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Monitoring the Recovery of the Icelandic Summer Spawning Herring

by

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1. Introduction

During the last decade or so herring biologists have recommended fishing ban for the majority of herring stocks in the North Atlantic. Having successfully fought for this drastic management action they have been faced with the problem of assessing the state of these stocks without any fisheries data and during a period when they have either been in a depleted state or recovering. This problem has been tackled in several ways by the scientists concerned. Thus the state of the North Sea herring is primarily assessed on the basis of the International Larval Surveys and the International Trawl Surveys for I-group Fish. The state of the Atlanto Scandian herring is on the other hand assessed on the basis of the results of large scale tagging experiments and experimental fishing on the spawning grounds using a tag detector.

A third method, echo integration, has been used to monitor the state of the Icelandic summer spawning herring. The purpose of this paper is to describe the results of the echo integration carried out on the wintering grounds of this stock in Nov.- Dec. 1973-1979.

2. Material and Methods

Throughout the period 1972-1979 the same research vessel, the "Árni Friðriksson" has been used. She is equipped with Simrad scientific EK echo sounders and integrators.

The physical calibration of the instruments has been carried out using hydrophones just prior and sometimes also immediately after the surveys. Hull mounted transducers have been used throughout the surveys.

The timing of an echo abundance survey is of course very critical. In this case it was decided in 1972 to investigate the feasibility of carrying out such a survey on the wintering grounds in November-December as described in the following section. The choice of survey period was based on the results of extensive echo-surveys from earlier years. These had indicated that during November-December the stock assembled in a limited and well defined area where a detailed survey could be carried out with relatively small survey effort. In recent years the feasibility of carrying out an echo-abundance survey has been studied at other times of the year, e.g. in October and January-February, without positive results and therefore the first choice is still considered the best one.

For management purposes November-December is also a convenient period because the survey results are obtained soon after the short fishing season thus giving ample time to prepare management actions for the next one.

Despite the fact that the surveys have been carried out at the same time of the year it should be noted that the actual survey tactics had to be changed to some extend from year to year according to variations in the behaviour pattern of the herring on the wintering grounds as will be described in the following section.

The 1972-1979 echo surveys

The ban on herring fishing at Iceland started on 1. February 1972 and the first echo surveys to monitor the state of the stock were carried out in the late autumn of that year.

Judging by information from various sources such as fishing vessels and from research vessel surveys it was decided to concentrate the survey effort at south east Iceland. In this area a few wintering concentrations were located during 29 November - 2 December. The largest and most dense (Fig. 1) was about 50 x 10^6 m^3 and in all it was estimated that the total volume of these herring concentrations were in the order of 200 x 10^6 m^3. Sampling of the shoals using midwater trawl showed that they consisted mainly of the 1969 and 1970 yearclass (1 and 2 ringers) in equal proportions.

No integrator values were obtained in 1972 but assuming that there were 1 herring per cubic meter in the concentrations it was suggested (Jakobsson 1973) that the abundance of these two yearclasses was in the order of 100 x 10^6 herring as 1 and 2 ringers resp. The yearclasses are now estimated from VPA to have been 78 and 62 x 10^6 herring (Table 5).

In November-December 1973 herring concentrations mainly consisting of these two yearclasses were located in inshore waters at the eastern south coast (Fig. 2). At night these concentrations were indeed very close to the sandy beach where the bottom depth was less than 20 m. They were in fact so close to the shore that the ship could not be taken close enough to delimit the inner edge of the school. During daylight these concentrations moved to deeper waters for a brief period (Jakobsson, 1975-1976). An echo integrator survey was not carried out but the concentrations appeared to be in the order of 4 sq n.m. and the volume occupied by the concentrations was very similar to that observed in 1972 or just over 200 x 10^6 m^3.

In addition to these inshore concentrations a patch of 1 ringed herring was located some 10-20 n.m. off the coast. It was quite obvious from the echo recordings that the density of herring in this "off shore" area was much lower than in the near shore area.

Sampling, using a midwater capelin trawl, showed that the herring in this area all belonged to the 1971 yearclass (Table 1) The average weight of these herring was 83 g and the mean length was 21.1 cm.

This herring area was closely studied for six days before an integrator survey was successfully carried out during the late evening of 26 November and the early hours of the next day. During this six hour period the herring patch was at an even depth from 15-40 m over a bottom depth of about 100-150 m. The patch was practically continuous over an area of 19.2 sq. n.m. and a cross section taken immediately after the integration was finished, showed that the herring were still in the same area. It is of course of vital importance to check this because one might otherwise be grossly mislead if the herring had moved during the few hours of the integrator survey.

It should be noted that considerable effort was spent surveying the neighouring coastal and off-shore areas without locating any additional herring concentrations as shown on Fig. 2.

In 1974 herring surveying at the south coast was carried out from 14 November to 2 December. Despite considerable survey effort only one herring school was located. This school kept so close to the beach at night that proper coverage of the area was very difficult. After some studies on diurnal behaviour of the herring it became apparent that the most appropriate survey time would be just before dawn when the herring were beginning to migrate very slowly from the beach. Thus, on the 27 November an integrator survey was carried out from 0630-0830 hrs. and finished just before dawn. Immediately thereafter the school broke up and settled on the bottom (Fig 3). The area of this school or herring concentration was 9.5 sq n.m. and the mean vertical extention was 13.1 m. Sampling by midwater trawl showed that the 1971 yearclass predominated although older yearclasses were also present (Table 1).

In 1975 the herring survey took place from 27 November - 6 December and the wintering school was located in very much the same area as in 1974. The diurnal behaviour of the herring was also similar to that of the previous year and therefore similar survey tactics were adopted. Thus on 2 December an integrator survey was carried out just before dawn (0700-0900 hours) and immediately afterwards 4 samples were taken by mid-water trawl. The samples were evenly distributed along the length school and approximately 3 n.m. apart. Tha age distribution (Table 1) was predominated by the 1971 and 1973 year-classes i.e. 3- and 1 ringers.

In 1976 the herring surrveying at the south coast was carried out from 2-17 December. The wintering school (Fig 4) was located in the same area as in 1974 and 1975. The behaviour of the herring was also similar and the survey tactics therefore remained unchanged. Thus after a few attempts an integrator survey was carried out on 15 December using a close Zig-Zag grid as shown on Fig 4. The school was then about 1-2 n.m. off the beach where the water depth was about 20-60 m. The age distribution in 1976 (6 samples taken by pelagic trawl) was as in 1975 predominated by the 1971 and 1973 yearclasses but the 1974 yearclass was also well represented (Table 1). Intensive searching for herring in the neighbouring areas revealed that 1-group herring (1974 yearclass) was distributed over most of Öræfagrunn (Öræfabank) 12-20 n.m. off the coast. At night the herring were recorded as a very thin layer (about 1-2 m) on the bottom but during the day this "layer" of herring was practically indistiquishable from the bottom echo. No integrator survey was attempted but the area of distribution was at least 50 sq n.m..

In 1977 the herring integrator survey at the south coast took place from 6-16 December. As described above, the wintering school had in 1974-1976 been located in the same area each year i.e. close to the eastern south coast just west of 16°W. The school had been approcimately 12 n.m. long and about 3/4 n.m. wide. However in 1977 only a "small school (7 x 1/2 n.m.) was recorded in this area while the major wintering herring school was located further west along the south coast (Fig 5). In this new area the herring was not so close to the beach as on the traditional grounds but remained in a 5-20 m thich layer on the bottom throughout the day and night. As the bottom was uniformly flat fine sand there was no danger of bottom interferance. Echo integration and sampling was effectively carried out in one day (11 December) after 4-5 days of studying the behaviour of the herring. Similarly the echo integration of the small school on the former wintering grounds was carried out the following day. It should be noted that in 1977 the area of the wintering schools was much larger or about

3 times that of the previous years. The age distribution was predominated by the 1974 yearclass i.e. 2 ringed herring (Table 1) while the 1975 and 1971 yearclass were also well represented. It is noted that the 1973 yearclass, which was predominant in the pelagic trawl samples taken on the wintering grounds in 1975, and in 1976, contributed only 5% to the age distribution in 1977.

In 1978 the herring survey at the south coast took place from 30 November - 18 December. During the first week in December the wintering school was located at the south coast, even further west (at about 18°W) than in 1977. The school was then about 17 n.m. long and about 0.6 - 1.5 n.m. wide. However the weather deteriorated before the echo integration was quite finished and from 6-12 december an easterly gale prevented further surveying.

When work could be resumed again the herring had completely disappeared from the area at 18°W . In stead a very dense wintering school was located much further east at about 16°W, i.e. in the wintering area of the 1973-1976 period. Then on 15 December 1978 an echo-integration survey was carried out under perfect weather conditions. The herring concentrations were located in a water depth of 15-50 m (Fig. 6). The school was obviously much denser than experienced before while the area was much smaller or 6.6 nm^2 as compared to about 30 nm^2 in 1977. The age distribution was predominated by the 1975 yearclass (2 ringers) while the 1974, 1976 and the 1971 yearclass were also important (Table 1).

In 1979 the herring survey at the south coast was carried out from 1-10 December. Weather conditions were exellent during the first 8 days of the survey and the main wintering school was located much further east than in previous years or between 14° and 15°W (Fig. 7). It should be noted that a small patch of herring was also observed in the old wintering area further west by Ingólfshöfði.

After studying the behaviour of the main wintering school in this new area for a few days an echo integrator survey was carried out on 6 December from 0600-1000 hours. The school was 9.6 $n.m^2$ (Fig 7). The water depth was from 20-50 m with the herring near the centre of the water column. The average thickness of the school was 10.3 m. The following night the echo integration was repeated with similar results.

4. The results of the echo integrator surveys.

In an earlier paper (Jakobsson 1978) the term echo abundance was used to describe the product of the area of the wintering schools (square nautical miles) and the mean echo intensity per sailed n.m. measured as an elevation in m.m. on the Simrad Echo Integrator. The results of the integrator surveys in 1973-1979 expressed in this way are given in table 2.

In 1973 the wintering school consisted exclusively of one (1971) yearclass. The area was relatively large and the echo intensity was low compared to later years. During the three year period 1974-1976 the area of the wintering school remained more or less constant but with somewhat varying echo intensity.

In 1977 two wintering schools were located and the combined area was about 3 times that of the 1974-1976 period while the echo intensity remained similar to that observed in 1976.

In 1978 and 1979 the area of the wintering schools was drastically reduched. Instead echo intensities were high.

As shown in the last column of Table 2 the echo abundance in 1978 and 1979 was more than 10 times that observed in 1973.

Using the results of the single fish countings which were carried out in 1973 (Jakobsson 1978) the echo abundance in that year corresponded to about 17.500 tons of herring. If the echo abundance as defined above is proportional to fish abundance one can simply use the last column in Table 2 multiplied by 17.500 tons to calculate the tonnage each year. Using also mean weigths and the age distributions on the wintering grounds (Table 1) the stock in number by age can be calculated and these results are given in Table 3. When using this method it is of course clear that one is assuming that the integrated echo intensities were directly proportional to the weight of the fish. Norwegian scientists (e.g. Nakken & Olsen 1977 Dalen et al 1976) have obtained results which indicate that the echo intensities are related to the length of the fish rather than weight. This was however not confirmed by Johannesson (1979).

As described by Vilhjálmsson et al (1980) a density coefficient per unit area is used in the joint Icelandic-Norwegian capelin surveys to convert integrated echo intensities to number of fish. The relation between this density coefficent and the length of the fish is given by:

$$C = axl^{-1.91} \times 10^{6}$$

where l is the length of the fish and a is a factor which must be dependent on the characteristics of the acoustic instruments.

This implies e.g. that 100 herring weighing 10 g each will give a higher echo intensity than 10 herring weighing 100 g each.
It is thus clear that the length dependent method gives higher stock estimates than the weight dependent method when the former is applied to older and larger herring than the single fish countings were based on as is the case with the Icelandic herring abundance surveys. Considering the dangers involved in managing a fishery on a small but recovering herring stock management advice has been based on the estimates given in Table 3.

Since 1977 the results of the echo abundance surveys have been used to calculate the fishing mortality generated by the herring fishery in the season immediately preceding each survey. These estimates of fishing mortalities have then been used to initiate a VPA. This has been described by Jakobsson (1978) and Anon (1979 and 1980). In Table 5 the stock estimates of the latest VPA are shown. However it should be noted that owing to the low mortalities (Table 4) the stock estimates obtained by VPA for e.g. 1974-1975 are still dependent on the input F_s which were derived from the results of the echo surveys. When comparing the two sets of estimates, i.e. the VPA and the echo survey estimates, it is also important to note that the results of the 1974 survey correspond to the 1975 VPA adding 1 to the age of the fish. The reason for this is that the echo abundance surveys are carried out at the very end of the year while the VPA estimates refer as usual to the 1st of January each year. In Table 6 the two sets of estimates have been arranged in this way for easy comparison. It is clear from Table 6 that the echo survey estimates have each year been lower than those obtained from the VPA. This difference is especially pronounced for the earlier years prior to 1977. It seems reasonable to assume that with increasing experience the results from later surveys are probably more accurate than the first ones.

In Table 7 the volumes of the wintering schools are given as well as the total number of herring and the number per m^3 based on the results of the echo surveys. It is seen that the lowest mean density was only 0.13 herring per m^3 in 1973 when the single fish countings were carried out. The highest densities were observed in 1978 when 3.66 herring were observed per m^3. Thus the number of herring per m^3 has varied considerably but the highest densities appear to be within the range observed when using underwater photography on the over wintering grounds of the Atlanto-Scandian herring east of Iceland during the early sixties while much higher densities have been observed (Olsen 1980) on the present overwintering grounds at the Norwegian coast.

The temperature at a depth of 10 m in the herring wintering areas 1976-1979 is shown in Figs. 8-12. In 1976 the herring over wintered where the temperature was just about 6°C as shown on Fig 8. In 1977 (Fig 9) the temperature in the 1976 wintering area had dropped to 3-4° as shown on Fig 9. The main herring concentrating had, however, moved further west were the temperature was 4-5°C or at least 1°C lower than in the previous year. In 1978 (Fig 10) the the herring had moved east again and kept in temperature between 5-6°C. In 1979 the temperature on the traditional wintering grounds was high (above 6°) and the herring had moved much further east (Fig 12) where the temperature was 2-4°C. As mentioned here above considerable diurnal migrations of the herring were observed. The figures quoted above show the situation at dawn but during the long winternights the herring kept closer to the coast than shown on the figures i.e. in somewhat colder and especially in less saline coastal water.

It is well known that traditionally the Atlanto-Scandian Herring over wintered near the southeast borders of the cold East Icelandic current while the Icelandic spring and summer spawners kept to the more temerate waters of South Iceland. It was therefore especially interesting to observe that in December 1979 the Icelandic summer spawning herring chose to spend the winter at the south western borders of the cold watermasses where the temperature was similar to those observed in the traditional wintering area of the Atlanto-Scandian herrring. The depressed rate of metabolism in such temperatures probably contributes considerably to evergy saving during the long fast of the winter months.

Discussion

In their review on the Meeting on Hydroacoustical Methods for the Estimation of Marine Fish Populations Suomala and Yudanov (1980) emphasize that the optimum conditions for gathering acoustic data are: calm wind and seas, a single species of fish of uniform size and stable behaviour, and distribution of the fish in a continuous layer of uniform density, away from the surface and the bottom. It is clear that the optimum conditions for an acoustic abundance survey include all of these plus perhaps the most important factor, i.e. a thorough understanding of the distribution, both in space and time, of the fish population concerned.

Although these optimal conditions cannot be met in all respects in the echo abundance surveys on the Icelandic summer spawning herring it is of interest to note that in many ways conditions are favorable. Although the Icelandic area is not known for calm wind and sea in mid winter practically all the abundance estimates have been obtained under these conditions. This is because these estimates can be obtained in a few hours after the necessary preparatory work has been done.

The waiting for the ideal weather conditions has on the other hand often been long, even more than a week. When the herring have assembled in the wintering area, mixing with other species has been negligeable so for all practical purposes on can say that in this respect one has a single species of fish but with the exception of 1973 they have not been of uniform size.

The behaviour has not always been stable but by studying the changes that have taken place it has been possible to adjust the survey tactics to these changes. The herring have, for instance, sometime been very close to the bottom during the day. Usually the densitiy has then been very high and the bottom stop on the integrator could not be used due to the whiteline effect. At night on the other hand the herring have often been so close to the beach that there has been insufficient waterdepth for the vessel and in any case in such very shallow water the ships disturbance on the herring will almost certainly be very pronounced. Therefore one could draw the conclusion that the echo integration was not possible because it could not be carried out at night or during the day. However by selecting the time in the early hours of the morning when the herring is slowly migrating to deeper waters, but has not quite descended to the bottom, almost optimal conditions have been encountered for carrying out the echo abundance survey. Nothing of this kind could of course be done without a thorough knowledge of the general distribution and migration pattern of the herring. If for instance the survey effort had been more or less random in Icelandic waters with the cource lines, say 20-40 n.m. apart the wintering school might not have been detected at all or at most one section might have passed through it probably at the wrong time of the day! But how does one know that there is perhaps not another concentration in quite another part of the sea at Iceland? During the last few years one has had the opportunity to carry out an echo abundance survey at the end of the 2-3 month fishing season. Since some 140 boats participate in the herring fishery it is possible to follow very closely the development of the fishing areas and study how these converge towards the overwintering area. In order to complete this picture a research vessel acoustic survey has been carried out each year 2-3 weeks prior to the echo abundance survey. During this preparatory survey, areas not kept under surveillance by the fishing fleet have been searched. The combined information from the research and the fishing vessels have, especially in the last few years, been so extensive that it is most unlikely that an important part of the stock could have escaped attention.

The most important test of the results of these echo abundance surveys is of course that they can be checked against fisheries data using the VPA. As yet however the two sets of results are still interdependent to some extent. In another 2-3 years this will change when the results of the VPA will give estimates of the abundance, of e.g. the strong 1971 yearclass, which are completely independent of the input or terminal Fs. The fact that the VPA estimates of that yearclass are still dependent on the 1979 fishing mortality, however, indicates that one has succeeded in keeping the fishing mortalities at a low level.

Summary

During the period 1973-1979 the recovery of the Icelandic summer spawning herring has been monitored by echo- abundance surveys using the Simrad echo integrator system. The surveys have been carried out in late November or early December when the herring have assembled in an overwintering area at South east Iceland. The integrated echo intensity has increased about 12 times since 1973. The survey design and tactics are discussed and the results of the surveys are compared with fisheries data and the results of VPA.

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Table 1

Age distribution, mean length and weight at age in echo abundance surveys 1973-1979.

	1973			1974			1975			1976			1977			1978			1979		
Rings	Age distrib.	$\bar{l}$ cm	$\bar{w}$ g	Age distrib.	$\bar{l}$ cm	$\bar{w}$ g	Age distrib.	$\bar{l}$ cm	$\bar{W}$ g	Age distrib.	$\bar{l}$ cm	$\bar{w}$ g	Age distrib.	$\bar{l}$ cm	$\bar{w}$ g	Age distrib.	$\bar{l}$ cm	$\bar{w}$ g	Age distrib.	$\bar{l}$ cm	$\bar{w}$ g
1	100	21.1	83	3	21.3	80	43	26.7	21	21	20.6	67	25	19.7	71	17	20.8	63	2	20.6	71
2				74	26.8	187	6	26.7	167	30	26.4	166	48	24.4	123	35	23.6	102	18	25.7	139
3				10	30.7	263	40	30.1	220	4	30.0	227	5	29.4	201	22	28.5	196	36	27.4	170
4				11	32.4	297	5	32.2	255	32	32.0	269	2	32.2	262	5	30.7	248	25	30.1	224
5				1	33.2	314	3	33.3	288	6	33.3	295	15	32.7	271	2	32.7	292	5	32.5	277
6				1	33.2	306	1	34.0	300	4	34.0	322	2	33.7	304	11	33.4	302	4	33.5	304
7						410	1	34.4	350	2	34.3	355	2	34.8	320	3	34.6	327	9	34.2	317
8						400	1	34.0	350	1	35.0	355	1	35.7	340	3	34.8	348	1	35.2	364
8+						400			360			360			373	2	35.2	360			

Table 2

Results of the echo integrator surveys

	A elev[1] in mm. per n.m.	B Square n.m.	AxB		AxB / 263
1973	13.7	19.2	263		1
1974	57.5	9.5	546		2.1
1975	94.9	9.5	901		3.4
1976	74.2	9.2	682		2.6
1977	73.1	28.2	2061	2259	8.6
	34.8	5.7	198		
1978	410.6	6.6	2710		10.3
1979	312.2	9.6	3187		12.1
	120.0	1.6			

1) refers to 20 db gain on the Integrator

Table 3

Stock in numbers ($x10^{-6}$) as estimated in the Echo abundance surveys assuming that echo intensity is proportional to weight.

Rings	1973	1974	1975	1976	1977	1978	1979
1	211	5	155	48	250	185	18
2		132	22	68	493	373	186
3		18	145	9	49	233	369
4		20	18	73	21	52	263
5		2	11	14	153	23	53
6		2	4	9	24	119	42
7			3	5	22	31	90
8			3	2	7	32	6
8+						20	5
Total No		178	361	227	1019	1068	1032
Total in tonnes $x10^{-3}$		37	60	46	159	180	210

Table 4. Calculated fishing mortality, Icelandic Summer Spawners 1969 - 1979. M= 0.10, Initial F= 0.23. 1)

RINGS	1969	1970	1971	1972	1973	1974	1975
1	0.10	0.06	0.13	0.00	0.00	0.00	0.01
2	0.86	0.87	0.64	0.01	0.00	0.01	0.02
3	0.60	1.04	0.47	0.01	0.01	0.01	0.09
4	0.66	0.68	1.67	0.02	0.01	0.02	0.12
5	0.72	0.78	1.31	0.12	0.00	0.01	0.20
6	0.83	0.72	1.34	0.06	0.01	0.01	0.09
7	0.91	0.85	1.89	0.07	0.01	0.00	0.07
8	0.89	1.00	3.07	0.06	0.01	0.00	0.20
9	0.86	1.68	2.12	0.68	0.01	0.00	0.17
10	1.15	0.66	1.70	0.45	0.22	0.00	0.01
11	1.22	0.87	0.99	0.22	0.06	0.10	0.00
12	1.11	1.20	0.02	0.02	0.07	0.07	0.12
13	0.80	3.56	0.03	0.07	0.02	0.08	0.08
14	0.70	1.00	1.00	0.04	0.02	0.02	0.10
AVERAGE WEIGHTED BY STOCK IN NUMBERS							
AVE 3-13	0.71	0.95	1.25	0.03	0.01	0.02	0.10
AVE 4-14	0.75	0.77	1.65	0.05	0.01	0.02	0.15

RINGS	1976	1977	1978	1979
1	0.00	0.00	0.01	0.00
2	0.07	0.04	0.04	0.08
3	0.05	0.19	0.13	0.11
4	0.12	0.16	0.15	0.23
5	0.18	0.21	0.18	0.23
6	0.20	0.23	0.25	0.23
7	0.15	0.26	0.37	0.23
8	0.09	0.25	0.49	0.23
9	0.25	0.13	0.47	0.23
10	0.30	0.45	0.33	0.23
11	0.38	0.08	1.19	0.23
12	0.00	1.08	0.06	0.23
13	0.15	0.00	0.57	0.23
14	0.10	0.20	0.21	0.23
AVERAGE WEIGHTED BY STOCK IN NUMBERS				
AVE 3-13	0.12	0.20	0.18	0.18
AVE 4-14	0.14	0.20	0.23	0.23

1) Other input parameters such as catch in numbers and mean weight at age are given in CM 1980/H8.

Table 5. Stock in numbers, millions, Icelandic Summer Spawners 1969 - 1979. M= 0.10, Initial F= 0.23.

RINGS	1969	1970	1971	1972	1973	1974	1975
1	49.188	33.925	77.955	77.589	471.708	101.908	186.604
2	142.297	40.213	28.793	62.203	70.038	426.217	92.188
3	19.141	54.723	15.292	13.691	55.917	63.209	382.157
4	11.252	9.492	17.494	8.685	12.239	49.898	56.420
5	20.442	5.285	4.334	2.985	7.673	10.967	44.225
6	5.271	9.030	2.199	1.061	2.401	6.926	9.837
7	2.419	2.086	3.994	0.519	0.907	2.159	6.224
8	2.082	0.878	0.806	0.544	0.439	0.815	1.952
9	1.104	0.771	0.294	0.034	0.465	0.391	0.736
10	0.646	0.424	0.131	0.032	0.016	0.418	0.353
11	0.422	0.185	0.199	0.022	0.018	0.011	0.377
12	0.216	0.113	0.071	0.067	0.016	0.016	0.009
13	0.207	0.064	0.031	0.063	0.060	0.013	0.013
14	0.154	0.084	0.002	0.027	0.053	0.053	0.011
Adult stock weight 3-14	16.811	20.659	12.392	8.722	22.044	38.887	129.556

RINGS	1976	1977	1978	1979
1	561.802	605.681	228.142	
2	167.453	507.738	547.393	203.952
3	81.536	141.885	442.058	474.088
4	316.473	69.954	106.169	352.054
5	45.099	252.977	53.726	83.052
6	32.776	33.959	186.271	40.403
7	8.110	24.302	24.535	131.459
8	5.226	6.316	17.006	15.395
9	1.450	4.300	4.432	9.433
10	0.562	1.022	3.408	2.496
11	0.316	0.377	0.593	2.215
12	0.340	0.195	0.317	0.163
13	0.007	0.307	0.060	0.271
14	0.011	0.006	0.277	0.031
Adult stock weight 3-14	139.223	144.154	205.008	258.791

Table 6.

Comparison of echoabundance estimates (millions of herring) 1973-1979 and corresponding estimates from VPA (in brankets).

Rings	73(74)	74(75)	75(76)	76(77)	77(78)	78(79)	1979
1 (2)	211 (426.2)	5.35 (92.2)	155 (167.5)	48 (507.7)	250 (547.4)	185.4 (204.0)	19
2 (3)		132 (382.2)	22 (81.5)	68 (141.9)	493 (442.1)	372.9 (474.0)	186
3 (4)		18 (56.4)	145 (316.5)	9 (70.0)	49 (106.2)	233.1 (352.1)	369
4 (5)		20 (44.2)	18 (45.1)	73 (253.0)	21 (53.7)	52.2 (83.1)	263
5 (6)		2 (9.8)	11 (32.8)	14 (34.0)	153 (186.3)	13.3 (40.4)	53
6 (7)		2.0 (6.2)	4 (8.1)	9 (24.3)	24 (24.5)	118.8 (131.5)	42
7 (8)		(2.0)	4 (5.2)	5 (6.3)	22 (17.0)	31.1 (15.4)	90
8 (9)		(0.3)	3 (1.5)	2 (4.3)	7 (4.4)	32.2 (9.4)	6.0
8+ (9+)		(0.8)	(1.2)	(1.9)	(4.6)	19.0 (5.2)	5
Total	211.1 (410.8)	194.0 (213)	567 (443.2)	326 (1043.3)	1253 (1386.4)	1068 (1315.0)	1032
3 (4) and older		46.0 (119.1)	289.4 (410.4)	162.2 (393)	344.8 (396.7)	509.7 (637)	748.1

Table 7.

Icelandic echo integrator surveys
Dimentions of the wintering herring shoals

	Area in naut. miles^2	Area in $m^2 x 10^{-6}$	Vertical extention in m	Volume Cubic m	No of herring $x 10^{-6}$	Average no of herring per cubic m
1973	19.2	65.8	64.0	1578	211	0.13
1974	9.5	32.6	13.1	427	194	0.45
1975	9.5	32.6	12.4	403	567	1.41
1976	9.2	31.6	15.2	479	327	0.68
1977	28.2 5.7	96.7 19.5	14.5 5.2	1499	1253	0.84
1978	6.6	22.6	12.9	292	1068	3.66
1979	9.6 + 1.6	32.9 5.5	13.9 4.3	481	1035	2.15

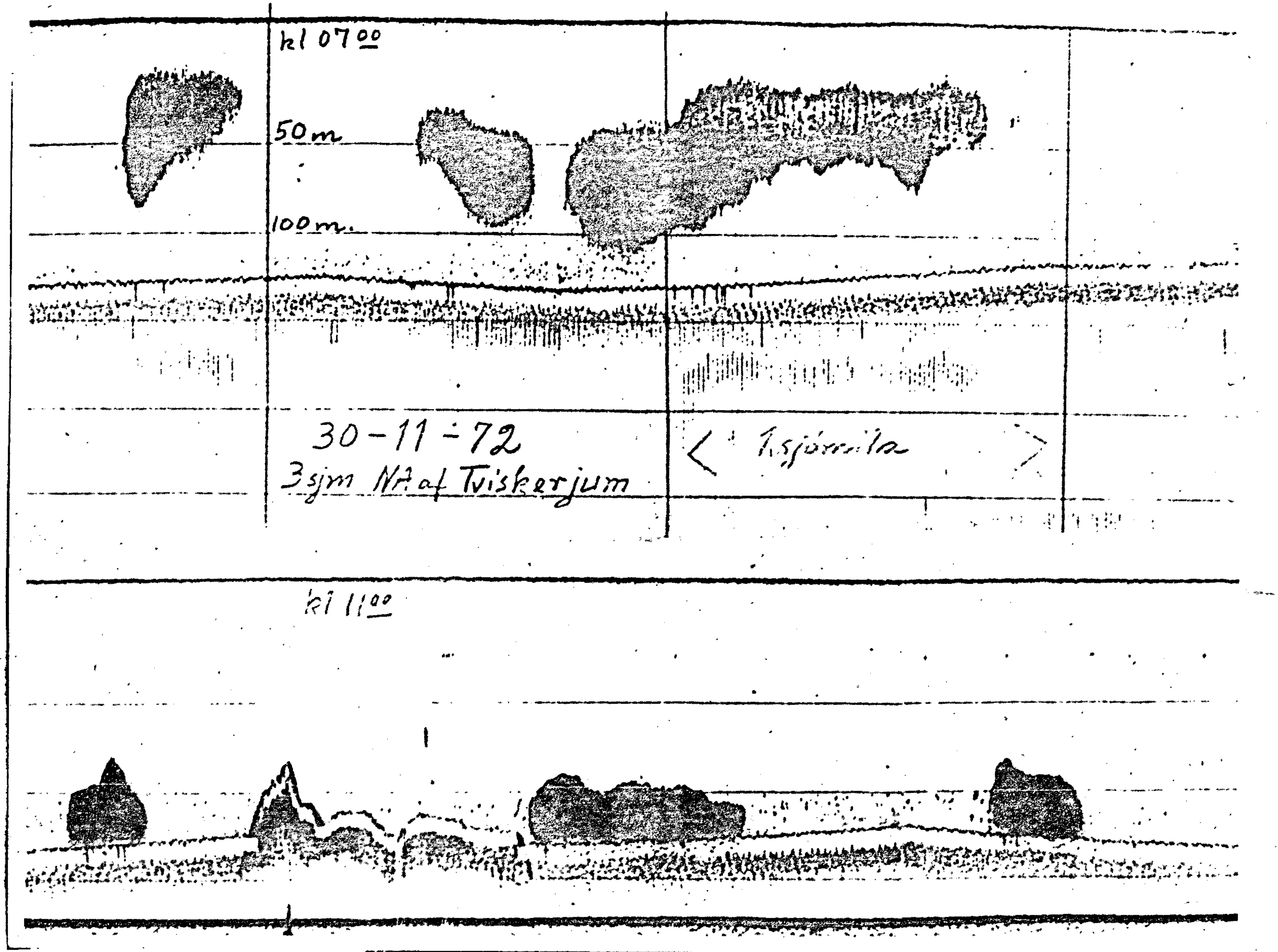

Figure 1. Echograms showing the main shoal of summer spawners ("the surviors") on the wintering grounds during the first year of the fishing ban. Upper section registrered in darkness, the lower in daylight.

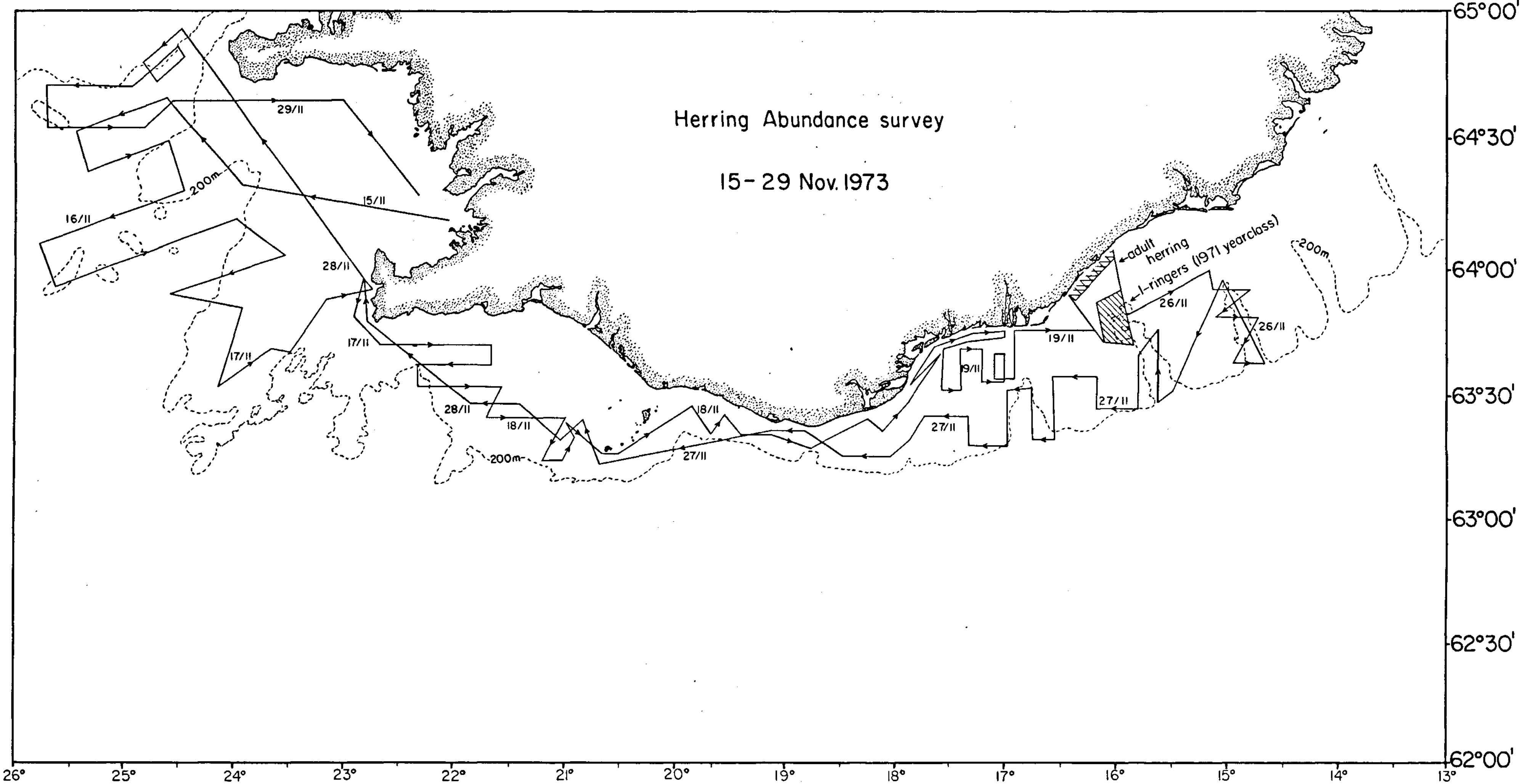

Figure 2. Survey tracks and herring areas located 15-29 November 1973.

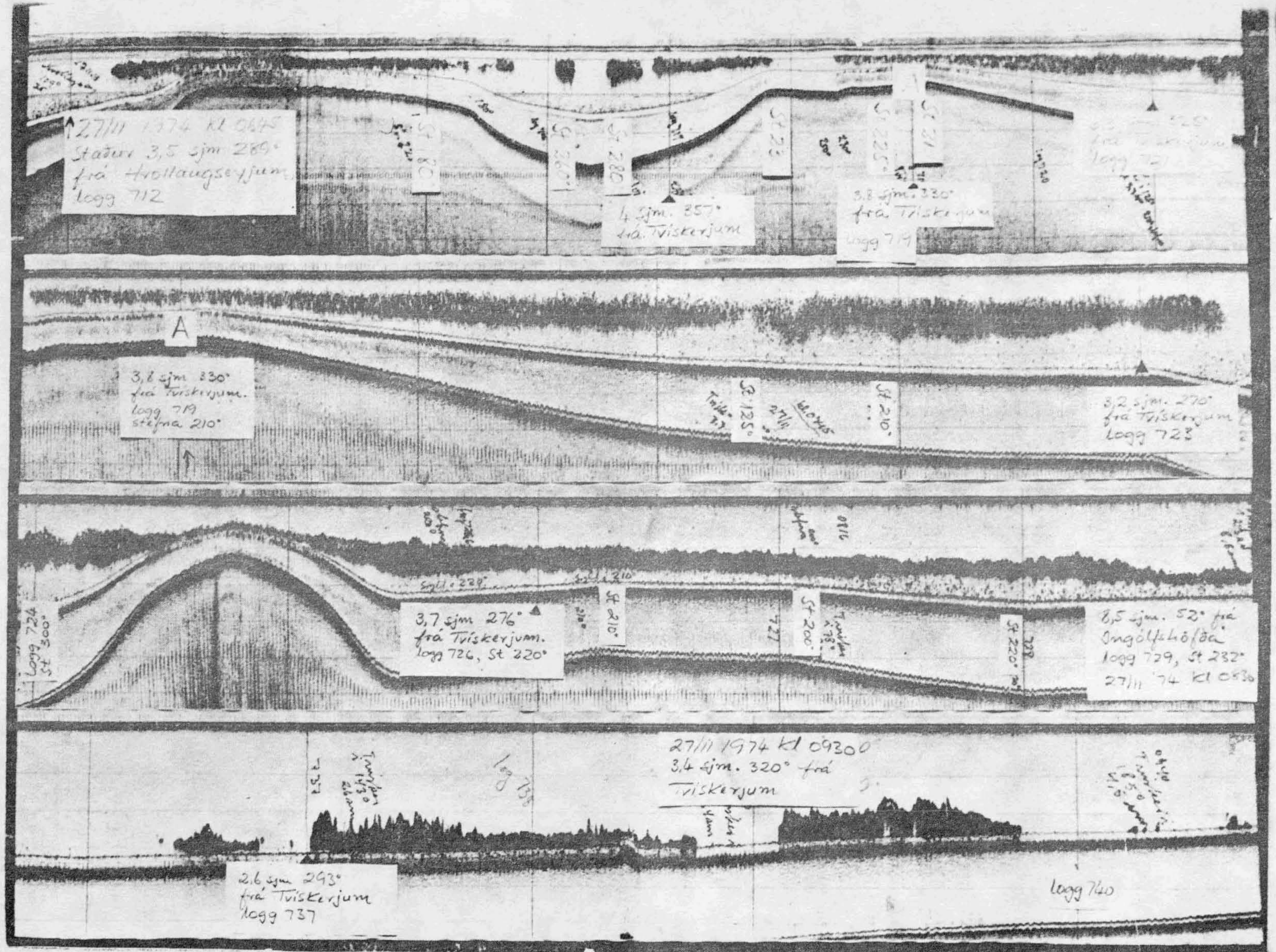

Figure 3. Echograms showing the continuous layer of herring in midwater during the echo abundance survey 1974. The daytime concentrations on the bottom are also shown.

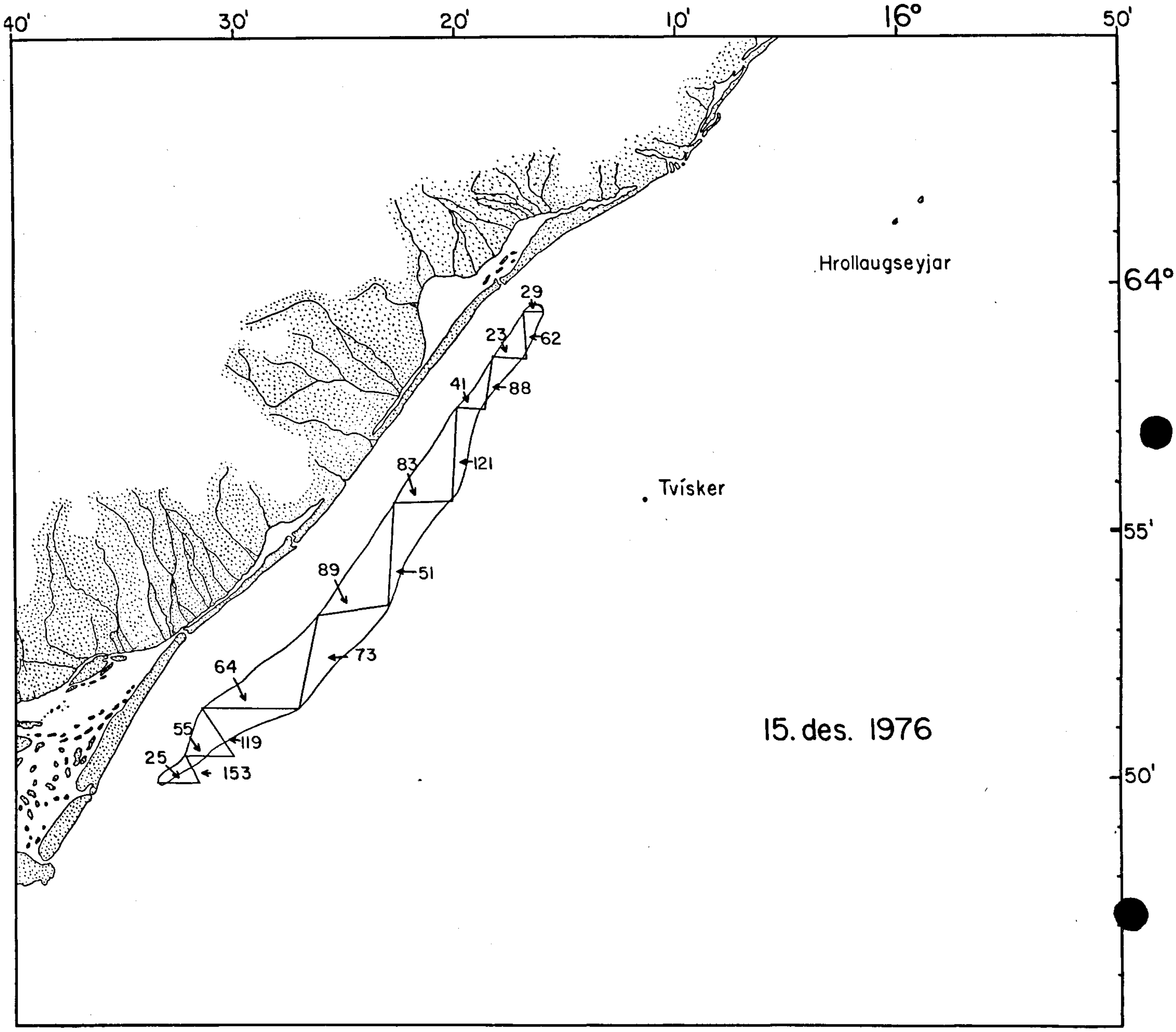

Figure 4. Wintering concentrations of Icelandic summer spawners 1976. Echo abundance densities are given in elevation in mm/n.m. sailed using a Simrad echo integration system with a gein of 20 db.

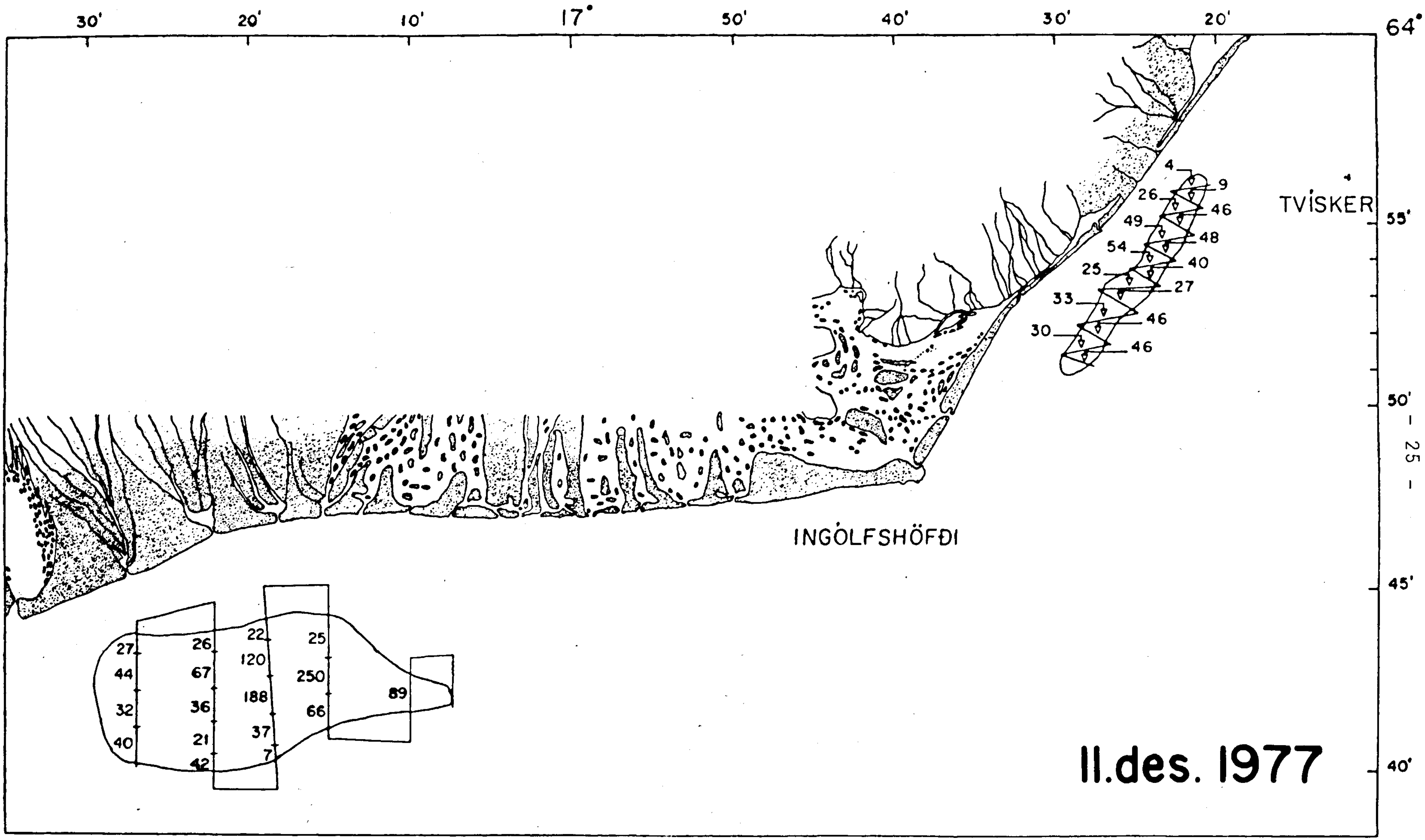

Figure 5. Wintering concentrations of Icelandic summer spawners 1977. Echo abundance denotations as in Figure 4.

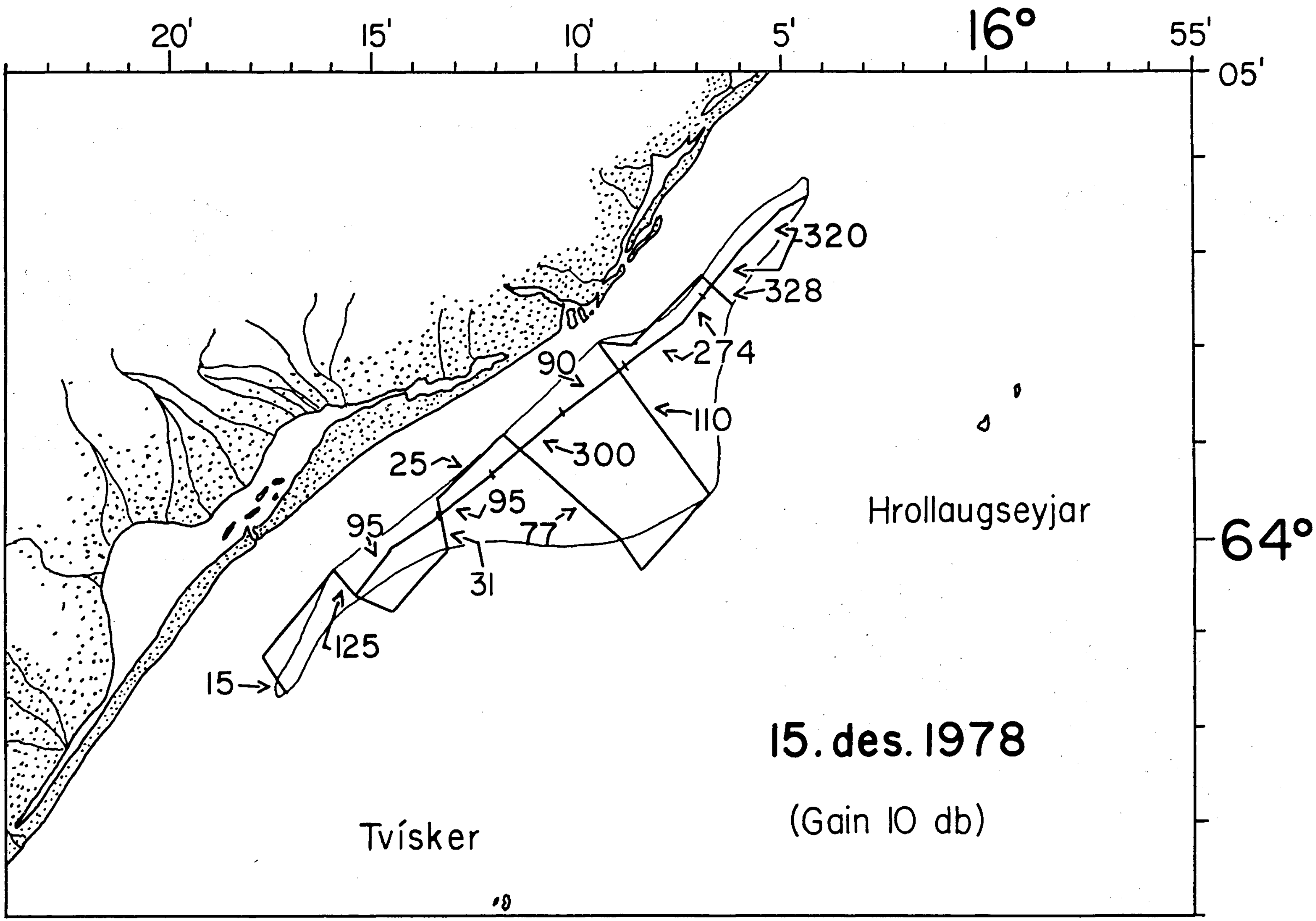

Figure 6. The wintering school of the Icelandic summer spawners 1978. Echo abundance densities are given in elevation in mm/n.m. sailed using a Simrad echo integration system with a gain of 10 db.

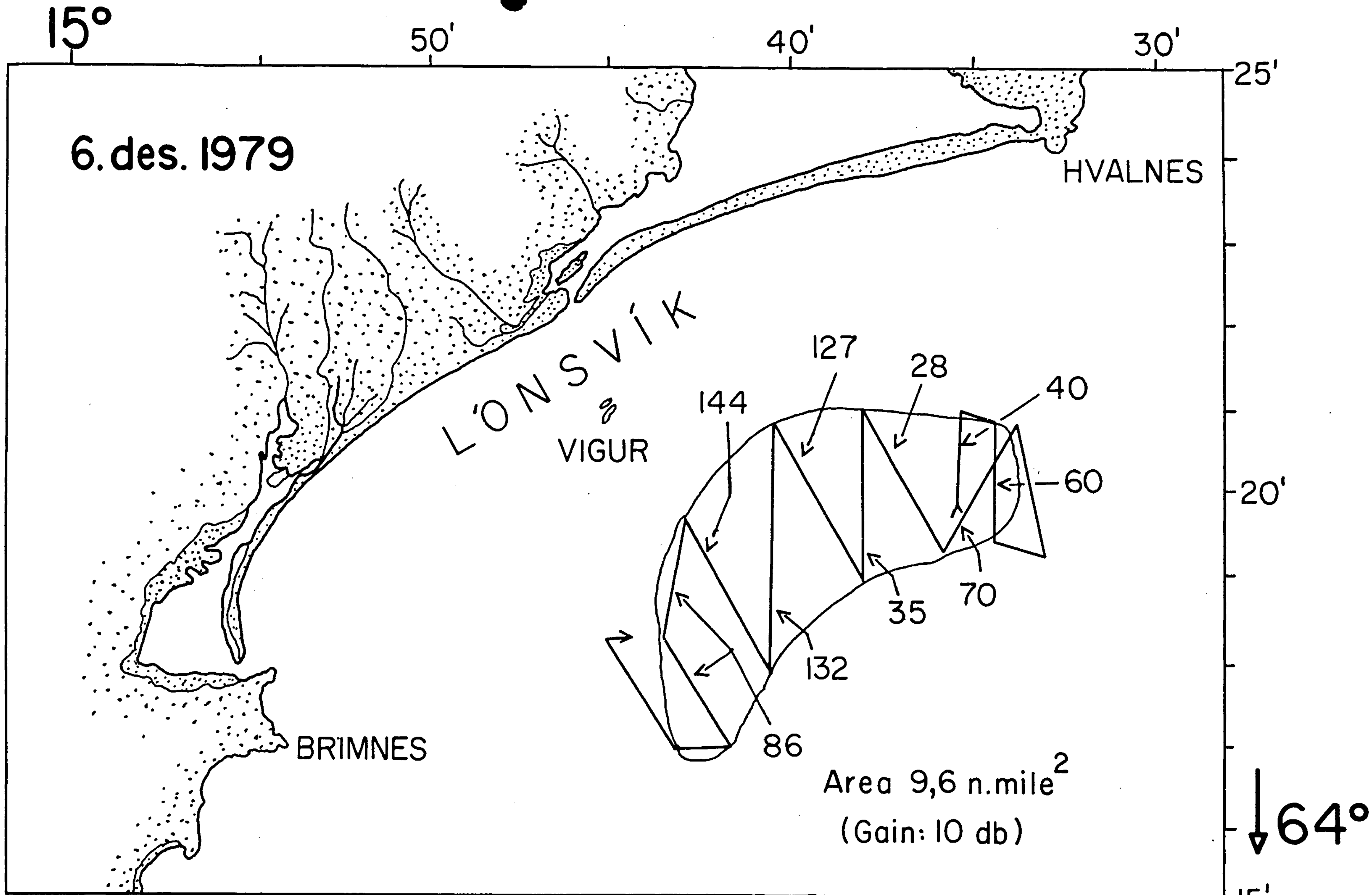

Figure 7. The wintering school of the Icelandic summer spawners 1979. Echo abundance denotations as in Fig 6.

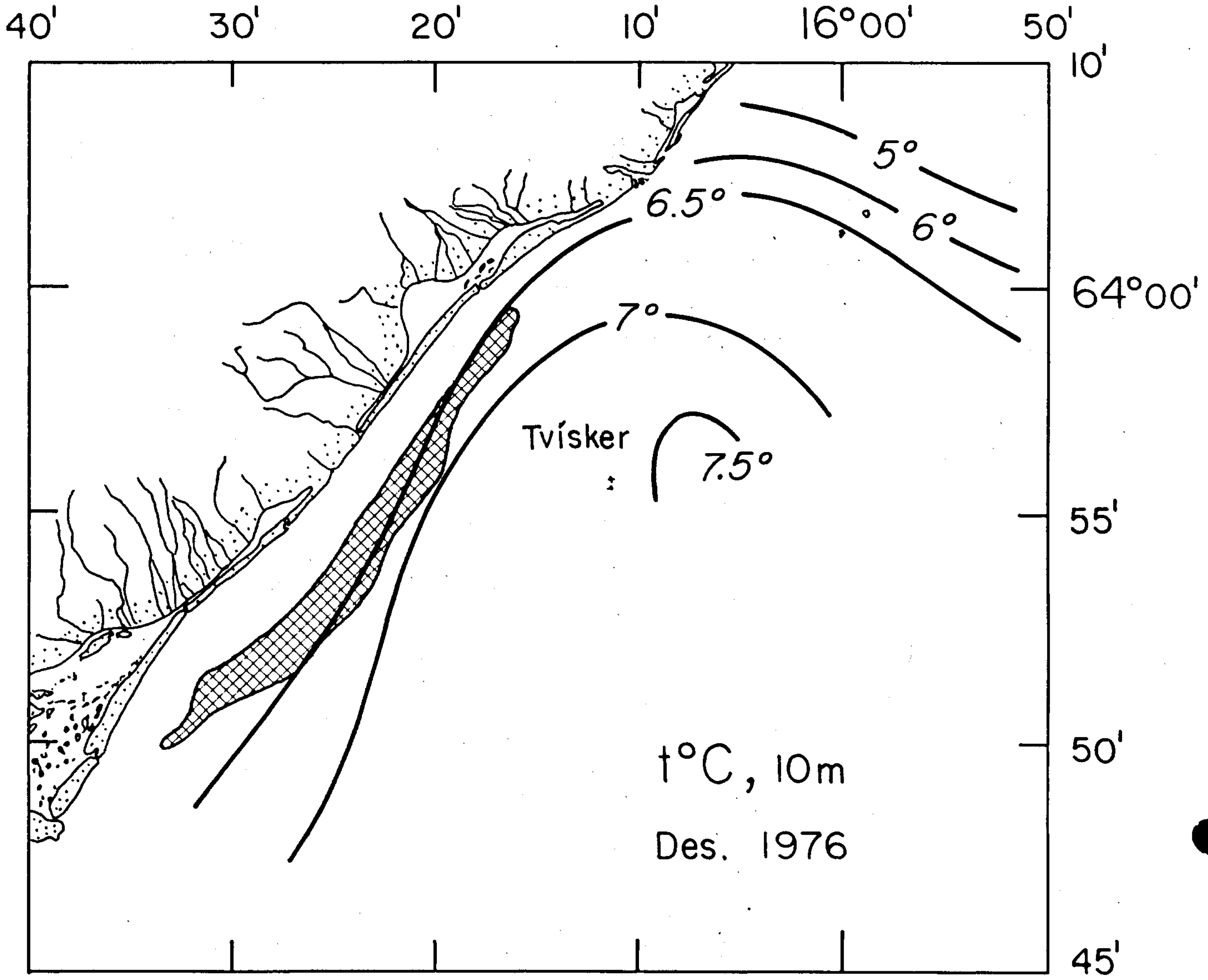

Fig 8. Temperature at 10 m on the herring wintering grounds in December 1976.

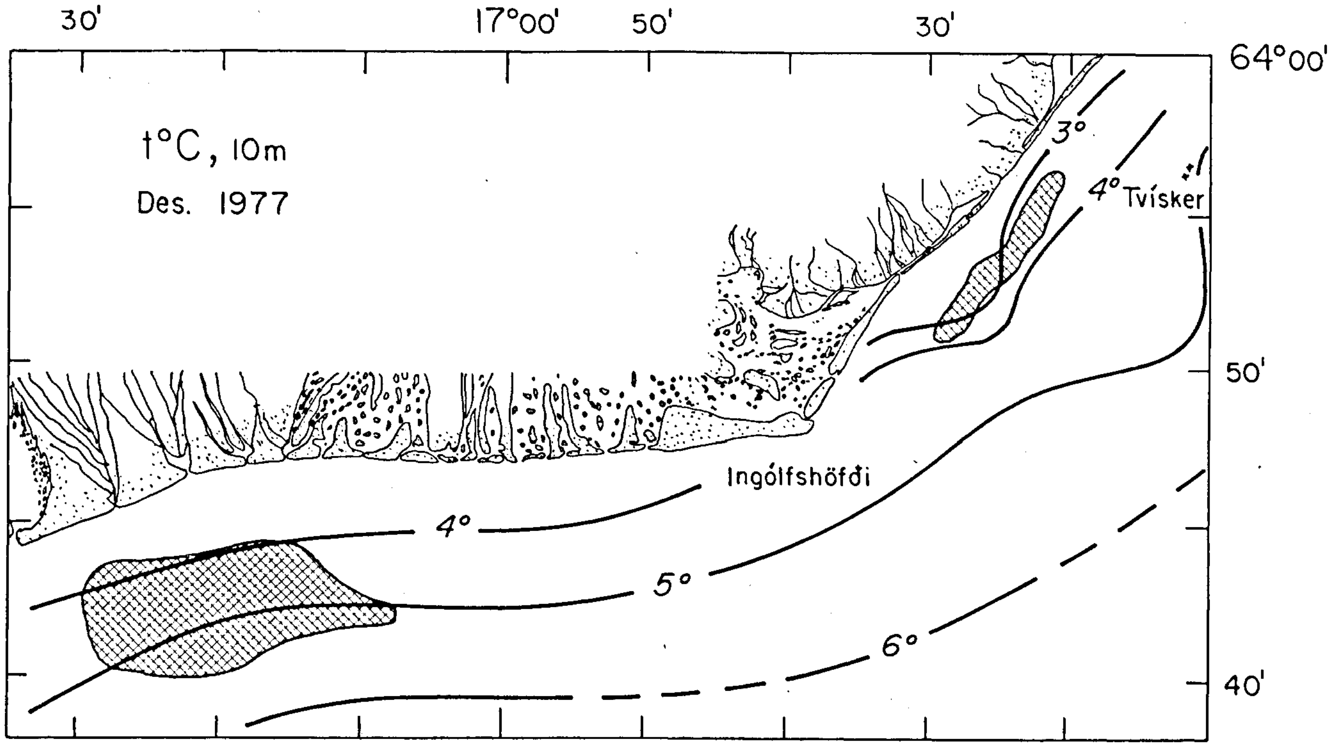

Fig 9. Temperature at 10 m on the herring wintering grounds in December 1977.

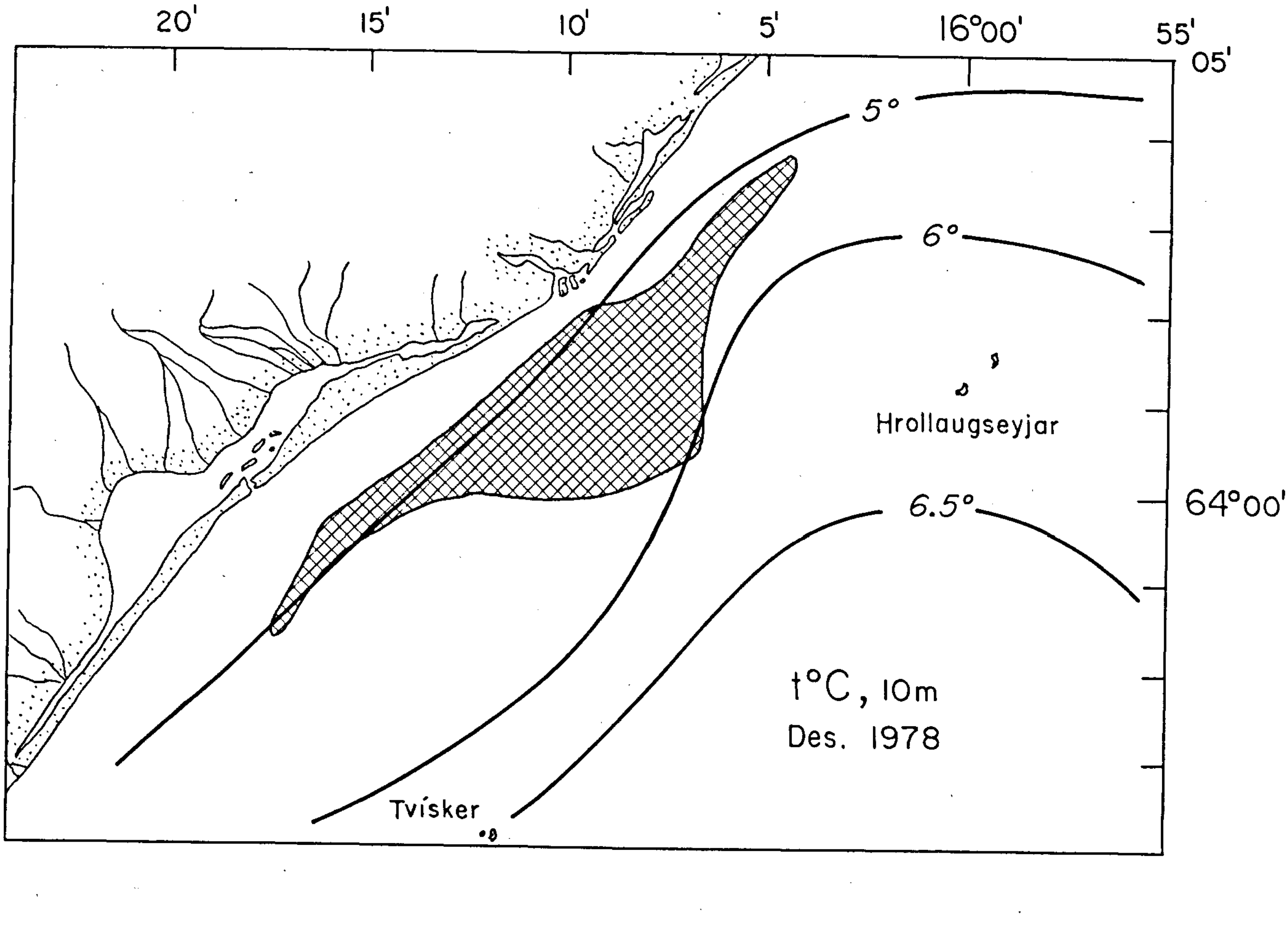

Fig 10. Temperature at 10 m on the herring wintering grounds in December 1978.

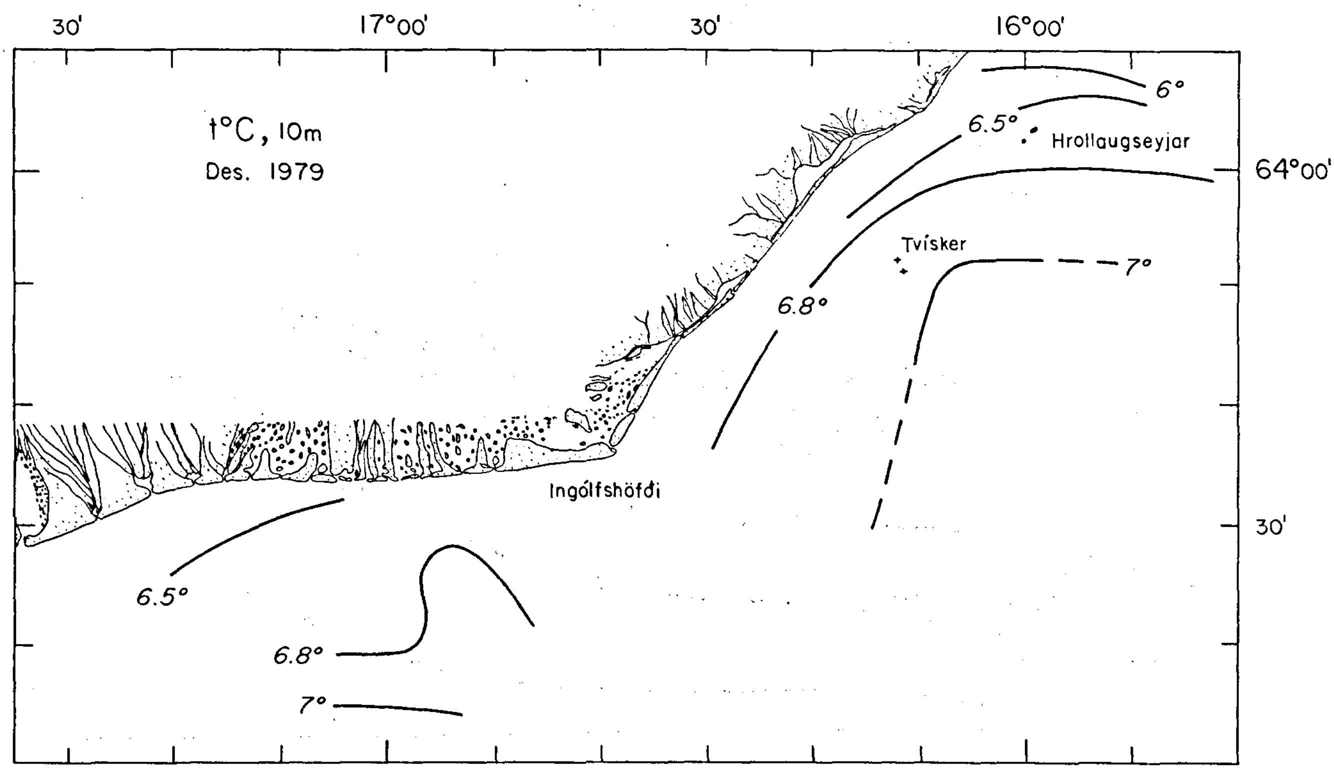

Fig 11. Temperature at 10 m on the traditional herring wintering grounds in December 1979.

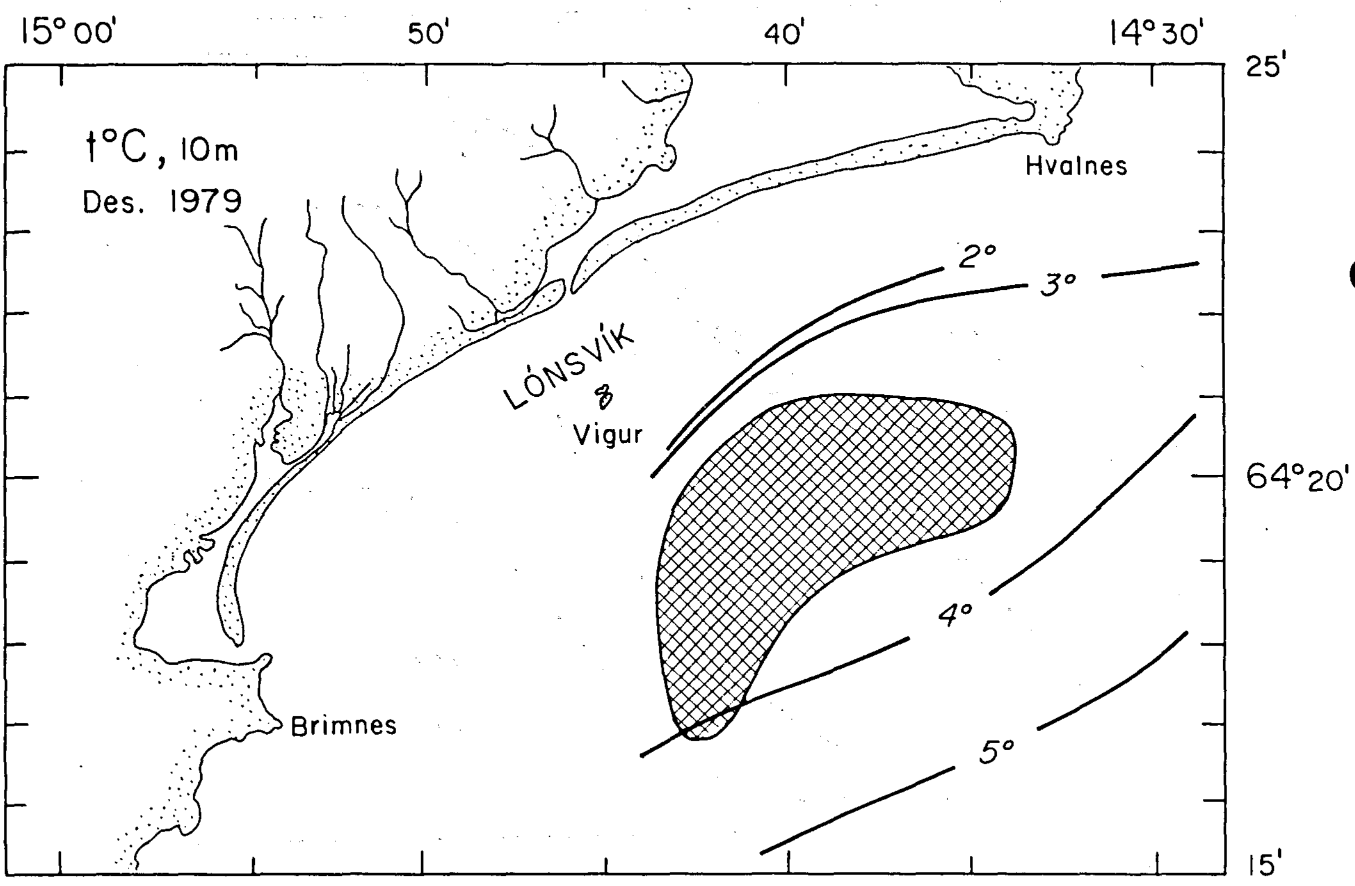

Fig 12. Temperature at 10 m on the new herring wintering grounds in December 1979.