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ACOUSTIC ABUNDANCE ESTIMATION OF THE ICELANDIC STOCK OF CAPELIN 1978-1982

by

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1. Abstract

During the period October 1978 - February 1982 several abundance estimates and yearclass composition of the Icelandic capelin stock were obtained by acoustic methods. Surveying has been carried out in July-Agust, September, October, November as well as in January-February and on one occasion in early March. It has been found that consistent abundance estimates of the older yearclasses (excluding 0- and 1-group fish) can be obtained in autumn and winter by this method while the fish still occupy deep water areas off NW-, N-, NE- and E-Iceland. Due to drift ice and periods of bad weather it has at times proved necessary to wait or repeat surveys for these reasons. This paper describes and discusses the abundance estimates obtained during the above period. They have been used for management purposes.

Extrait

Durant la période octobre 1978-février 1982, plusieurs estimations sur les quantités et l'age des réserves de capelan islandais ont été obtenues par des méthodes acoustiques. Les évaluations ont été réalisées en juillet-aout, septembre, octobre, novembre, en janvier-février, ainsi qu'une seule et unique fois en mars. Il s'est révélé que les évaluations quantitatives des especes les plus agées (a l'exception des poissons des groupes 0 et 1) pouvaient etre obtenues en automne et en hiver grace a cette méthode, alors que le poisson occupe les eaux profondes des zones N-O, N, N-E et E de l'Islande.

Il a été parfois nécessaire de repousser ou de répéter certains controles, a cause de déplacement des glaces flottantes ou du mauvais temps. Cette étude décrit et discute les estimations quantitatives obtenues durant la période nommée plus haut. Elles ont été utilisées a des fins pratiques de régulation des réserves.

2. Introduction

Prior to 1964 the catch from the Icelandic capelin stock was only for bait and amounted to a few hundred tons annually at most. In 1964 Iceland started a purse seine capelin fishery for reduction to meal and oil. During 1964-72 this fishery was limited to coastal waters during the spawning season but in 1975 was extended to include more offshore waters off E- and NE-Iceland. Since then the winter season has begun already in the first days of January. This development resulted in a sharp increase in the winter catch which then stabilized around 450 thousand tons. Apart from a small catch taken by the Faroes in 1977-79 the winter capelin fishery has been conducted by Iceland alone.

In 1976 Iceland started a summer and autumn fishery for capelin on the feeding grounds in deep water areas off NW- and N-Iceland. This fishery proved highly successful, the catch increasing from about 115 thousand tons in 1976 to nearly 500 thousand tons during the 1978 season.

In 1978 Norway joined the summer fishery of the Icelandic capelin taking 155 thous. tons in the area W and NW of Jan Mayen. In the summer of 1979 the Norwegian catch in that area amounted to 126 thous. tons when a ban was imposed in early September.

The latest development is a capelin fishery by the Faroes as well as EEC countries in the area between E-Greenland and Jan Mayen. This fishery has yielded some 30-40 thousand tons during the last two summer and autumn seasons.

During the last three seasons Iceland and Norway have bilaterally agreed to limit their catches in order to preserve the spawning stock.

The above developments in the fishery on the Icelandic capelin stock are illustrated in Table 1.

The migration and behaviour of this stock have been studied by acoustic methods since the sixties. With the rapid increase in catches following the advent of the multinational summer and autumn fishery the need for accurate assessment of its abundance soon became of paramount importance for management purposes. Since the autumn of 1978 the Icelandic Marine Research Institute has estimated the abundance of the stock in late autumn and in winter. During the summer and autumn of 1979 such estimates of stock size were obtained through acoustic surveys carried out jointly by the above institute and the Institute of Marine Research, Bergen. Since then Norway and Iceland have surveyed the stock jointly in October and the Marine Research Institute, Reykjavík, has carried out additional autumn surveys when needed as well as continued its surveying in January/February in the following year. The results of these surveys were subsequently used in order to manage the fisheries on the 1979, 1980, 1981 and 1982 spawning stocks.

The purpose of this paper is to describe and discuss the results of the above acoustic abundance estimates of the Icelandic capelin stock.

3. Material and Methods

All material was collected by research vessels and samples were aged and weighted (volume to nearest ml) on board.

Cruises were timed as follows:

1) 16-30 October 1978, R/V Bjarni Sæmundsson
2) 1-9 February 1979, R/V Bjarni Sæmundsson
3) 14 February - 1 March 1979, R/V Bjarni Sæmundsson
4) 26 July - 12. August 1979, R/V Bjarni Sæmundsson
   R/V G.O. Sars
5) 25 September - 5 October 1979, R/V Bjarni Sæmundsson
   R/V Michael Sars
6) 14-26 October 1979, R/V Bjarni Sæmundsson
7) 4-30 January 1980, R/V Bjarni Sæmundsson
8) 11-22 October 1980, R/V Bjarni Sæmundsson
   R/V G.O. Sars
9) 5-29 January 1981, R/V Bjarni Sæmundsson
   R/V Árni Friðriksson
10) 5-16 February 1981, R/V Bjarni Sæmundsson
11) 14-23 October 1981, R/V Bjarni Sæmundsson
    R/V G.O. Sars
12) 3-13 November 1981, R/V Bjarni Sæmundsson
13) 26-30 November 1981, R/V Bjarni Sæmundsson
14) 11-22 January 1982 R/V Bjarni Sæmundsson
    R/V Árni Friðriksson
15) 27 January - 21 February 1982, R/V Bjarni Sæmundsson

Initially, during the R/V Bjarni Sæmundsson surveys in October 1978 and February-March 1979, a slightly different technique of data evaluation as well as C values were used (Vilhjálmsson and Reynisson, 1979). After intercalibrations with R/V G.O. Sars in August 1979 it was, however, possible to recalculate the above surveys results. The intercalibration was carried out on a scattering layer of 0-group

fish, mostly capelin, off NW-Iceland and the following relationship was established $M_{GOS} = 1.07\ M_{BS} + 10$ (see also Fig. 1):

Where:

M_{GOS} are integrator values obtained by G.O. Sars and M_{BS} are integrator values obtain by Bjarni Sæmundsson, both referred to 40 dB integrator gain.

The relation between R/V G.O. Sars and R/V Michael Sars had been previously established by the Institute of Marine Research, Bergen.

The intercalibration with G.O. Sars was repeated on a similar scattering layer of 0-group fish in October 1980 with the same results as in the year before.

In the course of the survey intercalibration of the acoustic systems on both ships were done in two different ways in October 1981.

1) Standard target calibration with a copper sphere with a diameter of 60 mm and target strength -33.7 dB (Foote et al. '81). Integrated echo intensity simulated over 1 nautical mile gave the following result:

$$M_{GOS}/M_{BS} = 0.027$$

Here the difference in the directivity of the transducers has not been considered.

2) Intercalibration on a scattering layer, mostly 0-group capelin and plankton. The following relationship was established with a correlation coefficient r = 0.98.

$$M_{GOS} = 0.026\ \ M_{BS} + 4.7 \quad \text{(Figure 2)}$$

The latter equation was then used when converting the echo intensities recorded by R/V Bjarni Sæmundsson to G.O. Sars values.

The reason for these drastic changes in the M_{GOS}/M_{BS} relationship from that of the years before is that the acoustic system on board R/V Bjarni Sæmundsson had been renewed so that only the old transducer remained.

In January 1982 it was decided to change the receiver gain and when comparing copper sphere calibrations from October 1981 and January 1982 the M_{GOS}/M_{BS} = 0.33 was calculated and used.

In January 1981 and 1982 the acoustic surveys of capelin were carried out on the two Icelandic research vessels Bjarni Sæmundsson and Árni Friðriksson. The relation between the two ships had previously been established by the Marine Research Institute, Reykjavík. All results could therefore be referred to G.O. Sars values as standard.

The basic integration technique applied was described in detail by Nakken and Dommasnes (1975). The variant adopted for the present purposes may be summarized as follows:

Integrated echo intensities were registered continously from the depth column along the ships' track producing fish traces and the values obtained were recorded as average/nautical mile for each 5 nautical miles sailed. Trawling was undertaken as neccessary in order to ensure adequate biological sampling and to check changes in the echo recordings.

In all instances a 38 kHz acoustic system has been used.

The survey area was divided into suitable subareas depending on variations in the length composition of the capelin as observed from the trawl catches. The integrated echo intensity was converted to fish densities using the equation:

$$N = C \times M \times A$$

Where:

N is the total density in terms of numbers,

C is the number per unit area and dependent on mean length of the fish according to the equation

$C = 8.1 \times 10^6 \times L^{-1.91}$ (number of fish/1 $n.m^2$ / 1 mm elevation on echo the integrator recorder, ref. 40 dB), M is the mean integrated echo intensity for the relevant subarea (mm ref. 40 dB gain on echo integrator). A is the subarea measured in square nautical miles. The sum of the number of fish calculated for each subarea then gives the total stock size in number.

In the surveys the 0-group capelin is grossly underrepresented compared to older yearclasses. To some extent this also holds true for 1 group fish. Therefore the contribution by 0-group capelin to the echo abundance has been subtracted and the estimates of stock biomass presented thus exclude the 0-group fish.

4. Survey results

4.1. October 1978. R/V Bjarni Sæmundsson

In late October 1978, extensive scouting NW and N of Iceland revealed dense capelin concentrations in a fairly large area reaching from approximately 67°45'N, 24°45'W northeastwards to 68°45'N, 21°00'W. Prior to this, a Norwegian scouting vessels had searched the Jan Mayen area as well as the Iceland Sea south to about 69°00'N. Their results were negative except for a limited area near the 350 m isodepth E of Scoresby Sound. Most of the distribution area of the 1979 spawning stock of the Icelandic capelin was, therefore, covered during this cruise .

In the period 20-29 October the capelin area off NW-Iceland was successfully surveyed 3 times and acoustic abundance estimates obtained. (Figures 3-5)

A short spell of bad weather during 27 October probably produced an underestimate of stock abundance in the second survey.

The distribution and relative abundance for the three independent abundance estimates as well as the average of surveys I and II are given in Table 2. The average roughly constitutes the spawning stock since the youngest immature yearclass is excluded.

4.2. E- and NW-Iceland, January-February 1979
R/V Bjarni Sæmundsson

At about mid-January considerable concentrations of capelin were located off the eastern N-coast of Iceland. In the first week of February, when this migration had reached the area off E-Iceland, it was surveyed 3 times by R/V B. Sæmundsson (Figures 6-8). The stock abundance estimates from the above surveys in numbers and weight by age groups are given in Table 3.

At the time of the first survey the capelin were recorded as a continuous scattering layer in midwater but during the two subsequent ones dense shoals were occasionally encountered as the migration continued southwards. On the whole, however, the fish were more or less evenly distributed, their area of occupation well defined and there is little variation between the three estimates. The surveys, therefore, seem to present a reliable picture of stock abundance in the area, the average being 562 thous. tons for the spawning stock.

Surveying off N-Iceland during the later half of January was negative but during 8-10 February an additional component of the spawning stock together with a considerable number of immatures was located off NW-Iceland as shown in Figure 9. The acoustic abundance estimate of the size of these stock components is given by age groups and numbers in Table 4. (Survey I)

In the third week of February the capelin area off the NW-peninsula was resurveyed (Figure 10). Bad weather prevailed for most of the time and heavy shoaling was observed. During 17-18 February, however, the shoals scattered and an acoustic assessment of the spawning stock could be completed before surveying had to be abandoned due to deteriorating weather conditions. The stock abundance was estimated at 545 thous. tons. The division by weight and number at age is also given in Table 4. (Survey II)

4.3. Februar 27 - March 1 1979. R/V Bjarni Sæmundsson

After resurveying the western component of the 1979 spawning stock R/V B. Sæmundsson carried out a survey of the remnants of the eastern component in the shallow coastal waters (30-150 m) at SE-Iceland during the period 27 February - 1 March (Fig. 11).

At the time the capelin in this area were recorded as a more or less continuous scattering layer in midwater during the dark hours but in the daytime assembled to form dense shoals, which in places reached from surface to bottom. To comply with this pattern of behaviour surveying was carried out in darkness. The acoustic estimate of stock abundance thus obtained was just under 350 thous. tons of mature capelin exclusively. The division by weight and number at age is given in Table 5.

4.4. July-August 1979, R/V Bjarni Sæmundsson, G.O. Sars

During the period 27 July - 12 August an acoustic survey of the distribution and abundance of the Icelandic stock of capelin was carried out jointly by Iceland and Norway. This survey covered the area Iceland-Greenland-Jan Mayen from approximately 66°00'N to 72°00'N (Figure 12). The size of the stock was estimated at 490 thous. tons. The distribution by age groups and numbers at age is given in Table 6.

The capelin were mainly recorded in the frontal zone of the East-Greenland Current. The most abundant concentrations were located N of Cape Horn and W of Jan Mayen. The fish were mainly observed as small shoals close to the thermocline at a depth of 20-30 m. During the daytime, however, the capelin was sometimes found at greater depths and on some occasions it appeared as very small, dense shoals in the uppermost 3-4 metres, i.e. above the detection range of the transducer.

At the time of the survey there was much drift ice in the Denmark Strait south of Scoresby Sound rendering part of the stock inacessible. The abundance estimate was, therefore, regarded as an underestimate of an unknown magnitude.

In addition an attempt was made to survey the same stock on R/V Bjarni Sæmundsson in September. At that time the fish were even more scattered and generally had an even more shallow distribution. The stock abundance estimate was so low that it was never put down on paper and the experiment reported as a complete failure altogether.

4.5. Sept.-Oct. 1979. R/V Bjarni Sæmundsson, R/V Michael Sars

Iceland and Norway carried out another joint echo survey of the Icelandic capelin stock from 25 September to 5 October. This time practically no drift ice was encountered and surface shoaling was much less pronounced than during the August and September surveys. The distribution and relative abundance of the capelin is shown in Figure 13. Due to bad weather the area N of 71°N could not be surveyed but elsewhere little difficulties were encountered. Except for the northernmost regions covering of the distribution area was, at the time, considered adequate.

As shown in Figure 13 the bulk of the mature stock was assembled between 67°45'N and 70°N, 17°-19°W as well as near the 68th parallel between 21°W and 26°W. Immatures were recorded over the E-Greenland shelf, to the NW of the NW-peninsula of Iceland and about 60 n.m. off the central N-coast of Iceland.

The total stock biomass was estimated at 950 thous. tons. Details of this estimate are given in Table 7.

4.6. October 1979. R/V Bjarni Sæmundsson

This survey was carried out during the period 14-28 October in the area off N- and NW-Iceland as shown in Figure 13. In autumn the capelin aggregate in this area prior to the onset of the spawning migration to the S- and SW-coasts of Iceland in winter.

Compared to the joint September-October cruise weather conditions were less favourable. Thus, the northern boundary of the distribution area could not be accurately determined and occasionally surveying had to be halted for short periods of time. From the previous joint survey the majority of the large capelin had migrated southwards to assemble for a while in the area 67°45'-68°0'N, 18° - 21°W (Figure 14).

In most of the survey area shoaling was pronounced, particularly at night. Most of the shoals were, however, only of moderate density. During darkness the capelin sometimes came within 5-20 m from the surface but mainly kept to deeper waters in daytime (150-300 m).

The acoustic stock abundance estimate was 1060 thous. tons and distributed by number and weight per age groups as given in Table 8.

4.7. January 1980. R/V Bjarni Sæmundsson

According to echo surveying the 1980 spawning stock had a most unusual distribution in January. Thus, by mid-January, no capelin had been located neither off E- and NE-Iceland nor off the N-coast in spite of intense surveying by both research vessels and the fishing fleet. On the other hand all the capelin was still assembled near the southeastern boundary of the E-Greenland Current at the shelf edge to the NW- of the NW-peninsula of Iceland. During the first 20 days of the month these waters were periodically covered by drift ice which made an acoustic stock abundance estimate unobtainable.

After 20 January the drift ice receeded in a westerly direction and during the period 25-28 January the distribution area of the capelin was ice free altogether. The fish were mostly recorded as a scattering layer of varying density and due to previous survey effort as well as scouting by fishing vessels the boundaries of the distribution area were known. The weather was good and a detailed acoustic survey could, therefore, be completed during the above period under nearly ideal conditions. The distribution and relative density of the capelin is shown in Figure 15.

The total acoustic stock size estimate was 840 thous. tons. The distribution of weight and numbers by age groups is given in Table 9.

4.8. October 1980. R/V Bjarni Sæmundsson, R/V G.O. Sars

This time the capelin were recorded in three main areas. Area I between 68°20′ and 69°00′N, 19°50′ and 22°30′W, area II between 66°00′ and 67°00′N, 26°00′ and 28°00′W and area III between 67°10′ and 67°50′N, 19°10′ and 22°00′W. Distribution of echo intensity in the three areas is shown in Figure 16. In all areas juveniles were mixed with the adults, but were relatively most abundant in area III.

This is in contrast to the 1979 October situation when most of the adult stock was recorded from 68° - 70°N between 17° and 20°W and the juveniles elsewhere, i.e. over the East-Greenland shelf as well as in deep waters to the N and NW of the NW-peninsula of Iceland and off the central N-coast.

Geographically, the capelin were thus distributed much further to the W and SW than at the same time last year but as then kept to the zero and sub-zero temperatures of the East-Greenland Current and adjacent waters.

The total abundance estimate in weight of 1-3 years old capelin amounted to 678 000 tons, distributed by areas I, II and III as 81 000, 572 000 and 25 000 tons respectively. Details of the total stock estimate are given in Table 10.

4.9. January 11-22, 1981. R/V Bjarni Sæmundsson, R/V Árni Friðriksson

The capelin were recorded in a 5-15 n.m. wide area just off the shelf edge and as usual at the southern boundary of the East Icelandic Current. Their distribution was patchy, the fish most frequently being encountered as single shoals or aggregations of shoals of moderate density. The capelin kept to depths in excess of 100 m most of the time.

By the end of January the apex of the migration had reached the area E of Langanes, about 70-80 n.m. offshore.

Three consecutive surveys were carried out in the period 20-29 January. The results of these surveys were as follows:

1) Bjarni Sæmundsson, 20-22/1 1981. Echo stock 430 thous. tons.
2) Árni Friðriksson, 20-22/1 1981. Echo stock 270 thous. tons.
3) Bjarni Sæmundsson and Árni Friðriksson, 24-29/1 1981. Echo stock 322 thous. tons.

Difficulties were encountered due to changing drift ice in the northernmost region of the distribution of the capelin as well as the behaviour of the fish. Evaluation of the data was therefore unusually difficult. The distribution and integrated echo intensities during the last and most detailed survey are shown in Figure 17. Further details of this stock abundance estimate are given in Table 11.

During the period 5-16 February the area off the NW peninsula of Iceland was sureyed by R/V Bjarni Sæmundsson. Results were negative.

4.10. October 14-23 1981, R/V G.O. Sars, R/V Bjarni Sæmundsson

As often before at this time of the year the capelin were recorded in three main areas. Area I between 69°30′ and 70°30′N, area II between 67°30′ and 68°30′N, and area III between 66°00′ and 66°30′N. Distribution of echo intensity in the three areas is shown in Figure 18. The population in areas I and II was predominately adults, while juveniles were most abundant in area III.

The northern component of the capelin stock, which has its feeding grounds in the area W of Jan Mayen, was now located between 69°30′N and 70°30′N. This is about 60 n.m. further to the NE than its counterpart in 1980. The main concentration was now found between 67°30′ and 67°30′ which also is considerably further to the NE than last year. A small area, containing mostly immature fish was located between 66°00′N and 66°30′N to the W of the NW-peninsula of Iceland.

It should be noted that the area between 66°15'N and 67°30'N west of 21°40'W was now covered by drift ice with the exception of the relatively shallow waters from the coast to 40-50 n.m. offshore. This corresponds to the area where the bulk of the stock was located last year.

Geographically, the capelin were thus distributed much further to the N and E than at the same time last year but the small amounts recorded kept as usual mostly to the zero and sub-zero temperatures of the E-Greenland Current.

The total abundance estimate of 1-3 year old capelin amounted to 144 thous. tons only. Although good weather prevailed throughout the survey it was concluded that because of the extension of drift ice as well as the generally scattered distribution of the fish the October survey result probably was an underestimate of the total stock abundance.

Details of the stock abundance estimate are given in Table 12.

4.11. November 3-13, 1981. R/V Bjarni Sæmundsson

In order to check the results of the previous survey it was decided that another survey should be undertaken as soon as possible.

This survey began off NW-Iceland on 3 November and due to exceptionally good weather the area south of 67°00' - 68°15'N could be covered during the following 10 days. The area from 68°00' to 69°00'N between 18°00' and 14°00' was surveyed later.

In the beginning of the survey there was much less drift ice in the Iceland-Greenland channel than in October and access was obtained to considerable areas previously covered by drift ice.

Capelin were recorded in three main areas. Area I between 66°00' and 66°30'N, area II between 67°10' and 68°15'N west of 18°40'W and area III between 67°00' and 67°45'N east of 18°40'W (Figure 19).

The population in area I was mostly juveniles. In area III the population was predominantly adults while in area II a mixture of both was observed.

The main concentration of capelin was now located a little to the east of the Kolbeinsey ridge (16°- 18°W) representing an easterly movement of the stock since the October survey of more than two degrees in longitude. Only minor accounts of maturing fish were recorded near the ice border and scouting in the area north of 67°N did not reveal important concentrations there.

Details of this stock abundance estimate are given in Table 13 (Survey I).

4.12. 26-30 November 1981. R/V Bjarni Sæmundsson

Evidently the maturing component of the capelin stock continued on an E and SE course in November. A quick survey of the main capelin grounds during this period revealed that the apex of the migration had reached the area E of Langanes (66°15'N, 11°50'W), the rest being recorded in a very narrow zone along the continental shelf (Figure 20).

An area rich in 1 group capelin was further located on the west side of the adult fish concentrations near the shelf between 66°05' and 66°45'N, 11°45' and 12°20'W.

Details of this estimate are given in Table 13 (Survey II) after including the catch taken during the intervening period.

4.13. January 11-22, 1982. R/V Bjarni Sæmundsson, R/V Árni Friðriksson

As has been customary in the last few years final acoustic surveys of the spawning stock were carried out in the beginning of the year. At that time this capelin has not yet entered the shallow coastal waters at S- and SW-Iceland and the spawners are usually relatively free of immatures.

Four consequtive surveys were carried out. During the first survey the distribution area of the capelin was established. The survey grid was consequently rather coarse and the abundance estimate was approximately 100 thousand tons. During the following two surveys bad weather prevailed with consequent underestimates. Nevertheless it was established that during the night the capelin was recorded as continuous pelagic

scattering layer highly convenient for acoustic abundance estimates.

A fourth and final survey was completed during 20-22 January in good weather, working at night only (Figure 21). The acoustic abundance estimate for the spawning stock component was about 150 thous. tons. In addition some immatures were also recorded further to the east and north.

The details of this stock abundance estimate are given in Table 14.

4.14. 27 January - 21 February 1982. R/V Bjarni Sæmundsson

The purpose of this survey was twofold:

1) To search for and estimate the abundance of further spawning migrations than those observed in January.

2) To determine the distribution and abundance of immature capelin of the 1979 and 1980 yearclasses.

Investigations were begun off NW and N-Iceland.

Practically no mature or immature 2-3 group capelin were recorded there and spawning migrations from that area seem most unlikely this year to say the least.

The next stage of the cruise was spent off the eastern S-coast but added nothing to observations previously carried out off E-Iceland in January. Surveying during the above parts of the cruise was often difficult because of bad weather.

During the period 16-21 February the area off E- and NE-Iceland was surveyed in detail under excellent weather conditions (Figure 22).

Immature capelin, mainly of the 1979 yearclass was recorded off E- and NE-Iceland. In addition mature capelin was recorded in a limited area at the shelf edge NE of Langanes. The amount was low but must be considered an addition to the January abundance estimate of one month earlier.

Details of this abundance estimate are given in Table 15.

5. Discussion

Most of the Icelandic capelin spawn as 3 year olds. A varying proportion of each yearclass does, however, not mature until one year later. Thus, the spawning stock consists of 2 age groups, 3 and 4 year olds, the ratio of which varies depending on relative yearclass strength as well as external factors such as feeding conditions. Spawning mortality is for all practical purposes considered total.

Because of the capelin's short life span and high mortality researches have to depend on direct observations of stock size. Comparative measurements of the abundance of 0-group capelin have been obtained in August annually since 1972. (Fig. 23). During the period 1972-75 the 0-group index indicates a high level of recruitment which is followed by a downward trend and a distinctly lower level during the last 5 years. This development coincides with the large increase i fishing effort as well as the change in fishing pattern brought about by the new multinational summer and autumn fishery (Table 1).

Although changes in 0-group abundance are useful as an indicator of changes in abundance later in the life of the fish they are, in the case of the capelin, not yet accurate enough for direct management purposes.

As described in previous sections the abundance of the capelin spawning stocks of the period 1979-82 has been estimated several times by acoustic methods. In the following discussion evidence for the consistency of the acoustic method used will be presented and an attempt will be made to evaluate the quality of individual estimates and to explain deviations when they have occurred.

The feeding area of the Icelandic capelin stock is wide. Apart from the shelf areas off N- and NW-Iceland 1-3 group capelin generally feed in the area Iceland-Greenland-Jan Mayen. During the feeding period which lasts from April to September-October the stock may, therefore, be distributed anywhere within the above waters

depending on environmental conditions.

When estimating the abundance of a fish stock by the acoustic method sources of error may be encountered due to variations in the behaviour and migration patterns of the species concerned as well as the nature of the area it occupies. In the case of the Icelandic capelin the most important of these are distribution of fish above transducer range and inaccessability to parts of the distribution area due to drift ice. Since these factors are subject to periodic variations appropriate timing of the surveys as well as their design are highly important.

In September 1978 an attempt was made to obtain an acoustic abundance estimate of the Icelandic capelin stock. It failed completely.

The joint Icelandic-Norwegian survey carried out in late July-early-August 1979 resulted in an underestimate of all yearclasses. The reasons for this are the inaccessability to parts of the distribution area due to drift ice, and the occurrence of small dense schools above hull mounted transducer range. Drift ice is a common phenomenon in the Denmark Strait in spring and summer but has usually receeded or sometimes almost vanished by autumn. As May-September constitute the main feeding period of the capelin in this area, shallow distribution is to be expected at times. The success of an acoustic estimate of stock abundance is, therefore, very uncertain during the spring and summer months.

The surveys carried out in autumn and winter yield more consistent estimates. During this period the maturing part of the Icelandic capelin stock has a relatively limited distribution in an area which is more or less free of other sound scatters. Under such circumstances, repeated acoustic estimates of stock size can be carried out in a very short time for comparison.

As mentioned in a previous section it has been customary to estimate the abundance of each spawning stock (1979-82), i.e. the 3 oldest yearclasses, both in autumn and in winter.

In Fig. 24 these abundance estimates are shown together with the catch during the intervening period. No attempt has been made to estimate and incorporate losses by natural mortality. Estimates of abundance which were obviously defective (Sept. 1978, July-August 1979 and Oct. 1981) have been omitted.

These estimates show a very good fit with the exception of that carried out in Sept.-Oct. 1979. At that time only part of the northern stock component had returned from its feeding grounds to the over-wintering area off North-Iceland and may still have been feeding in the surface layers. There is little doubt that the subsequent October 1981 survey yielded too low an estimate for the same reason. Furthermore, it is likely that in both instances cruise tracks were sparsely spaced considering the distribution of the fish.

The very limited distribution area of the capelin in late autumn and winter has made it possible to survey the same stock component two or more times in a very short space of time. In this way the reliability of the acoustic method of abundance estimation can be tested.

This was first done in October 1978. The area was covered three times with essentially the same results apart from the second survey which had to be terminated prematurely due to bad weather.

In February 1979 the eastern stock component was surveyed three times in succession under favourable conditions, i.e. continuous pelagic scattering layer. The maximum deviation from the average was 5.5 percent. The western component of the spawning stock was then surveyed twice in the same month. Deviation from the average was 4.9 percent.

In January 1981 three successive surveys of the spawning stock abundance were carried out. The capelin were recorded in a long but very narrow region just outside the shelf edge from E of Langanes northwestwards to nearly 18°W. Distribution was highly sporadic. Single shoals or aggregations of shoals alternated with areas of very low densities. The bulk of the migration, therefore, was assembled within a minor part of the total area of distribution. Under such circumstances it is highly doubtful if deviations, positive or negative, will even out as they do under more normal conditions, unless the survey

grid is very densely spaced. The best estimate probably is an average of all three surveys or about 350 thous. tons which happens to be approximately the result of the last survey when the grid was much denser than in the other two.

In November 1981 two surveys of the 1982 spawning stock were completed with an interval of about two weeks. After account has been taken of the catch during the intervening period the deviation from the average is 6.3 percent.

In January 1982 four consequtive surveys of the spawning stock were carried out. Because of bad weather as well as variations in the behaviour of the fish the results of the first three surveys were not accepted as valid.

It should be borne in mind that a certain relationship has been used when converting integrated echo energy into numbers or tons of fish. This relationship need not necessarily show the exact size of the fish stock but rather reflects relative changes in its abundance. The alarming rate of decline of the spawning stock of the Icelandic capelin is a case in point and is shown in Figure 25.

6. Conclusions

The acoustic method of estimating the abundance of fish stocks is clearly suitable when applied to the adult component of the Icelandic stock of capelin. This is supported by the generally small variation in repeated surveys carried out on the same biomass in a very short time as well as the comparison of autumn and winter stock assessments when account has been taken of the catch during the intervening period.

It is equally obvious that care must be taken regarding timing of cruises and one must be prepared to wait for the rigth moment both as regards weather, fish behaviour and ice. On the whole this has been the general practice.

As regards the adult stock, surveying should not start earlier than October and will probably not succeed after the spawners have entered the shallow coastal waters at S- and SW-Iceland.

7. References

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7.8. Vilhjálmsson, H., Reynisson, P., Hamre, J. and Röttingen, I. Acoustic Abundance Estimates of the Icelandic Stock of Capelin, October 1978 - January 1980. I.C.E.S. C.M. 1980/H:63. (Mimeo).

TABLE 1

The total annual catch from the Icelandic capelin stock 1964-1980 (tons x 10^{-3})

Year	Winter season		Summer and autumn season			Total
	Iceland	Faroes	Iceland	Norway	Faroes and EEC	
1964	8.6					8.6
65	49.7					49.7
66	124.5					124.5
67	97.2					97.2
68	78.1					78.1
69	107.6					170.6
1970	190.8					190.8
71	182.9					182.9
72	276.5					276.5
73	440.9					440.9
74	461.9					461.9
75	457.6		3.1			460.7
76	338.7		114.4			453.1
77	549.2	25.0	259.7			833.9
78	468.4	38.4	497.5	154.1		1.158.4
79	521.7	17.5	441.9	126.0	2.5	1.109.6
1980	392.0		367.2	118.6	38.7	916.5
81	156.0		484.6	91.4	37.0	769.0

Table 2

Echo stock by number and weight by yearclasses (N x 10^{-9}, W x 10^{-3} tons), 16-29 October 1978.

	1974		1975		1976		Total 1974-76		1977	
Yearclass	N	W	N	W	N	W	N	W	N	W
Survey I	0.4	13.6	20.5	548.5	50.5	944.4	71.4	1506.5	0.4	3.5
" II	(0.3	10.6	16.0	426.8	39.3	734.8	55.6	1172.2	0.3	2.7)
" III	0.5	17.0	22.6	603.4	55.4	1036.1	78.5	1656.5	0.4	3.5
Average	0.5	15.4	21.6	576.5	52.9	989.6	75.0	1581.5	0.4	3.5

Table 3

Echo stock by number and weight by yearclasses (N x 10^{-9}, W x 10^{-3} tons), E-Iceland, 1-7 February 1979.

	1974		1975		1976		Total 1974-76		1977	
Yearclass	N	W	N	W	N	W	N	W	N	W
Survey I	0.4	1.7	3.1	77.8	23.2	457.0	26.7	536.5	5.0	31.5
" II	1.0	3.1	3.2	80.3	24.0	472.8	28.2	556.2	5.2	32.8
" III	1.0	2.3	3.4	85.3	25.7	506.2	30.1	593.8	5.6	35.2
Average	0.8	2.4	3.2	80.3	24.3	478.7	28.3	562.2	5.3	33.4

Table 4

Echo stock by number and weight by yearclasses NW-Iceland, (N x 10^{-9}, W x 10^{-3} tons), February 1979.

	1974		1975		1976		Total 1974-76		1977	
Yearclass	N	W	N	W	N	W	N	W	N	W
Survey I			4.6	107.0	28.3	495.3	32.9	602.3	3.6	41.0
" II	0.1	3.1	6.0	132.0	23.5	411.3	39.6	546.4	2.4	26.9
Average	0.1	3.1	5.3	119.5	25.9	453.3	31.3	574.4	3.0	34.0

Table 5

Echo stock by number and weight by yearclasses (N x 10^{-9}, W x 10^{-3} tons), SE-Iceland. 27 February - 1 March 1979.

	1975		1976		Total 1975-76		1977	
Yearclass	N	W	N	W	N	W	N	W
	3.7	92.8	13.5	249.5	17.2	342.3	0.7	7.7

Table 6

Echo stock by number and weight by yearclasses (N x 10^{-9}, W x 10^{-3} tons), Iceland - E-Greenland-Jan Mayen. 27 July - 12 August.

	1975		1976		1977		Total 1975-77		1978	
Yearclass	N	W	N	W	N	W	N	W	N	W
	+	0.8	5.0	85.8	33.0	390.2	38.8	476.8	3.0	14.3

Table 7

Echo stock by number and weight by yearclasses (N x 10^{-9}, W x 10^{-3} tons), Iceland - E-Greenland - Jan Mayen. 25 Sept. - 5 Oct. 1979.

	1975		1976		1977		Total 1975-77		1978	
Yearclass	N	W	N	W	N	W	N	W	N	W
	+	3.6	8.0	166.5	42.0	638.8	50.0	808.0	22.0	140.6

Table 8

Echo stock by number and weight by yearclasses (N x 10^{-9}, W x 10^{-3} tons), N- and NW-Iceland/Greenland. 14-26 October 1979.

	1975		1976		1977		Total 1975-77		1978	
Yearclass	N	W	N	W	N	W	N	W	N	W
	0.4	8.3	9.1	209.3	49.7	780.3	59.2	997.9	10.0	62.0

Table 9

Echo stock by number and weight by yearclasses (N x 10^{-9}, W x 10^{-3} tons), N- and NW-Iceland. 25-28 January 1980.

	1976		1977		Total 1976-77		1978	
Yearclass	N	W	N	W	N	W	N	W
	3.8	92.1	41.7	663.7	45.5	755.8	13.5	84.2

Table 10

Echo stock by number and weight by yearclasses (N x 10^{-9}, W x 10^{-3} tons), N- and NW-Iceland. Oct. 1980.

	1976		1977		Total 1976-77		1978	
Yearclass	N	W	N	W	N	W	N	W
	4.8	128	19.6	378	24.4	506	23.6	171

Table 11

Echo stock by number and weight by yearclasses (N x 10^{-9}, W x 10^{-3} tons). 11-22 Jan. 1981.

	1977		1978		Total		1979	
Yearclass	N	W	N	W	N	W	N	W
	3.2	87.3	11.4	234.7	14.6	322.0	3.3	28.1

Table 12

Echo stock by number and weight by yearclasses (N-10^{-9}, W x 10^{-3} tons). 14-23 October 1981.

	1978		1979		Total 1978-79		1979	
Yearclass	N	W	N	W	N	W	N	W
	0.2	4	7.0	135	7.2	139	0.9	5

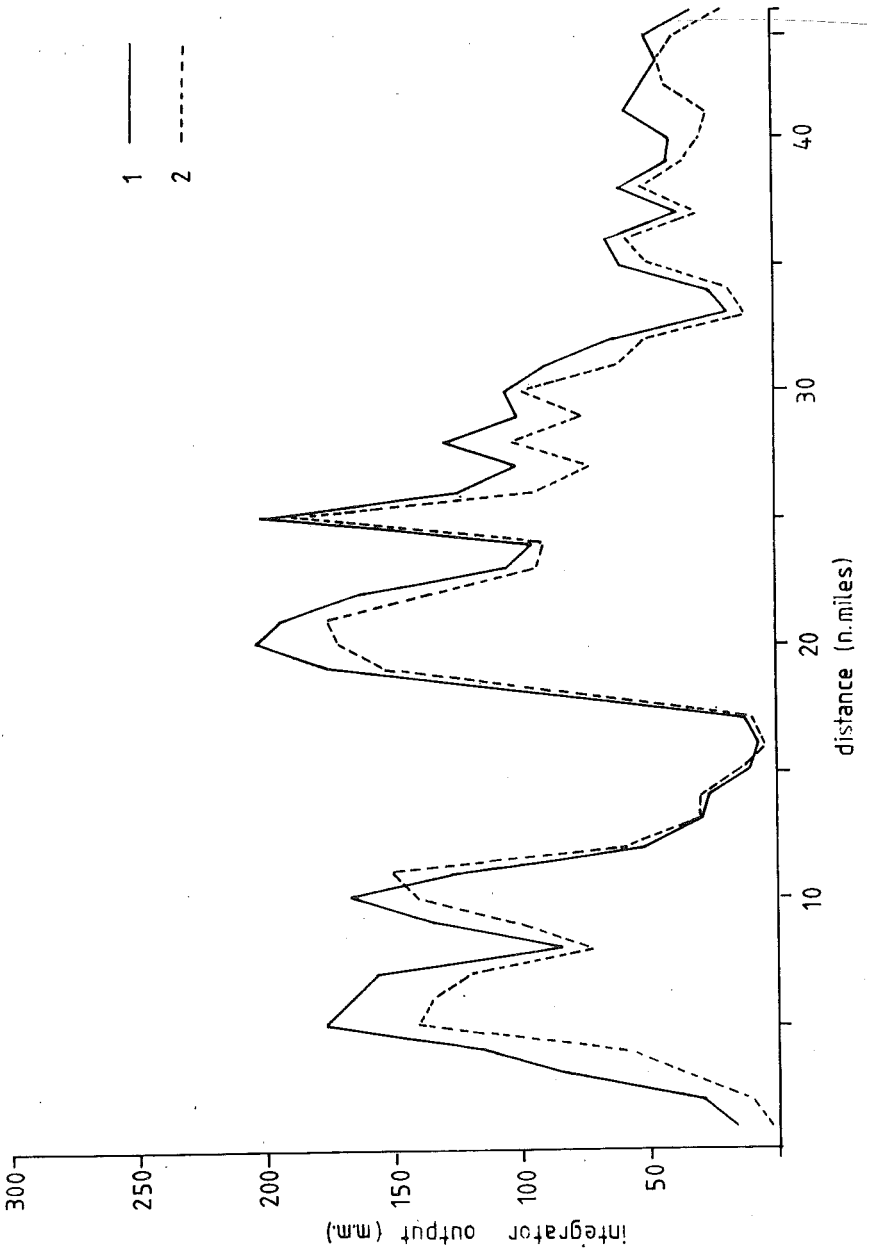

Figure 1. Intercalibration, 4 August 1979.
1) R/V "G.O. Sars" 2) R/V "Bjarni Sæmundsson".
Integrator deflection values versus sailed distance.

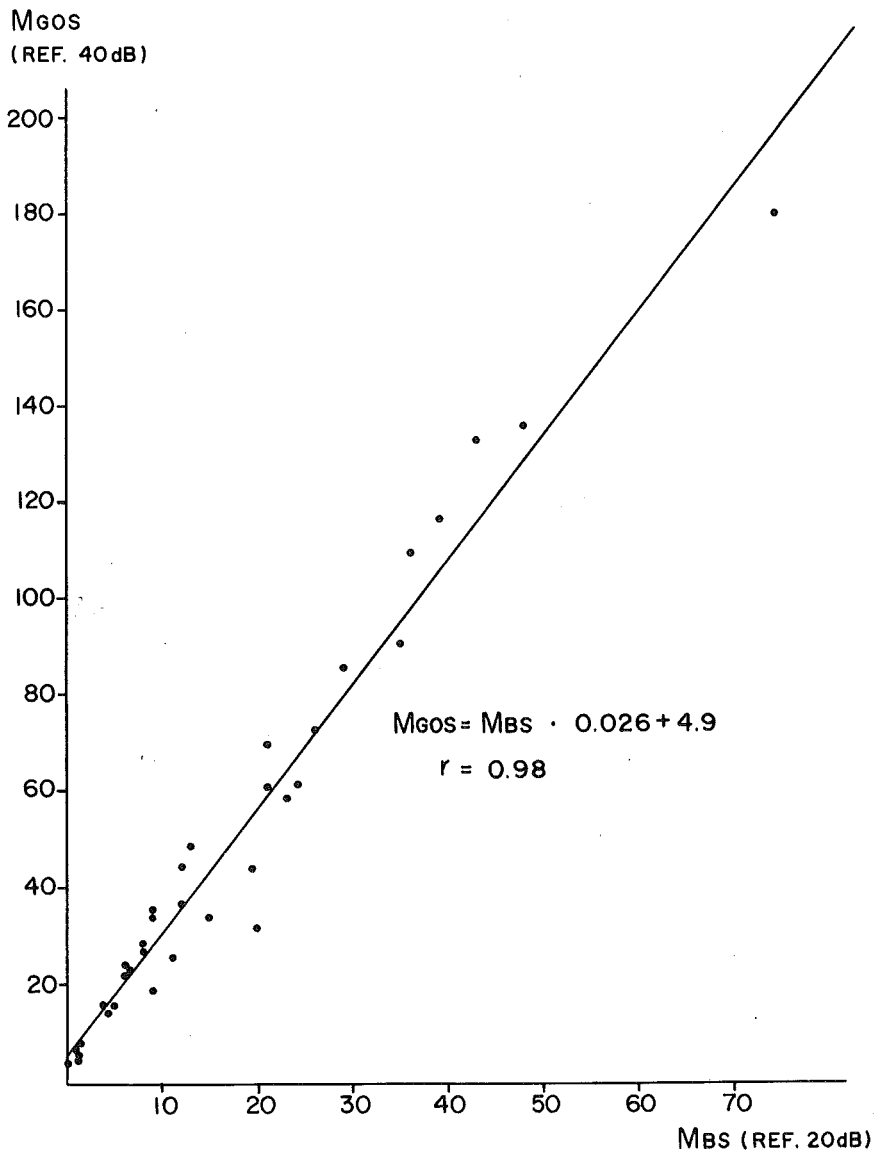

Figure 2. Intercalibration, October 1981.
Linear regression of integrator values.

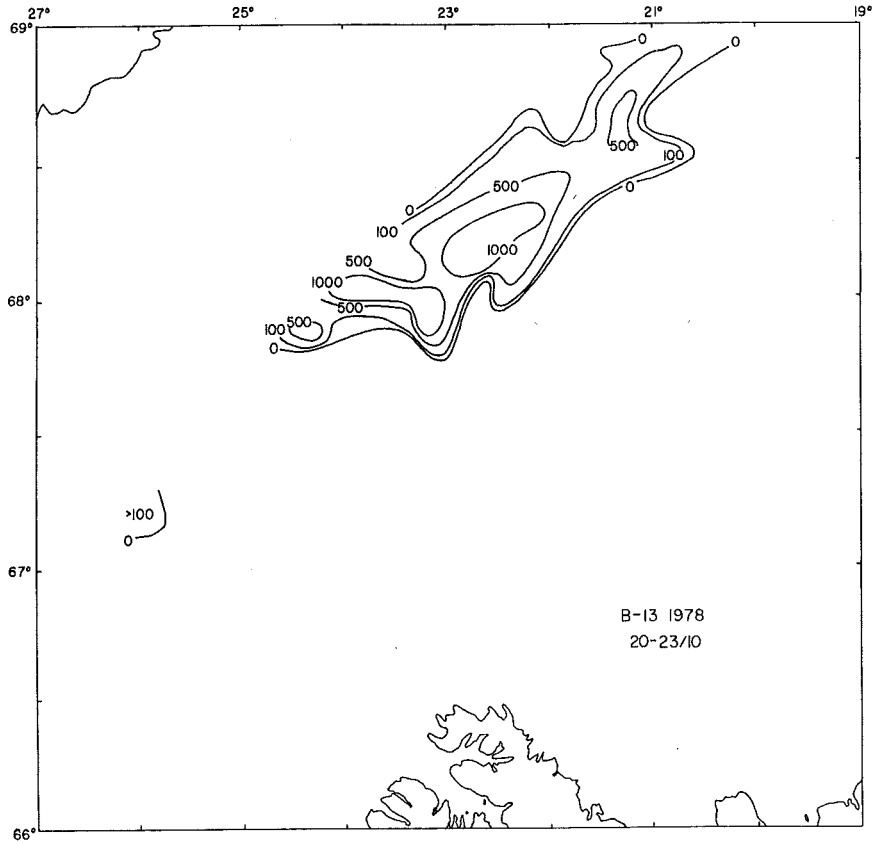

Figure 3. Distribution of echo abundance of capelin. NW-Iceland, 20-23 October 1978.

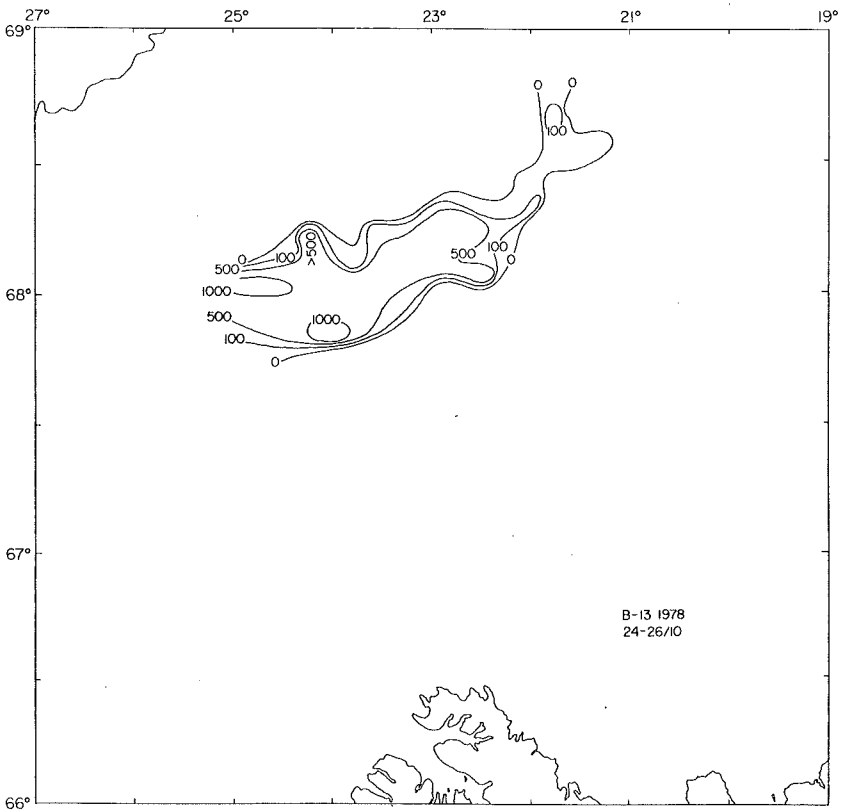

Figure 4. Distribution of echo abundance of capelin. NW-Iceland, 24-26 October 1978.

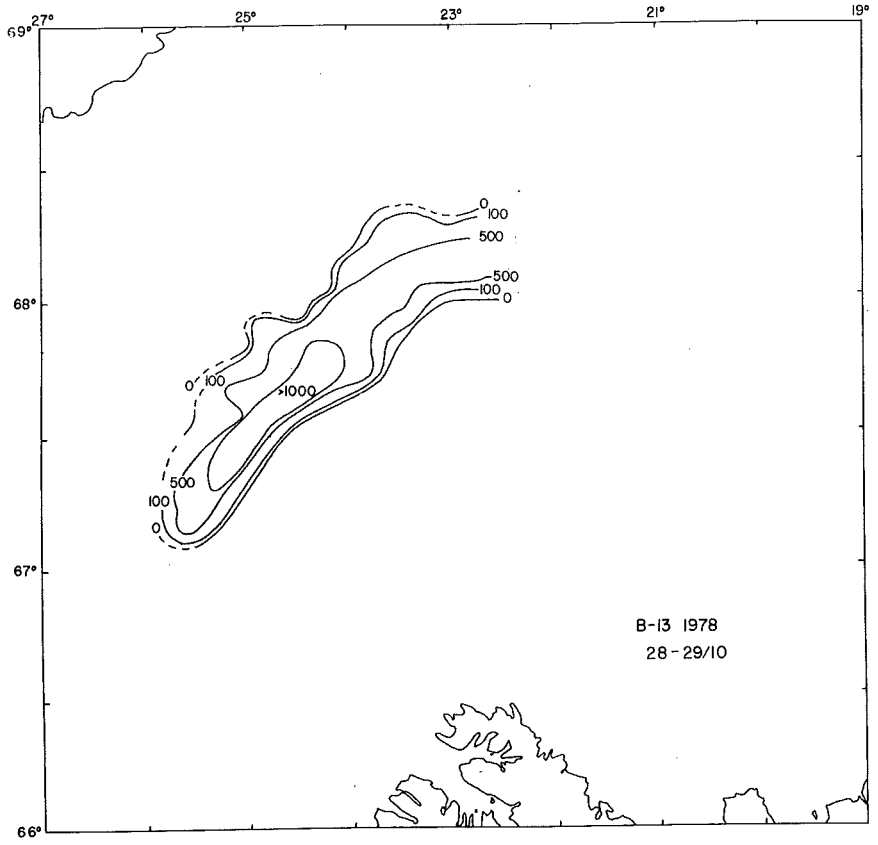

Figure 5. Distribution of echo abundance of capelin. NW-Iceland, 28-29 October 1978.

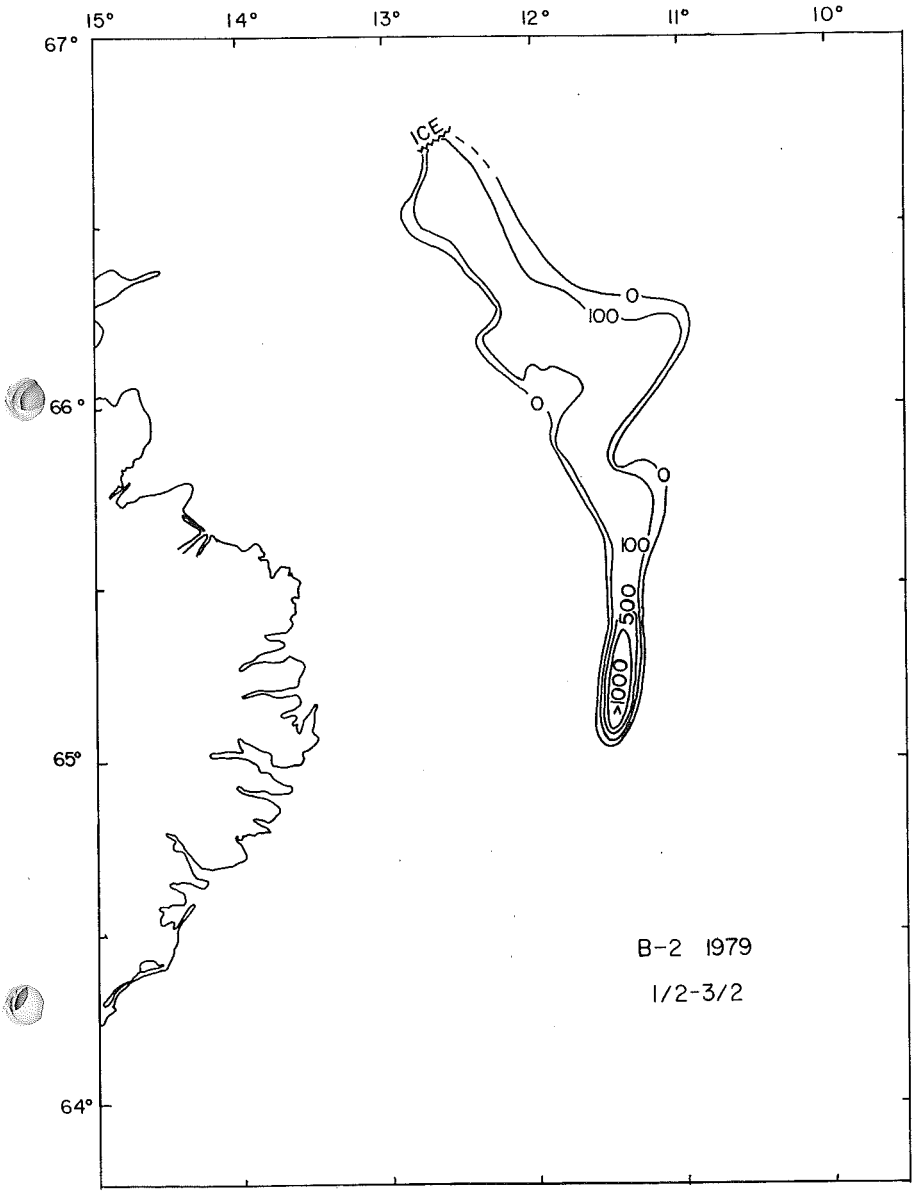

Figure 6. Distribution of echo abundance of capelin. E-Iceland, 1-3 February 1979.

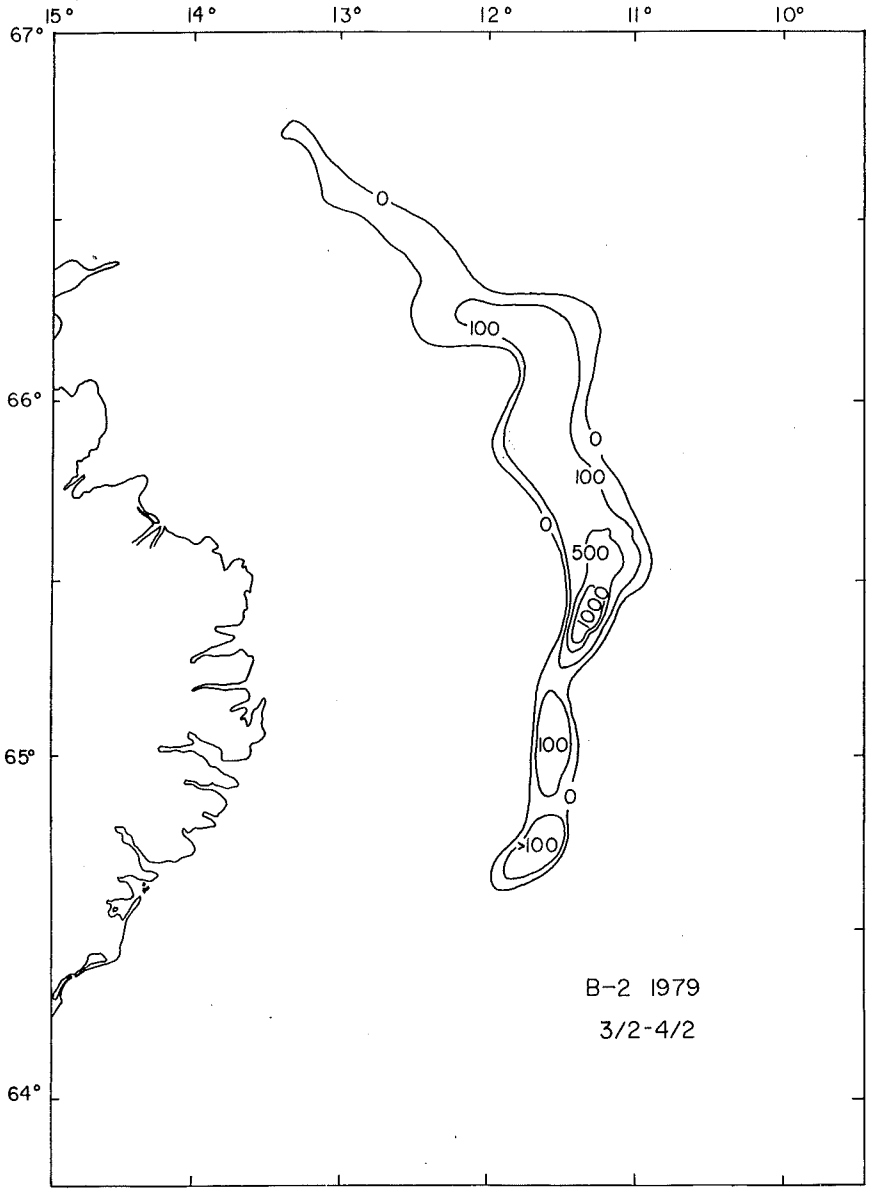

Figure 7. Distribution of echo abundance of capelin. E-Iceland, 3-4 February 1979.

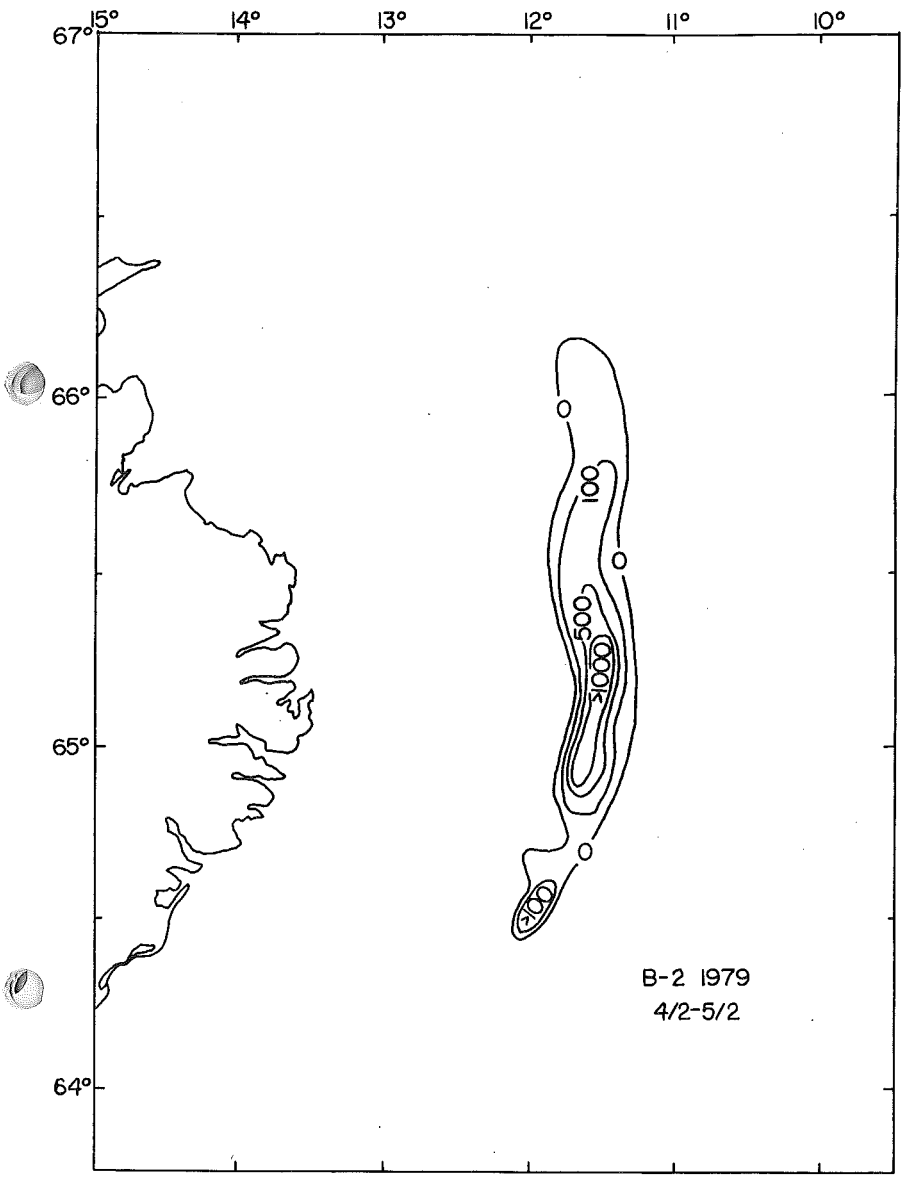

Figure 8. Distribution of echo abundance of capelin. E-Iceland, 4-5 February 1979.

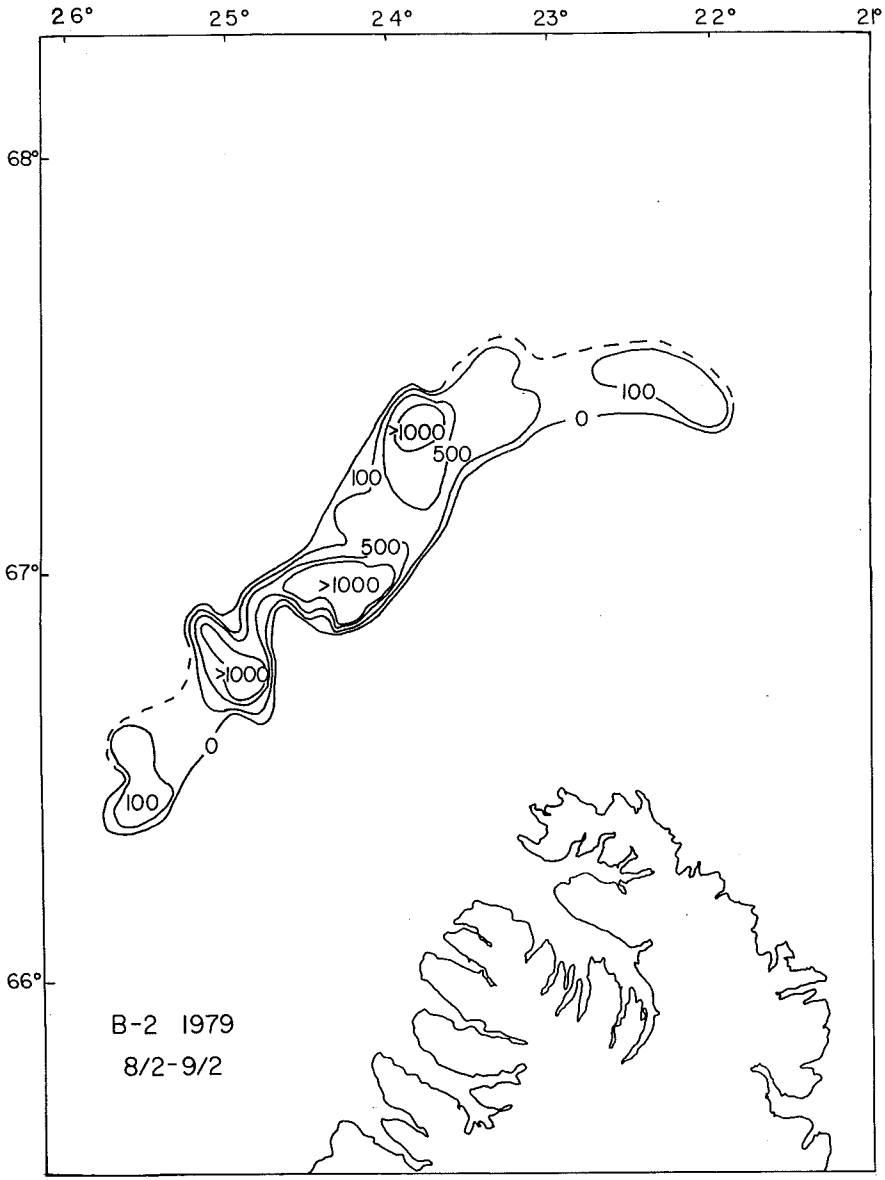

Figure 9. Distribution of echo abundance of capelin. NW-Iceland, 8-9 February 1979.

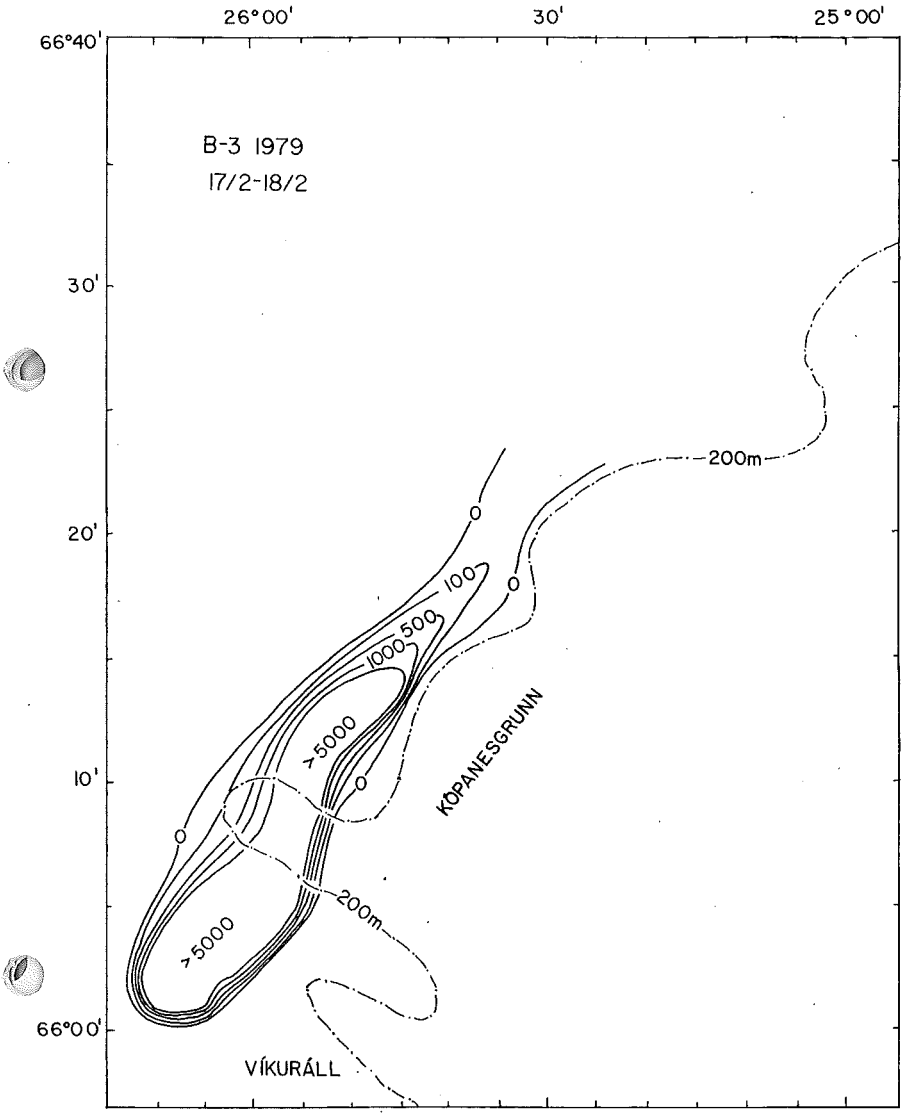

Figure 10. Distribution of echo abundance of capelin. NW-Iceland, 17-18 February 1979.

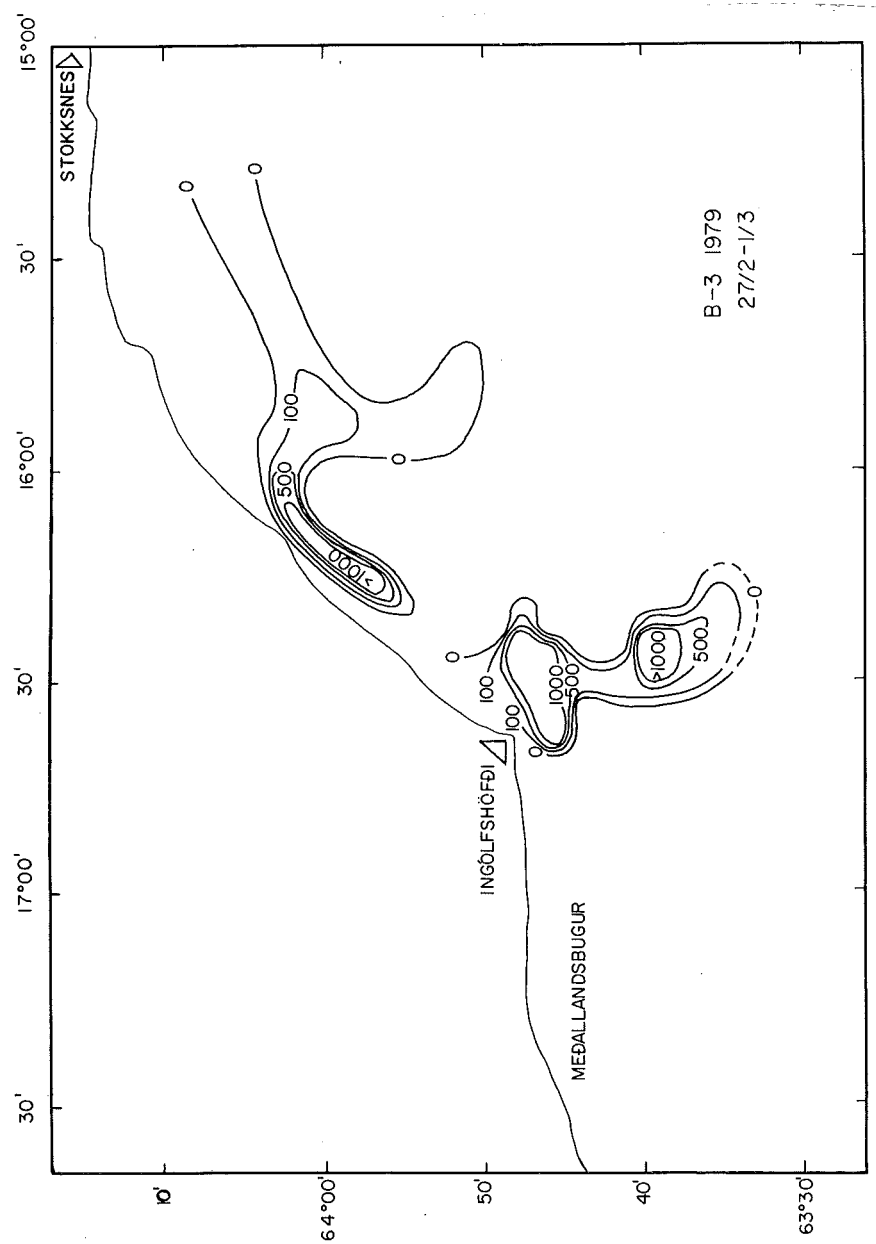

Figure 11. Distribution of echo abundance of capelin.
27 February - 1 March 1979.

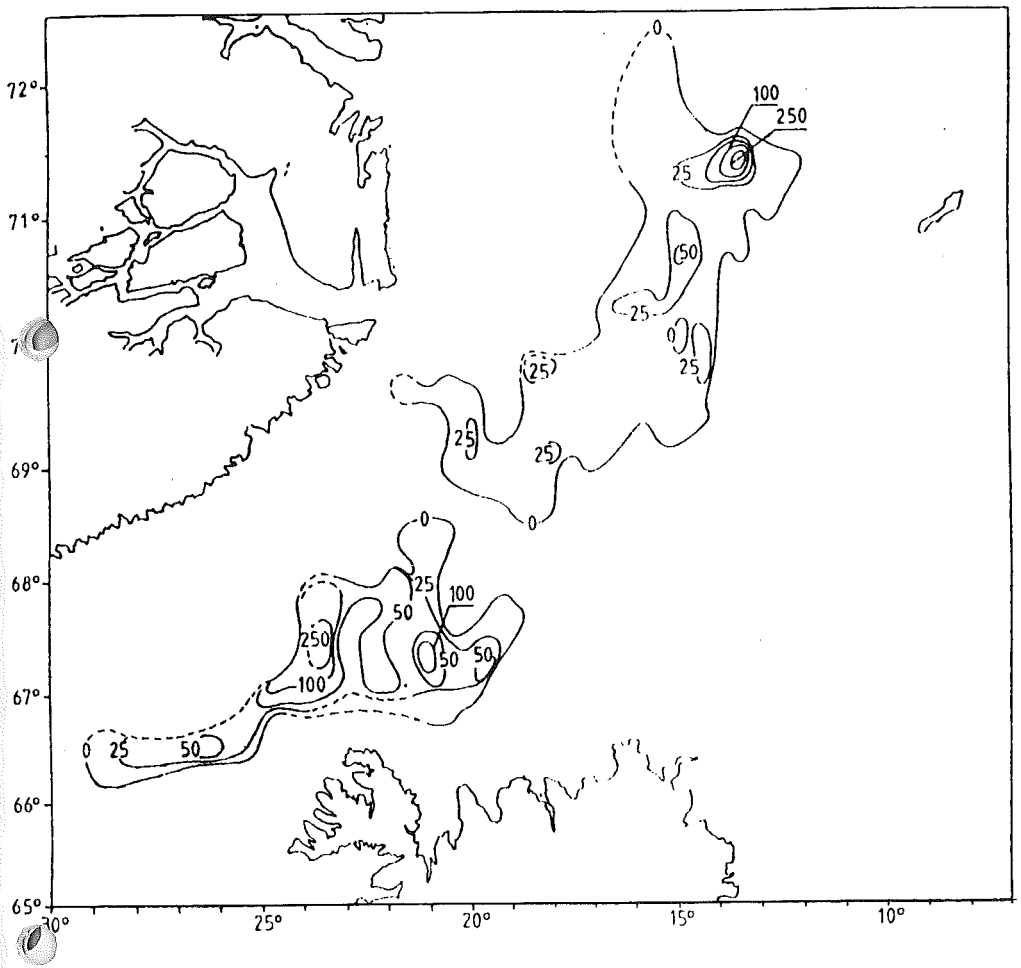

Figure 12. Distribution of echo abundance of capelin.
27 July - 12 August 1979.

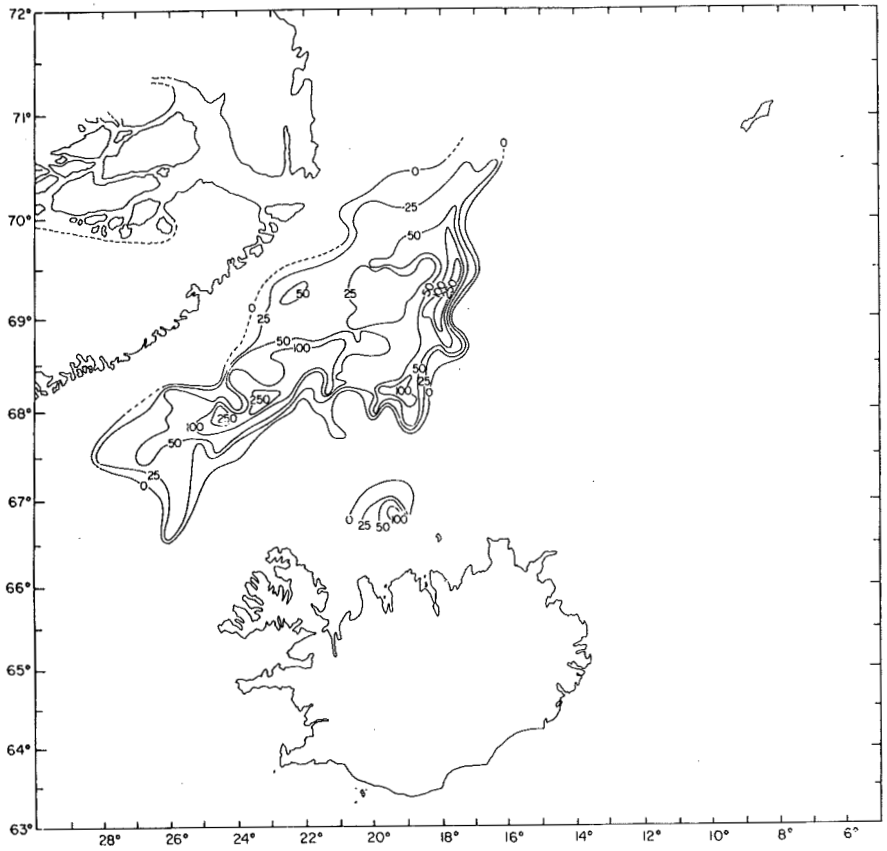

Figure 13. Distribution of echo abundance of capelin.
25 September - 5 October 1979.

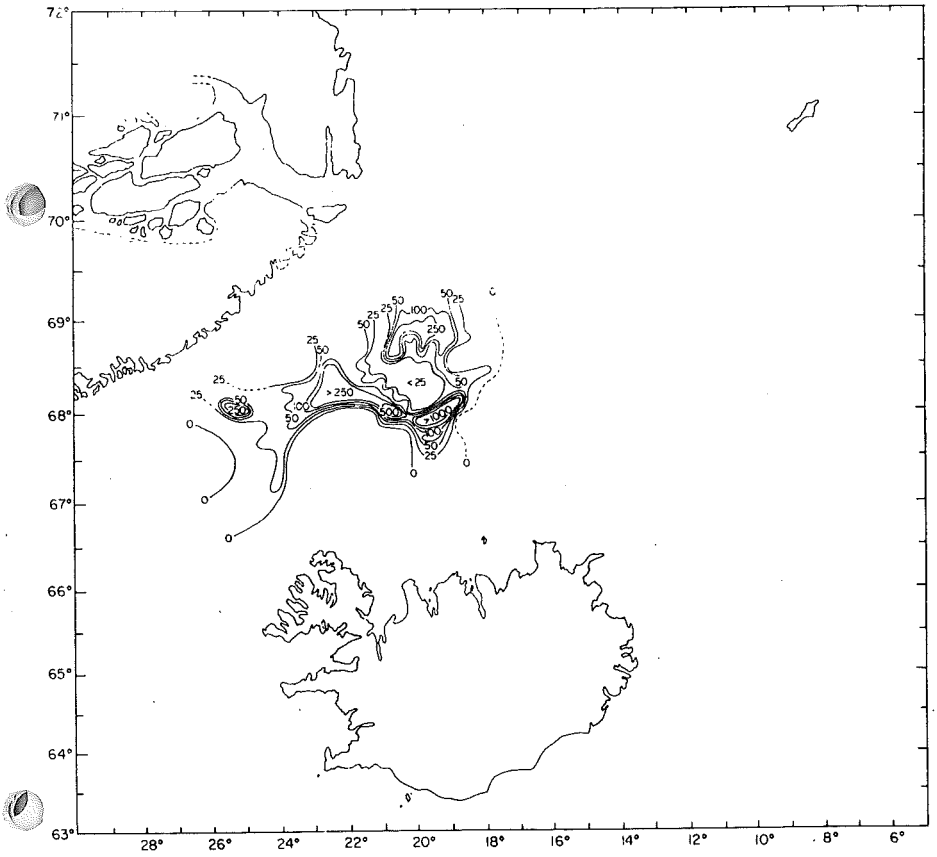

Figure 14. Distribution of echo abundance of capelin. 14-26 October 1979.

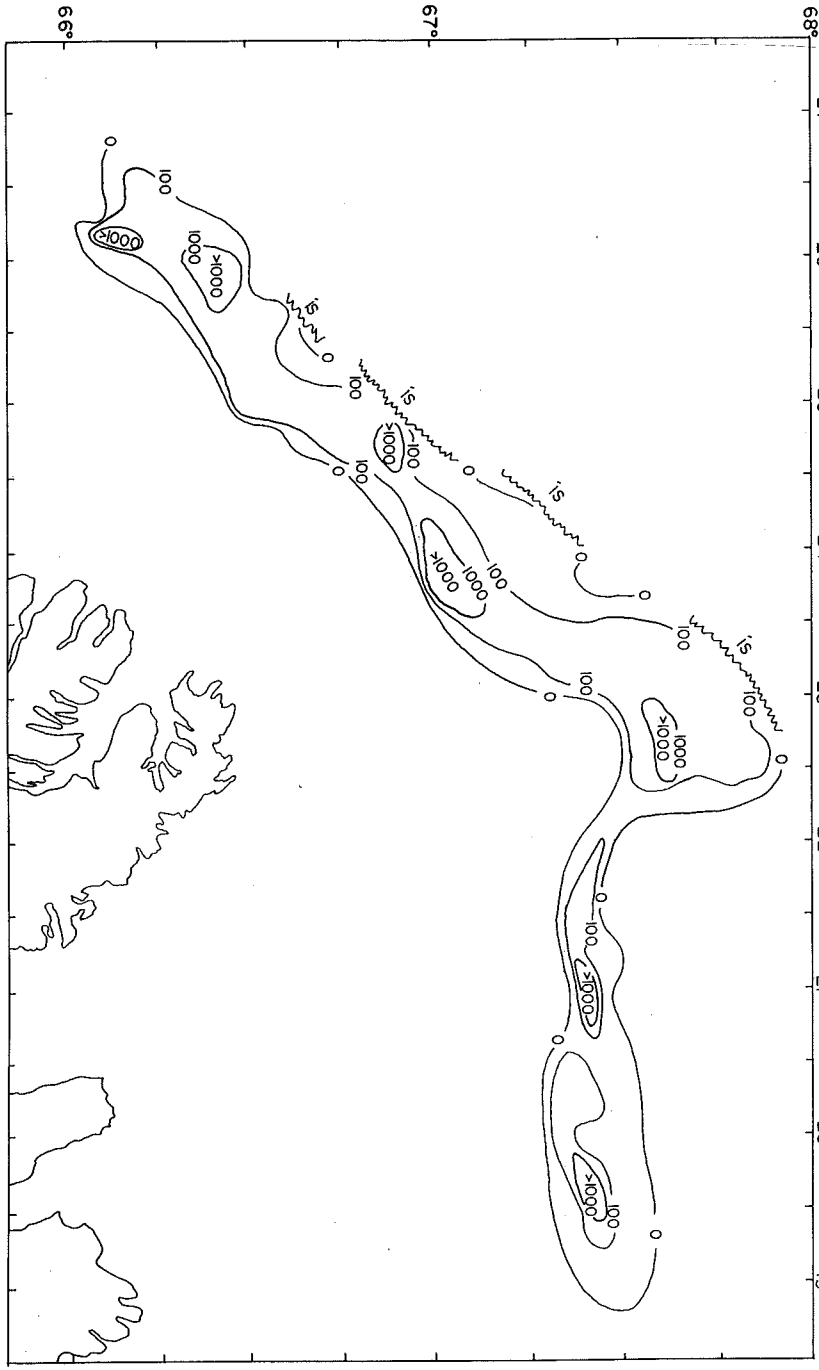

Figure 15. Distribution of echo abundance of capelin.
25-28 January 1980.

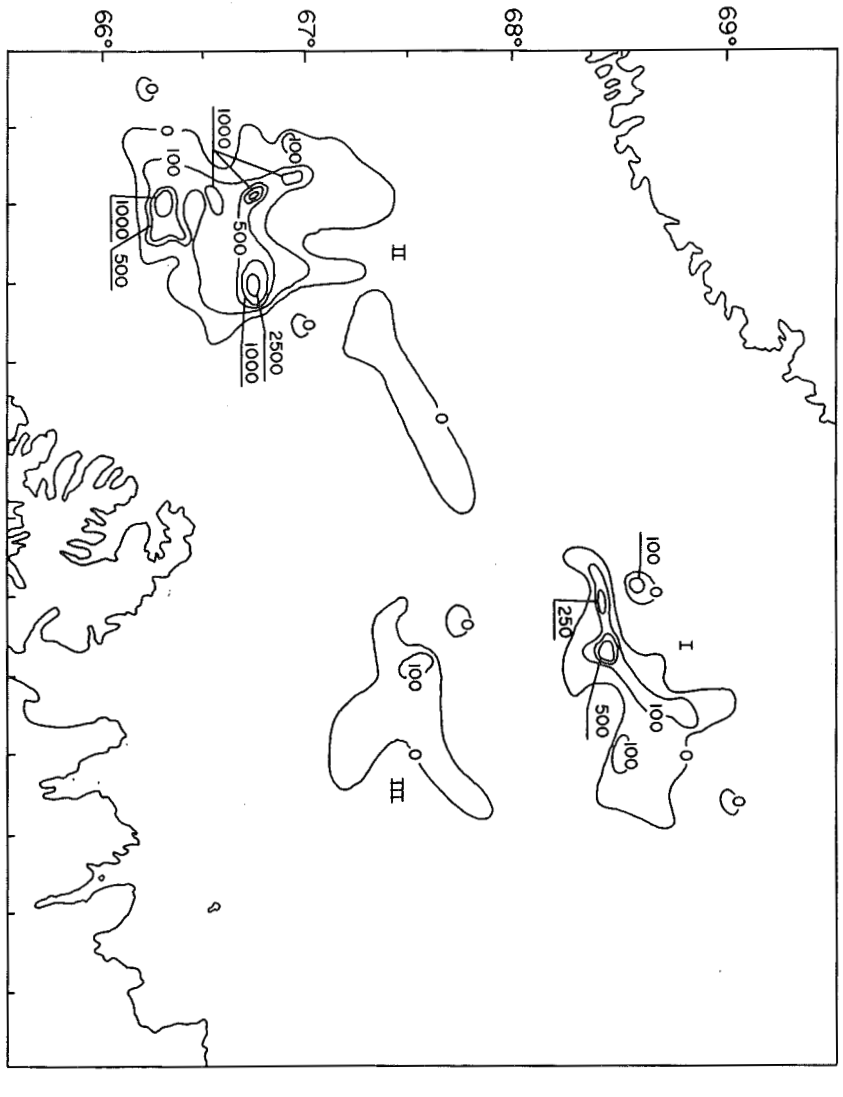

Figure 16. Distribution of echo abundance of capelin.
11-22 October 1980.

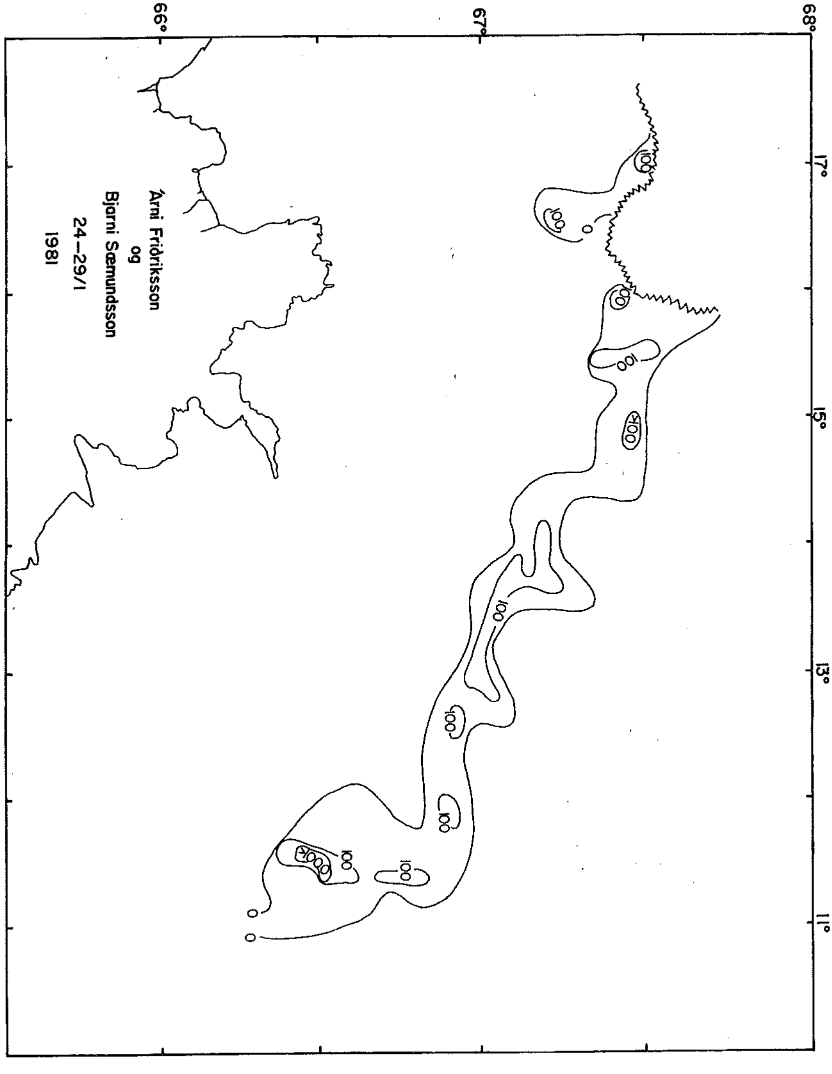

Figure 17. Distribution of echo abundance of capelin.
24-29 January 1981.

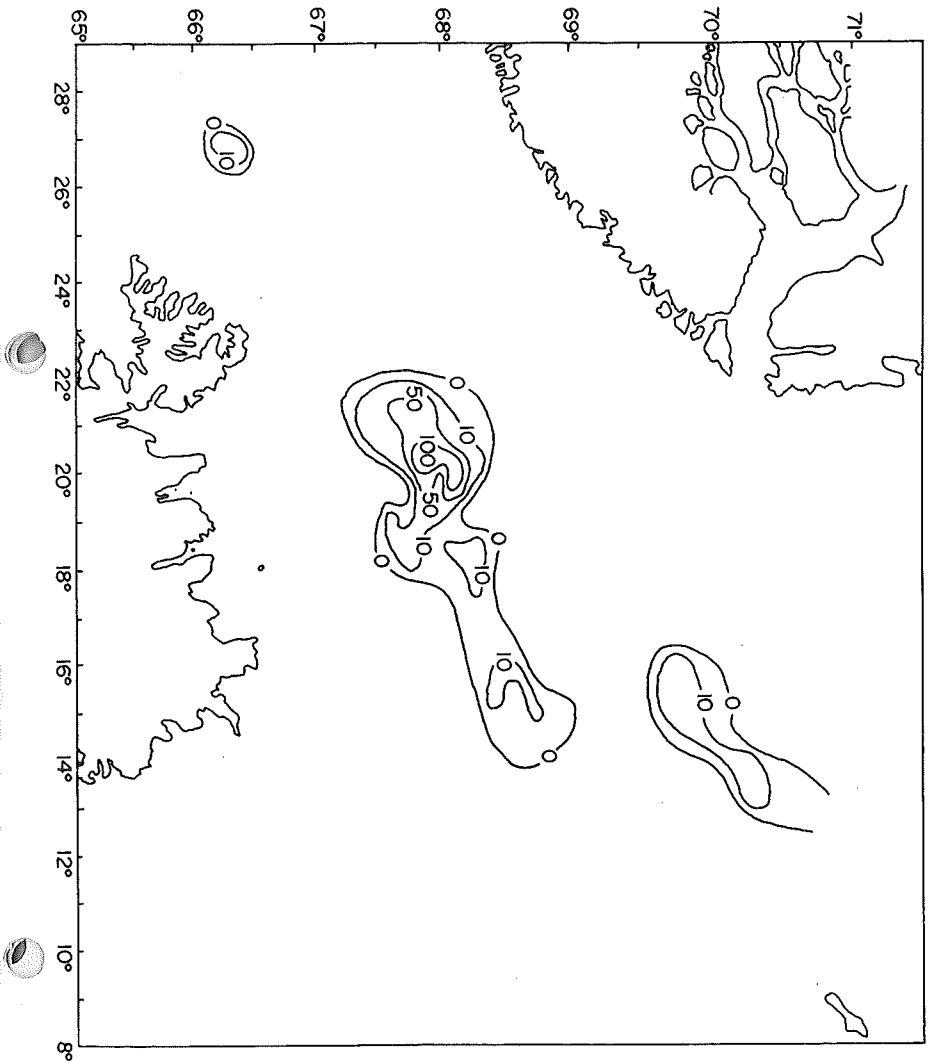

Figure 18. Distribution of echo abundance of capelin.
14-23 October 1981.

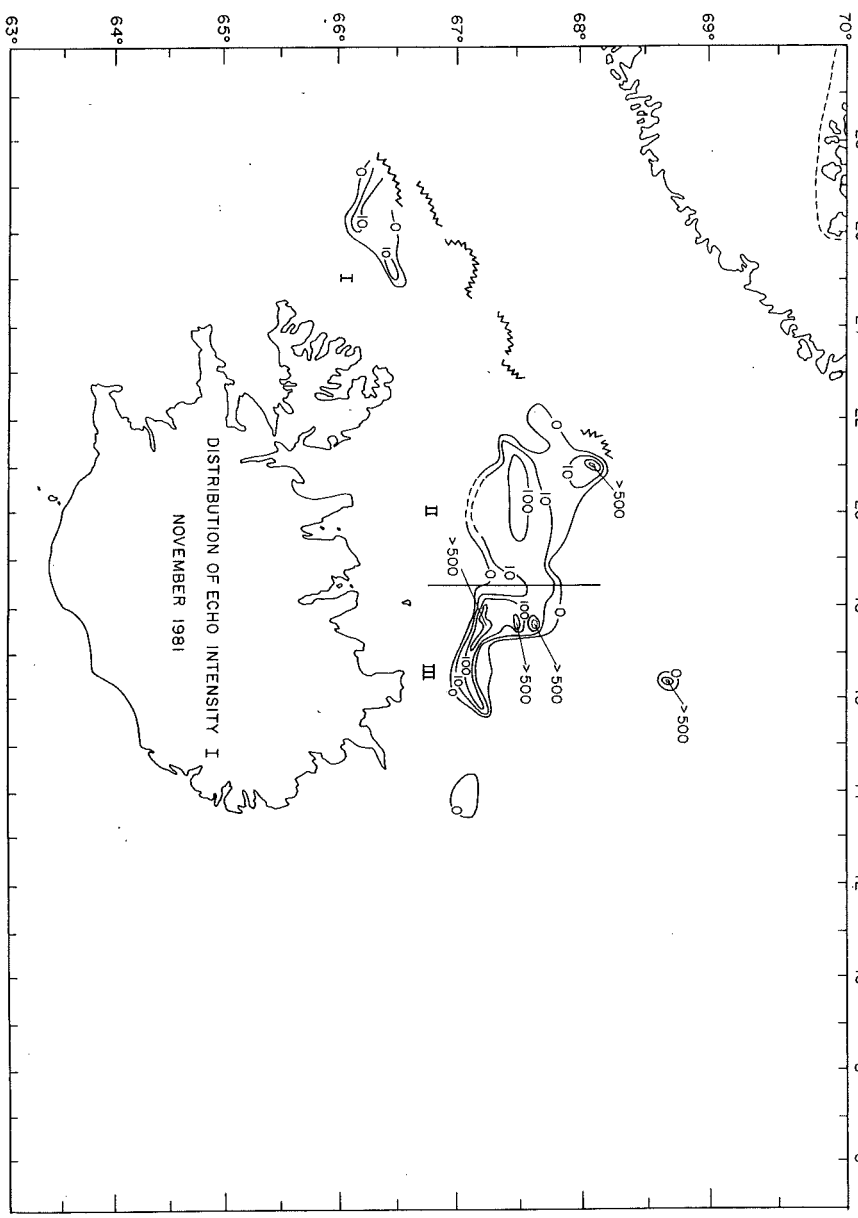

Figure 19. Distribution of echo abundance of capelin.
3-13 November 1981.

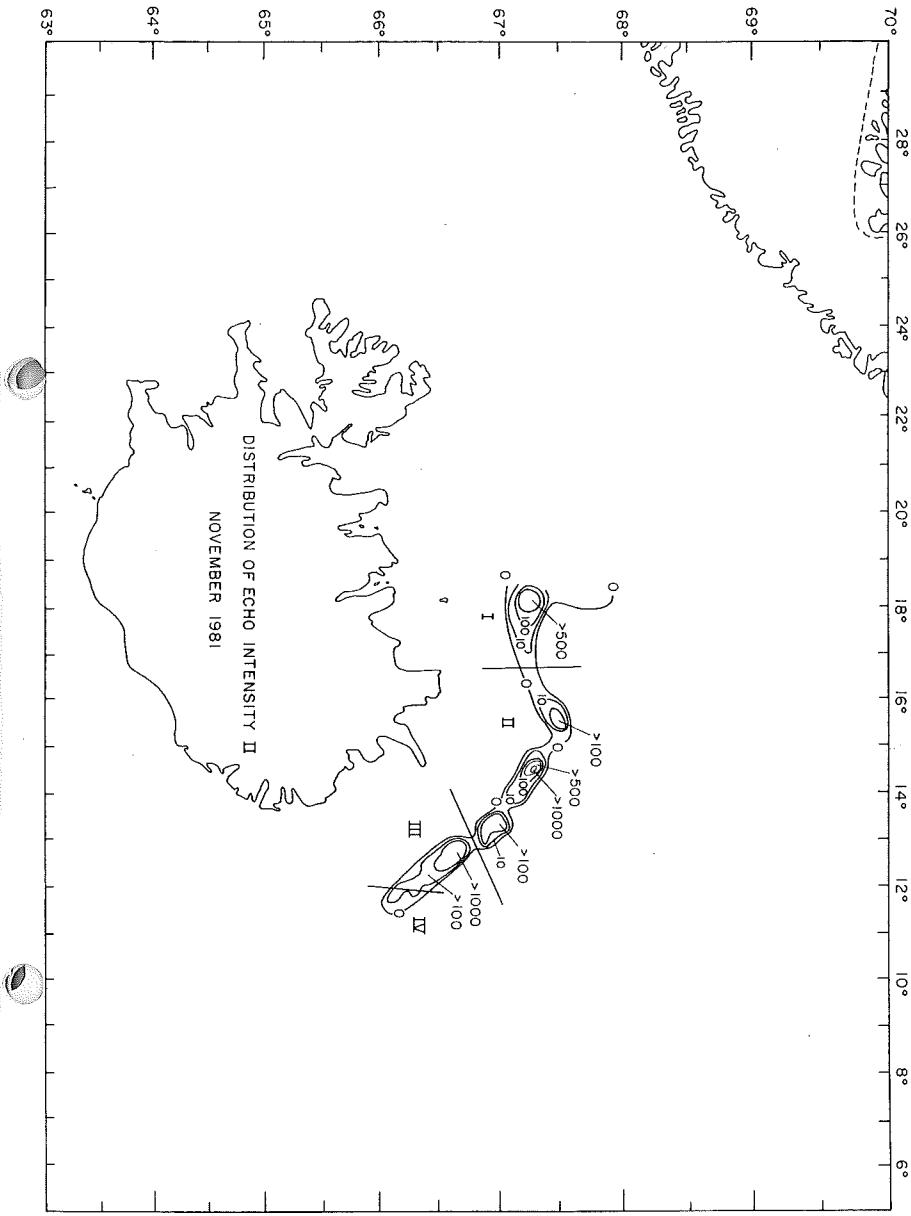

Figure 20. Distribution of echo abundance of capelin. 26-30 November 1981.

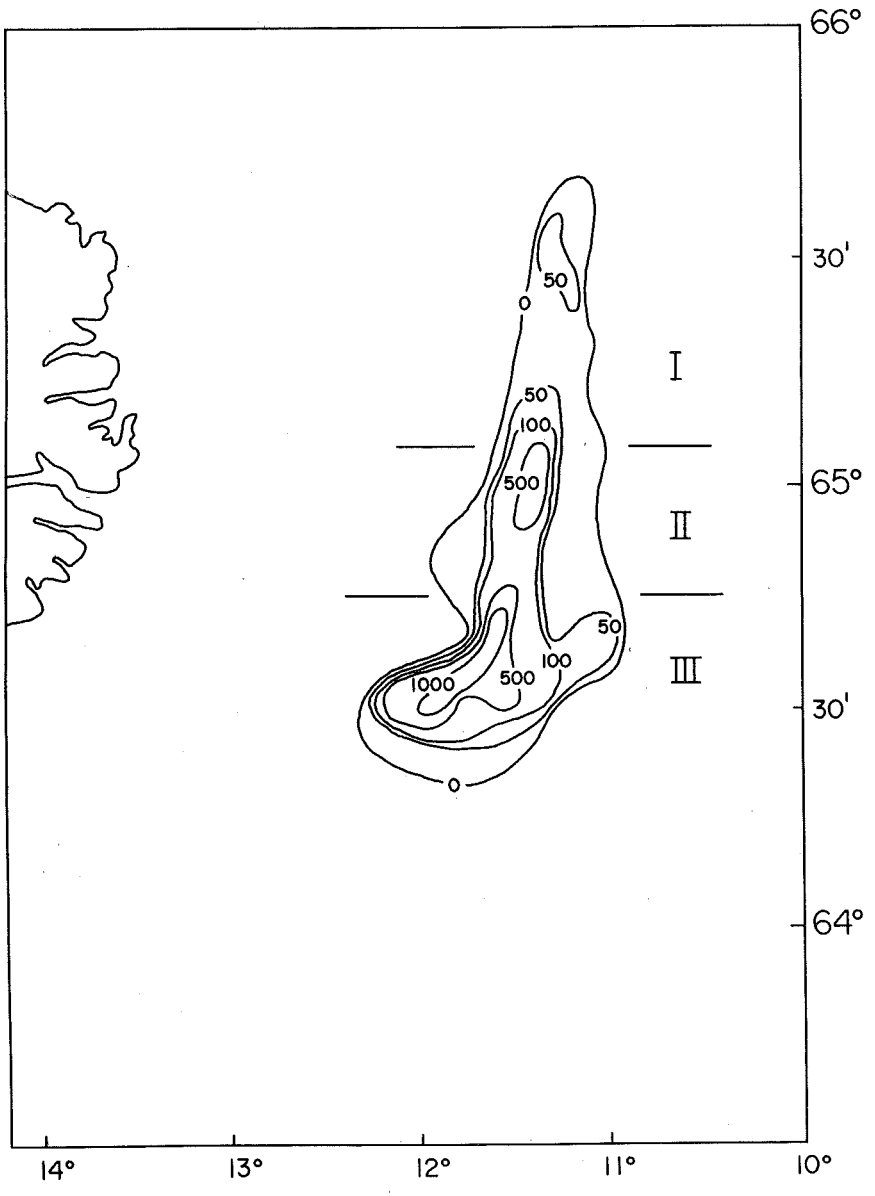

Figure 21. Distribution of echo abundance of capelin.
20-22 January 1982.

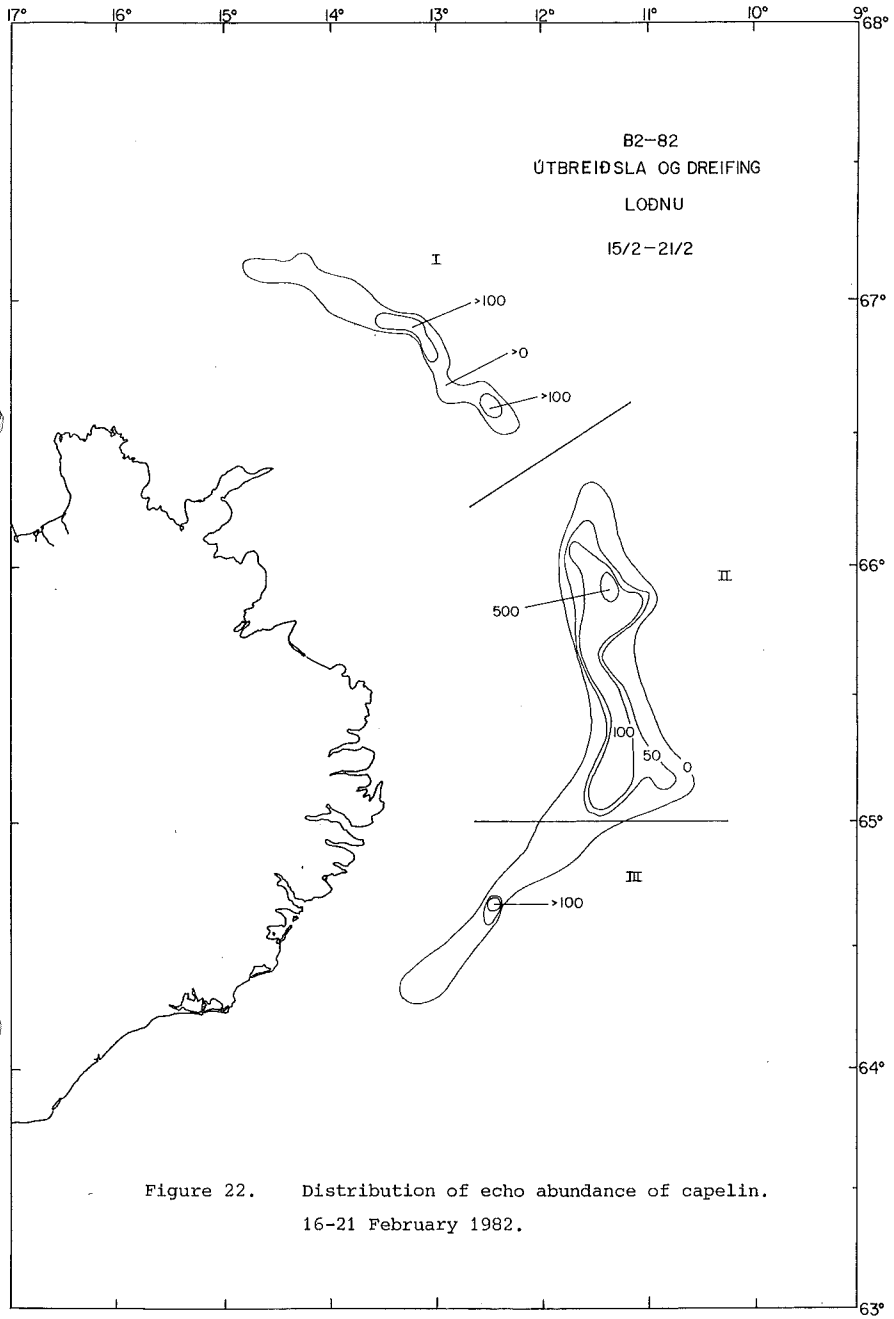

Figure 22. Distribution of echo abundance of capelin. 16-21 February 1982.

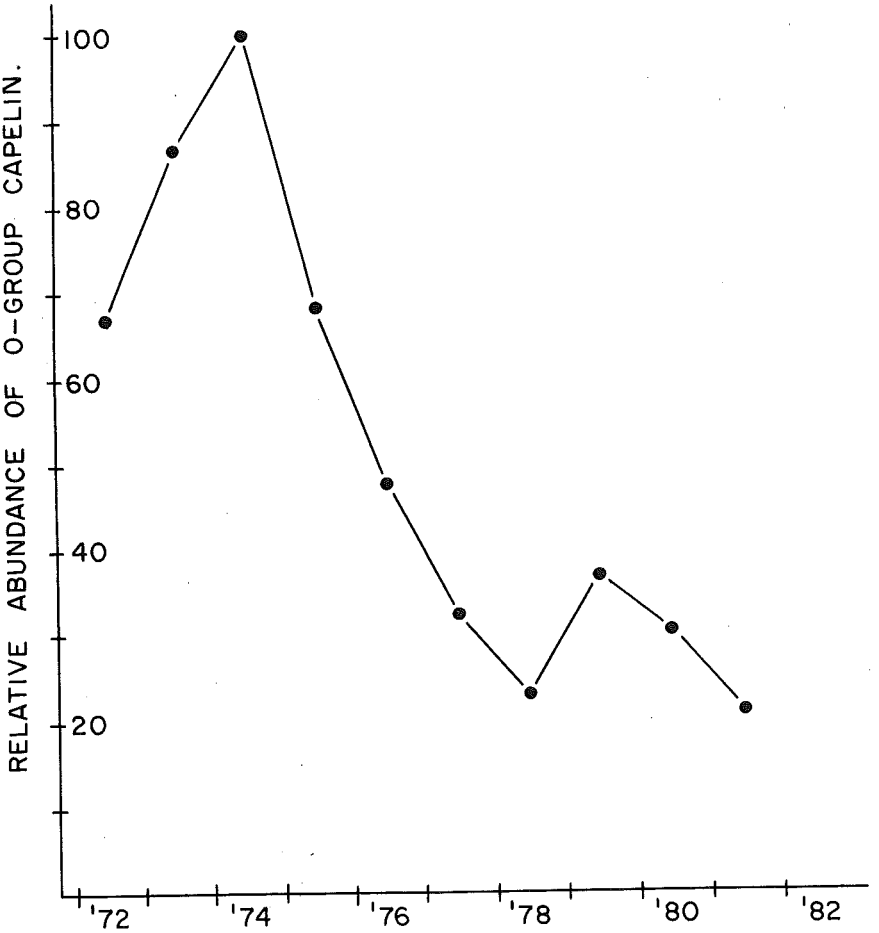

Figure 23. O-group indices, August 1972-1982.

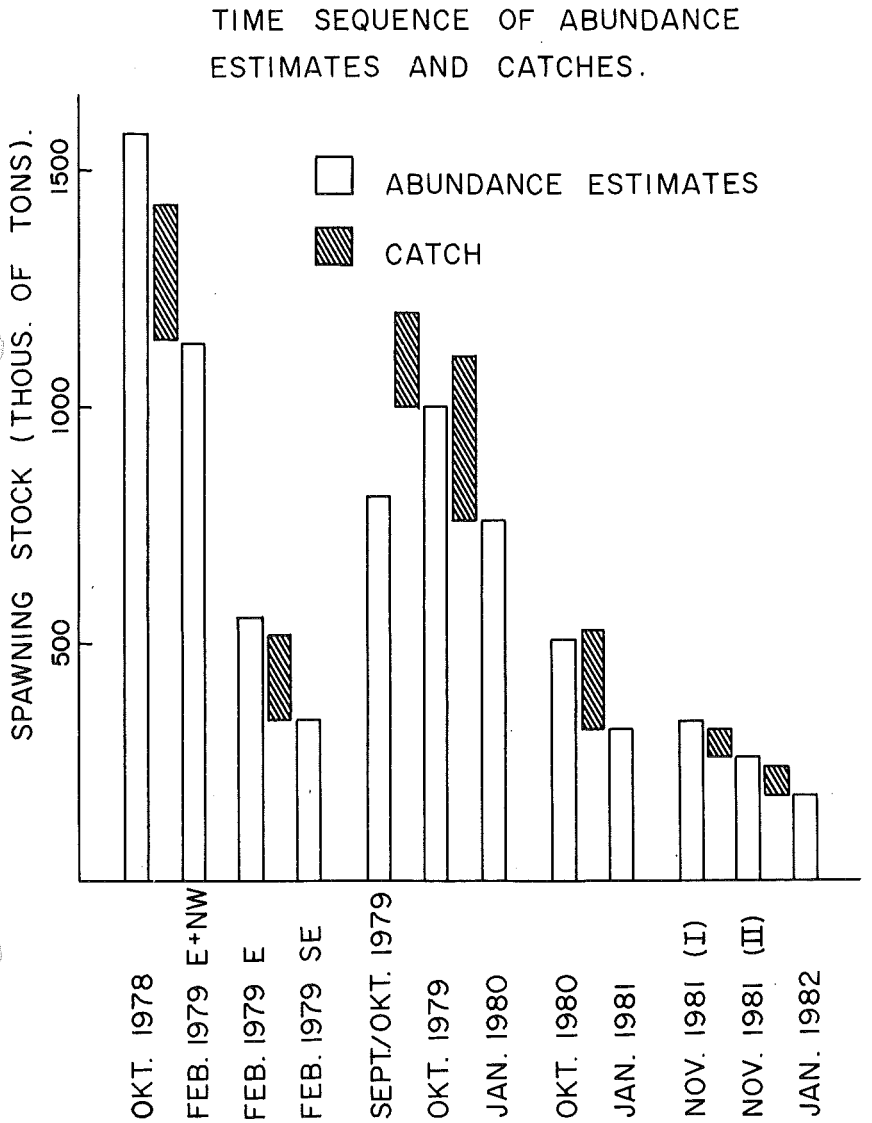

Figure 24. Successive acoustic abundance estimates of the Icelandic capelin stock and the catch during the intervening periods, October 1978 - January 1982.

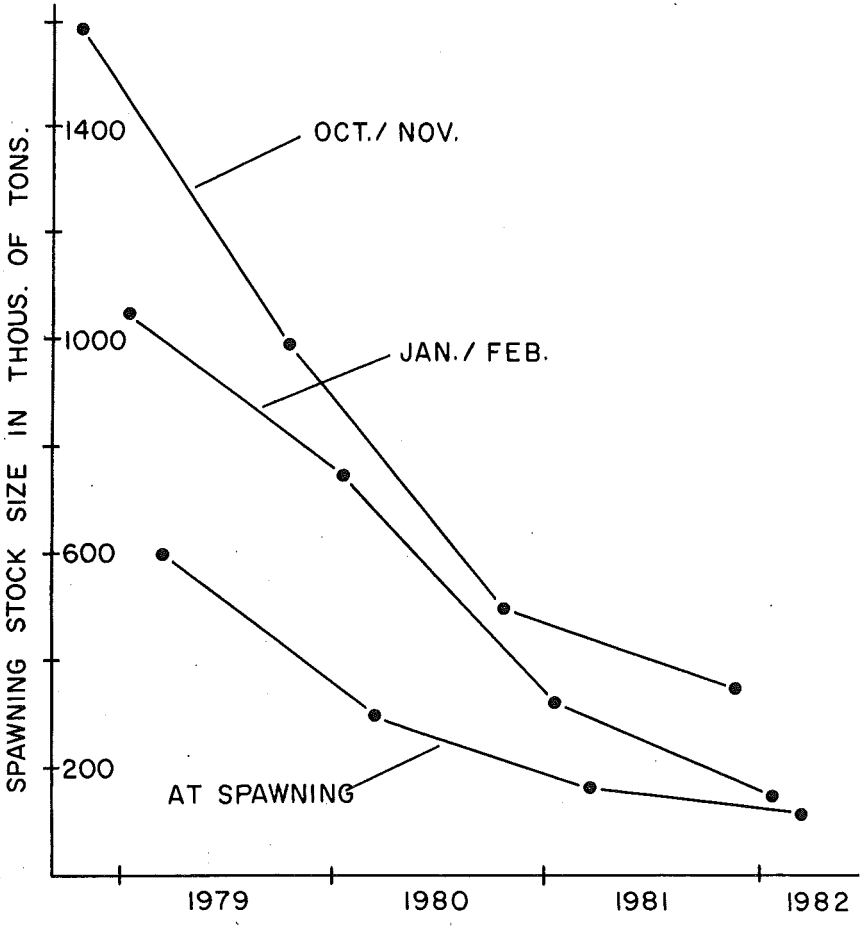

Figure 25. The decline in the abundance of the spawning stock of the Icelandic capelin 1979-1982, as estimated by the acoustic method.

Table 13

Echo stock by number and weight by yearclasses (N x 10^{-9}, W x 10^{-3} tons). 3-30 November 1981.

	1978		1979		Total 1978-79		1980	
Yearclass	N	W	N	W	N	W	N	W
Survey I	0.3	7.5	18.1	334.7	18.4	342.2	2.7	13.8
Survey II	0.8	17.5	17.5	328.3	20.7	388.3	21.2	76.7
Average	0.6	12.6	17.8	331.5	19.6	365.3		

Table 14

Echo stock by number and weight by yearclasses (N x 10^{-9}, W x 10^{-3} tons). 11-22 January 1982.

	1978		1979		Total		1980	
Yearclass	N	W	N	W	N	W	N	W
Survey IV	0.5	12.7	8.4	154.2	8.9	166.9	1.6	10.5

Table 15

Echo stock by number and weight by yearclasses (N x 10^{-9}, W x 10^{-3} tons). Feb. 1982.

	1978		1979		Total		1980	
Yearclass	N	W	N	W	N	W	N	W
	0.2	2.5	6.4	90.7	6.6	93.2	2.3	16.4