents Sea for the period 1971 - 1973 but for the North-West Atlantic it was calculated not for a definite period but " on the average for the last years " (Ponomarenko,V. and Ponomarenko,I., 1975;Winters,1975).

The amounts of capelin consumed by predators in the former and in the latter areas are comparable and are of the order of 4 - 5 million tons(table 4). But the estimates of the abundance of cod as the chief predator differ greatly and so do the removals - while the stock of cod in the Newfoundland and Labrador waters is greater than in the Barents Sea the removal of cod in the former area is relatively less than in the latter (Anon,1975;Campbell,Winters,1973;Ponomarenko,V. and Ponomarenko,I.,1975;Stat.Bull.,1972,1974,1975;Winters,1975). The catches and abundance estimates are shown in table 5.

In divisions 2HJ - $3KLNOP_s$ in 1966 - 1969 the cod stock was on the average 2.95 million tons.The amount of capelin consumed by cod annually ranged from 1.47 to 2.95 million tons.G.H Winters (1975) indicates that from 1955 - 1957 to 1964 - 1968 the stock of cod was decreasing.But the amount of capelin consumed by the cod was calculated for the estimated biomass of cod of 6.21 million tons and this ultimately gave the quantity of the eaten out capelin of 3.97 million tons.

Apparently,the estimated cod stock in divisions 2HJ - $3KLNOP_s$ was extremely large.It can be seen when comparing the estimates of cod stocks in the Barents Sea and in the Labrador and Newfoundland waters with removals in these areas (table 5).

Apart from the fact that the stock:removal ratio for the Barents Sea and that for the North - Western Atlantic are different which does not make it possible to decide which of the two methods to calculate the consumption of the capelin by cod should be preferred the both methods have no correction for the removal of cod (predators) which brings about the decrease in the quantity of eaten out capelin.

When the predator press diminishes because of the decrease in the abundance of predators due to natural causes or the fishing the intensity of food chains also decreases. A certain portion of food objects remain unconsumed.As a result, we have not only

" a surplus " biomass as in the case of the capelin (Winters,1975) but also an additional recruitment to the spawning population enhancing the stock's reproductive capacity what leads to the increase of the stock as a whole.Ø.Ulltang (1974) indicated that in the last years in the Barents Sea appeared a number of extremely strong capelin year-classes.The data of the international surveys of the 0 - group fish confirm this conclusion - in 1971 -1975 appeared 4 strong and 1 average year-classes (Anon.,1974,1975). Ø.Ulltang explains the appearance of strong year-classes by the stock's reaction to the intensive removal. At the same time the rate of growth of the capelin decreased because of the extremely great abundance of the stock.

The hypothesis of Ø.Ulltang is not without foundation for the decrease in the rate of growth of the specimens belonging to the strong year-classes and a general decrease in the rate of growth when the abundance of the stock increases is a widespread phenomenon and is associated with the limiting effect of the nutrient base (Nikolsky,1974).However,the increase in the abundance is associated not only with the compensating reaction of the stock to the removal but also with the decrease in the press of the chief predator.

The decrease in the cod stocks in recent years in the Labrador and Newfoundland waters as reflected by the increasing limitation of the removal of cod (ICNAF,Ann.Meet.May - June,1975)is a factor contributing to the increase of capelin stocks in the above areas.

Taking into consideration that the capelin abundance survey in divisions 2J and 3K gave clear cut underestimates of the abundance using the experience gained in the exploitation of the capelin stock of the Barents Sea we can say with maximum caution that the removal in the above divisions does not exceed 50% (0.4 - 0.45 million tons) of the actually determined biomass (0.98 million tons) which is not an excessive figure for a species with a short life span and a monocyclic spawning.

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Table 1. **Average density of capelin concentrations**

time	total number of photos	Number of photos with fish	total number of fish on photos	Specimens per 1 cubic metre
Day	226	24	2I6	I,I88
Night	278	34	2I2	0,873
Total	504	58	428	I,032

Table 2. **Capelin abundance in the experimental area obtained by echo survey and echo integrator readings**

Time	Period of observations	Number of observations	Specific volume of schools (V_{sp}) m^3 10^6 mi^2	Specific abundan, (Q) Spec.10^6 per mi^2	Total abundance (E) Spec 10^6	Integrator: Total readings in mm	Integrator: Reading in mm/min
Day	$I3^{00}$-$I8^{I5}$	24	I8,8	20,3	487,5	3724	I2,3
Night	20^{00}-02^{46}	I5	I3,2	I4,2	2I2,8	I557	7,4
Day /night			I,4	I,4	2,3	2,4	I,6

Table 3. Abundance and biomass of capelin (2J-3K)

Gradation s of density in Spec./mi^2 x 10^6	Average abundance Spec.mi^2 x 10^6 (Q_{av})	Area of concentrations in mi^2 (S)	Total abundance Spec. x10^6 (N)	Average weight of 1 Spec. in grams (m)	Total biomass in tons (W)
< I	0,8	I442,4	II53,9		24809
I,I-I0,0	5,6	66I,7	3705,5		79669
I0,I-25,0	20,2	443,9	8966,8	2I,5	I92786
25,I-50,0	40,I	2I5,6	8645,6		I85880
50,I-I00,0	85,I	48,2	4I0I,8		88I89
> I00,I	346,5	55,I	I9092,I		4I048I
		2866,9	45665,7		98I8I4

Table 4. Estimate of adult capelin stock and its biomass consumed by predators (in million tons)

Year	Barents Sea			Newfoundland and Labrador					
	Method			Method					
	I	2	3	I		2		3	
	Biomass			Div.	Bio mass	Sub area	Bio mass	Div.	Bio mass
I97I	I,7	5,7	5,07			2+3	>I,2--I3,7		
I972	3,7	6,2	5,I9	3LNOP$_s$	0,8	-"-	>I,3--I4,7		
I973	I,0-I,5	4,5	6,92			-"-	>I,7--I9,0		
I974	0,75			2J 3K	I,3	-"-	>I,I--I2,3		
I975				3M	I,05		?	2J3KLNOP$_s$	3.97*
I975				2J 3K	0,98				1.25*

Note: 1 - instrument ,2 - mathematical, 3 - consumption of capelin by predators. Methods 1 and 2 were used to determine the adult stock with the exception of divisions 3LNOP$_s$ in 1972. Method 3 gives the weight of capelin consumed by predators

* - Calculated without reference to a definite year. Capelin stock which remains after part of the stock has been consumed by predators.

Table 5. Stock and removal of cod in the Barents Sea and in the North - West Atlantic in 1971 - 1973 (million tons)

Area	I97I	I972	I973
Barents Sea (Subarea I, Div.IIa,IIb)	I,4I / 0,7	I,II / 0,57	I,6I / 0,8
North - West Atlantic (2HJ - 3KLNOP$_s$)	6,2I(2,95) / 0,65	6,2I(2,95) / 0,63	6,2I(2,95)*/ / 0,50

Note: numerator - stock, denominator - removal

* - 6.21 (Winters,1975);2.95 (Campbell,Winters,1973).

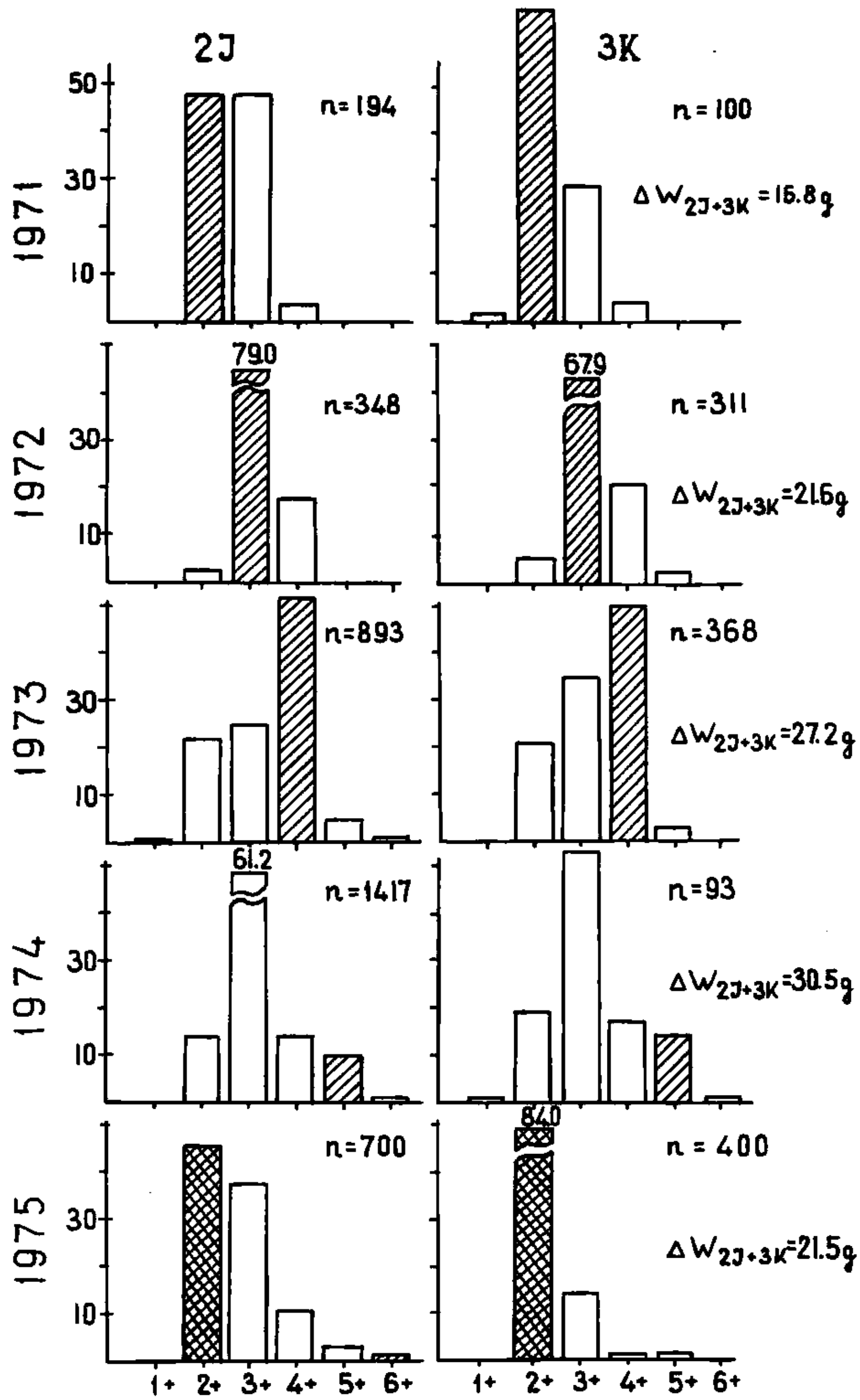

Fig.2. Age composition and average weight of 1 specimen in divisions 2J and 3K

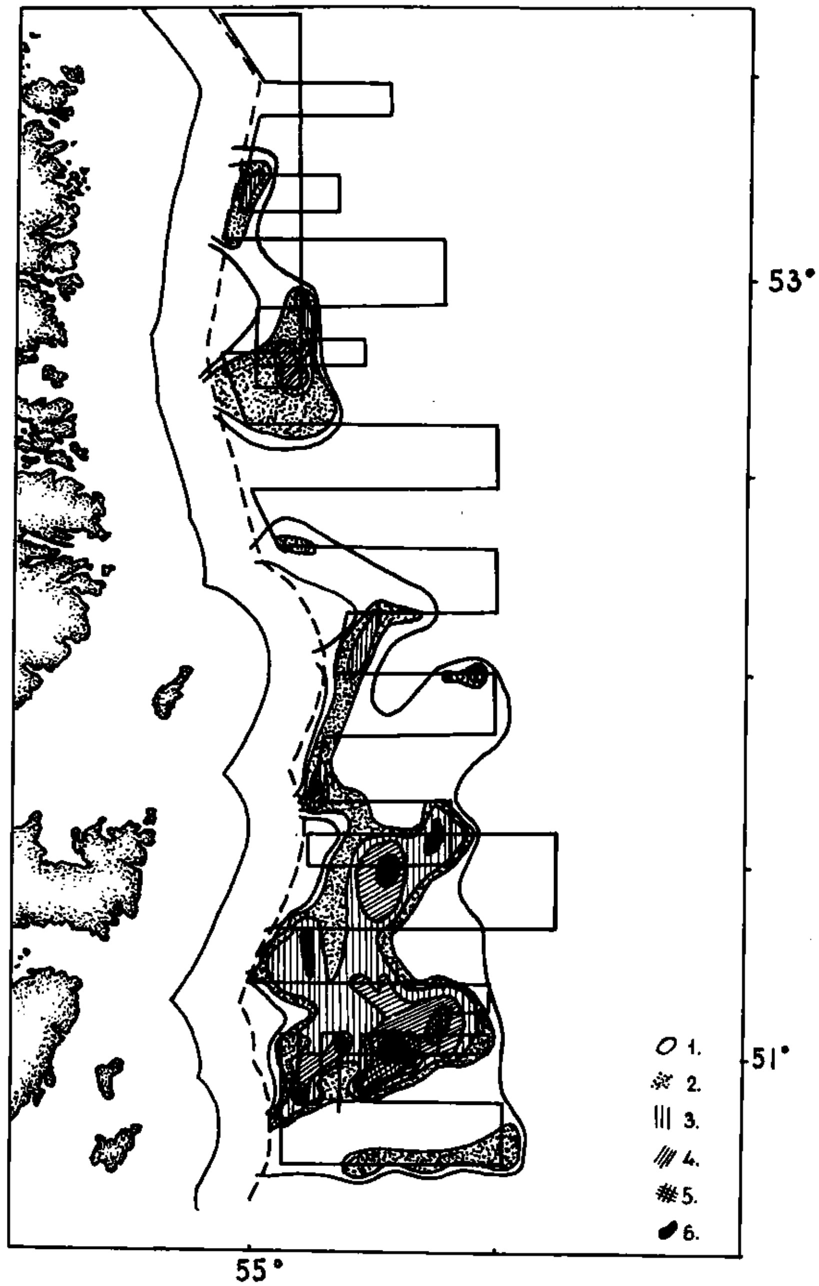

Fig.1. Capelin abundance survey October 21 - 27 ,1975.

1 - less than 1 10^6 Spec./mi^2

2 - 1.1 10^6 - 10 .10^6 Spec./mi^2

3 -10.1· 10^6 - 25 ·10^6 Spec./mi^2

4 -25.1· 10^6 - 50 ·10^6 Spec./mi^2

5 -50.1 ·10^6 -100 ·10^6 Spec./mi^2

6 -more than 100.1 ·10^6 Spec/mi^2