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INTRODUCTION

In 1967 the Marine Laboratory, Aberdeen, began an investigation of blue whiting Micromesistius poutassou stocks in the area west of Scotland and principally at Rockall Bank (Raitt 1967, Bailey & Seaton 1969, Bailey 1970a). Following reports by Mohr (1968) and Zilanov (1965, 1966) of a large population living pelagically in the southern Norwegian Sea, the Aberdeen investigations were extended to this area in 1969. This paper reports the results of three surveys in the area between the Faroe Islands and south-east Iceland in 1969 and 1970.

MATERIAL AND METHODS

The three surveys mentioned above were conducted by FRS "Explorer" from 23 September to 22 October 1969, only the period 3-10 October being in the area covered by this paper; from 9 to 22 December 1969, and from 30 November to 22 December 1970. The main purpose of these cruises was to locate midwater concentrations of blue whiting and to develop techniques for catching them by midwater trawl. On the two cruises in 1969 a Marconi 48 kHz Fishgraph with a narrow-beam transducer was used as the standard echosounder, while in 1970 a Simrad Scientific Sounder (EK 50) was used. Since the surveys were conducted on a trial basis, standard gain settings were not maintained throughout the surveys. Nevertheless, an attempt has been made to assess trace densities subjectively and the results are given below.

In October 1969 two pelagic trawls were used, a 1200-mesh Engel trawl and a 577-mesh trawl designed by the Marine Laboratory. In December 1969 a 1200-mesh Engel trawl was used, and in December 1970 a 1400-mesh Engel trawl. The codend was of 30 mm mesh, and on the last cruise this was provided with a cover of $\frac{1}{2}$" knotless netting.

The nets were used in conjunction with a Kelvin Hughes MS 33 headline transducer, together with Furuno equipment in December 1970, the latter with an acoustic link to the ship.

Owing to bad weather conditions only a limited amount of trawling was possible: seven hauls in October 1969, nine in December 1969 and six in December 1970. For comparative purposes, one haul was made using a SARO-type high-headline bottom trawl in October 1969.

At each haul a sample of 1-200 blue whiting was measured and a stratified sample of otoliths was taken for age determination, carried out by breaking the otolith transversely and counting the number of hyaline (winter) rings under transmitted light (Raitt 1968). Following the argument used by Bailey (1970b), the nucleus of the otolith was counted as the first winter ring. Outer rings in fish older than about four years of age are usually difficult to distinguish and for some samples two independent sets of age readings were carried out.

ECHO-SOUNDER RECORDS

Echo-traces similar in character to those attributed to blue whiting by Mohr (1968) and Blindheim et al. (1971) were encountered on all three surveys, and a photograph of a characteristic trace is shown in Figure 1. During the day, the traces consisted of a broken band about 10-20 m in width. In October 1969 they were recorded most often at a depth of around 300-330 m rising towards the surface from 1800 hrs onwards, and reforming in the morning by about 0900 hrs. In December 1969 and 1970, the traces were usually at around 240-260 m at which depth they remained from 1100-1600 hrs. While ascending at dusk the traces became more diffuse and during the night were dispersed as individual small markings throughout the top 100 m (or more rarely 150 m). On occasions in both December 1969 and 1970, the traces remained between 100 and 200 m even at night. The traces were similar in general appearance on all three surveys, varying only in intensity and degree of breakdown into discrete traces, possibly indicating the intensity of shoaling. The difference in timing of the vertical movements in October and December suggests that they are associated with and probably timed by the dark-light cycle. These findings are in agreement with previous reports of traces found in this area (Zilanov 1965, 1966, Mohr 1968), though during the summer Zilanov (loc. cit.) has reported an amplitude of vertical movement of only 30-100 m.

Since different echo-sounders were used on the surveys, a comparison of trace densities between surveys and with previous work was not possible. Furthermore, since the appearance of the traces changed in character diurnally and in different weather conditions (probably owing to the variation in motion of the ship), it is not possible to compare trace intensities in different areas in exact terms. Nevertheless, following the method used for blue whiting by Penin et al. (1970) and Blindheim et al. (1971), a somewhat subjective analysis of the distribution of traces on the three surveys is shown in Figures 2-4.

In October 1969 no area of dense traces was found; though scattered traces were found in most of the area surveyed over and to the north of the Faroe-Iceland ridge (Fig. 2). On this and subsequent surveys midwater traces were also found over the northern edge of the Faroe plateau, but they were more diffuse in character and therefore possibly caused by smaller organisms.

The survey in December 1969 was carried out in an area to the north of that surveyed in October (Fig. 3). Scattered traces were again found in most areas north of the Faroes, and dense traces were encountered mainly in the area from 64 to 65½°N. Further north the traces diminished in intensity. During this survey, continuous surface temperature recordings were made and the approximate positions of the isotherms, excluding minor variations, are shown in Figure 3. While traces were found in areas with a wide range of surface temperatures, they were densest at around the 3°C isotherm, and were distinctly less dense, in areas of lower surface temperature. While the traces were in no case associated with the surface layers as such, bathythermograph records taken on this cruise indicated little temperature variation with depth, except between 63°N, 3°W and 65°N, 5°W, where temperatures of 2-4°C were recorded at 200 m depth, compared with 4-6°C at the sea-surface. Thus, the traces appear to have been widely distributed in water of 3-7°C (as previously found by Zilanov 1968b), with a concentration at the lower end of this range, and very few in colder water. The isotherms shown in Figure 3 also suggest that there may have been a southward loop of cool water, presumably part of the East Icelandic Current, between 8° and 11°W and, if so, the blue whiting thought to cause these traces (see below) may have been concentrating at its edge.

The situation in December 1970 appeared to be more complex. Again, traces were found over much of the survey area (Fig. 4), but the survey did not extend as far north as the 3°C isotherm. At 10°W dense traces were recorded where the sea-surface temperature dropped from 7° to 4° over a short distance, and which may possibly have been at the edge of a current boundary.

While the tentative conclusions drawn above are to some extent speculative, the results in general support earlier conclusions that blue whiting occur in mid-water over a large part of the southern Norwegian Sea, concentrating along the south-eastern boundary of the East Icelandic Current (Zilanov 1966, Mohr 1968, Penin et al. 1970). The southern boundary of the traces appeared in October 1969 to be over the Faroe-Iceland ridge.

TRAWL HAUL DATA

The positions of trawl hauls on the three surveys are shown in Figures 2-4. Owing to difficulties experienced in the use of the netzsonde, and the lack of sufficient control over the positioning of the gear, the precision required to tow through the thin daytime traces suspected of being caused by blue whiting was rarely achieved. However, small numbers of blue whiting were caught in most hauls, the largest catch being about 30 baskets (c 950 kg) in a haul of 2 hrs 20 mins during daylight in December 1970.

Biological data

In three hauls made in October 1969, the blue whiting caught ranged in length from 16 to 35 cm (Fig. 5). There were some differences in length distributions between samples but two main peaks are recognisable, one at 22-23 cm and another at 27-29 cm. On the basis of the otolith readings for the three samples combined the fish were from 1 to 12 years old (Fig. 6) with peaks at 2 and 6 years. The few 1-group fish, and about half the 2-group of both sexes, had immature gonads, while all the remainder were about a quarter ripe on Bowers' (1954) scale, and so were presumably recovering spents. The overall sex ratio was 48% ♂♂: 52% ♀♀, but females predominated amongst the older fish. Mean lengths at age are shown in Table 1. As in other areas, females were larger than males at the same age.

A single bottom haul made on the Faroe-Iceland ridge (Fig. 2) also contained blue whiting ranging in length from 16 to 37 cm, with a mode at 30 cm (Fig. 5). The fish were from 1 to 11 years old (Fig. 6), again with a peak of 2-year-olds, and another of fish from 4 to 7 years old. The 1-group fish and some of the 2-group had immature gonads, while the remainder of the sample was a quarter ripe. The overall sex-ratio in the bottom sample was 29.5% ♂♂ : 70.5% ♀♀ and this was fairly consistent in all age-groups. The mean length at age in both sexes tended to be higher in the bottom sample than in those taken in midwater (Table 1).

In December 1969, samples were taken from five hauls made in two areas (Fig. 3). In both areas the fish ranged from 24 to 35 cm in length and from 2 to 11 years in age, with 6-9 year old fish predominating (Figs. 5 and 6), the younger age-groups present in October being almost absent. As in October, most fish were a quarter ripe, with about 10% of the males being half-ripe. There was no noticeable difference in age composition between the two areas sampled, though mean lengths at age tended to be higher and females predominated in the more westerly sample (38% ♂♂ : 62% ♀♀, compared with 54% ♂♂ : 46% ♀♀ in that taken further east; Table 1).

The length and age distributions of four samples combined taken on the December, 1970, cruise at around 64°N, 9°W are shown in Figures 5 and 6. Both were very similar to those found in December 1969; though in one haul there were a few fish from 1 to 3 years of age. The individual hauls on which the combined age distribution is based showed a consistent pattern, most fish being 6-8 years old. Independent checks on age readings also showed the same pattern with only minor variations in the ratios between age groups. Of the fish from three years of age upwards all the females and 65% of the males were a quarter ripe, the remaining 35% of the males being half ripe, that is a higher percentage than in the samples taken in December 1969. In the samples the sex ratio was 44% ♂♂ : 56% ♀♀. As in previous samples, females were consistently larger than males of the same age, and the half-ripe males also tended to be larger than quarter ripe males of the same age (Table 1). Another small sample of 50 fish caught at around 65°N, 7°W also contained a preponderance of 5-8 year old fish.

It is clear from the data summarised above that most of the blue whiting in the samples taken in the Faroe-Iceland region in 1969 and 1970 belonged to a mature population containing few fish younger than 4 years old. Despite the variation between hauls the majority of fish caught were in the length range 27-32 cm (Fig. 5) and age determinations based on the otoliths suggest that most were 6-9 years old (Fig. 6). Raitt (1968) found a similar age distribution in bottom samples taken south of Iceland in 1962 and 1963. Zilanov (1966), however, concluded from a sample of 453 fish taken in the Norwegian Sea in 1961 that the commonest age-groups were the 3-4 year-olds, with a modal length of 26 cm, though the time of year and exact locality of capture is not recorded. Nevertheless, on the basis of a further five thousand fish taken over the year in 1965-66, Zilanov (1968a) gives the mean length as 28.28 cm. The mean recorded by Mohr (1968) in December 1967 lay between 28 and 30 cm, and that given by Penin *et al.* (1970) and Blindheim *et al.* (1971) in May-June between 25 and 30 cm in different samples. Zilanov (1968b) has suggested that the prominence of the smaller fish in the earlier years was due to the success of the 1958 and 1959 year-classes.

The samples taken in October 1969 contained a higher percentage of younger fish than those taken in December, though whether this is a normal feature is not known. A sample taken on the bottom on the Faroe-Iceland ridge at the same time showed similar characteristics, though with females predominating. Thus, there is no evidence to suppose that blue whiting found in midwater and on the bottom in this area belong to different populations, though there may be differences in the behaviour of the two sexes.

DISCUSSION

That blue whiting are abundant in midwater in the southern Norwegian Sea is now well-established and Penin *et al.* (1970) report that a Russian fishery was established there in June 1970. Samples taken on the present surveys and those reported by Mohr (1968) show that in December in at least three years the population between the Faroes and Iceland consisted predominantly of fish from 26 to 30 cm in length, which were probably mainly 6-8 years old. The same age groups also appear to be abundant there at other times of year, and although younger fish occur, overall they appear not to form a major part of the population sampled. In December 1967, Mohr (1968) reports catching much smaller fish averaging 15 cm in length near the Norwegian coast and Zilanov (1968b) found that fish 11-23 cm in length accounted for 42% of the total catch in the north-eastern Norwegian Sea. Consequently, it may be that the south-western Norwegian Sea gains its recruits from further to the north and east.

Larvae of blue whiting have been recorded in the Norwegian Sea only off the coast of Norway (Zilanov 1968c), but no egg and larval surveys have been carried out in the Faroe-Iceland region. Thus, whether the population considered in this paper spawns in the area, or migrates south to spawn is not known. However, Penin et al. (1970) have provided evidence from echo-surveys of a northward movement in the southern Norwegian Sea in May and June, interpreting this as a post-spawning migration into rich feeding areas. Furthermore, since the mean length of fish in their samples changed from about 29 cm in May to 25-27 cm in June, they concluded that it was the larger and older fish that arrived first. Zilanov (1968b) has suggested that blue whiting may spawn in May around the northern edge of Faroe plateau, the larvae drifting northwards in the Norwegian current. It is also possible that the population in the Norwegian Sea is derived in part from spawning further south by dispersal during the early life history in the north Atlantic drift. If so, this might explain the apparent scarcity of 0 and 1-group blue whiting in catches west of Scotland.

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Table 1

Mean lengths (cm) of blue whiting at each age in the southern Norwegian Sea

MALES

Age group	October 1969		December 1969		December 1970		
	Midwater	Bottom	11°W	7°W	Total	¼ ripe	½ ripe
1	18.4	18.8	-	-	19.5	-	-
2	23.0	24.2	-	-	24.5	-	-
3	25.2	26.5	-	-	26.2	-	-
4	27.4	27.2	27.5	27.8	28.0	27.7	28.2
5	27.8	29.1	28.5	27.4	28.7	28.7	27.5
6	29.3	29.2	29.2	28.5	29.8	29.6	30.0
7	29.6	29.8	29.6	29.0	29.8	29.6	30.1
8	29.5	30.7	29.5	28.9	29.5	29.5	29.6
9	29.7	31.4	30.0	29.3	30.3	29.7	30.8
10	28.5	32.5	30.0	29.5	30.4	30.3	30.5
11	-	-	-	31.5	30.0	-	-
12	-	-	-	-	-	-	-

FEMALES

	October 1969		December 1969		December 1970
	Midwater	Bottom	11°W	7°W	
1	19.2	18.6	-	-	17.5
2	23.0	24.3	-	24.5	23.5
3	26.9	28.6	-	25.5	29.5
4	29.3	29.1	31.5	29.5	29.8
5	29.2	31.1	30.0	29.1	31.5
6	31.6	32.1	30.5	30.3	31.3
7	31.9	32.2	31.5	30.6	31.8
8	31.5	33.2	31.4	30.7	32.4
9	33.4	32.2	32.5	30.8	32.2
10	32.5	32.8	33.2	31.8	31.9
11	-	34.8	31.5	-	-
12	34.5	-	-	-	-

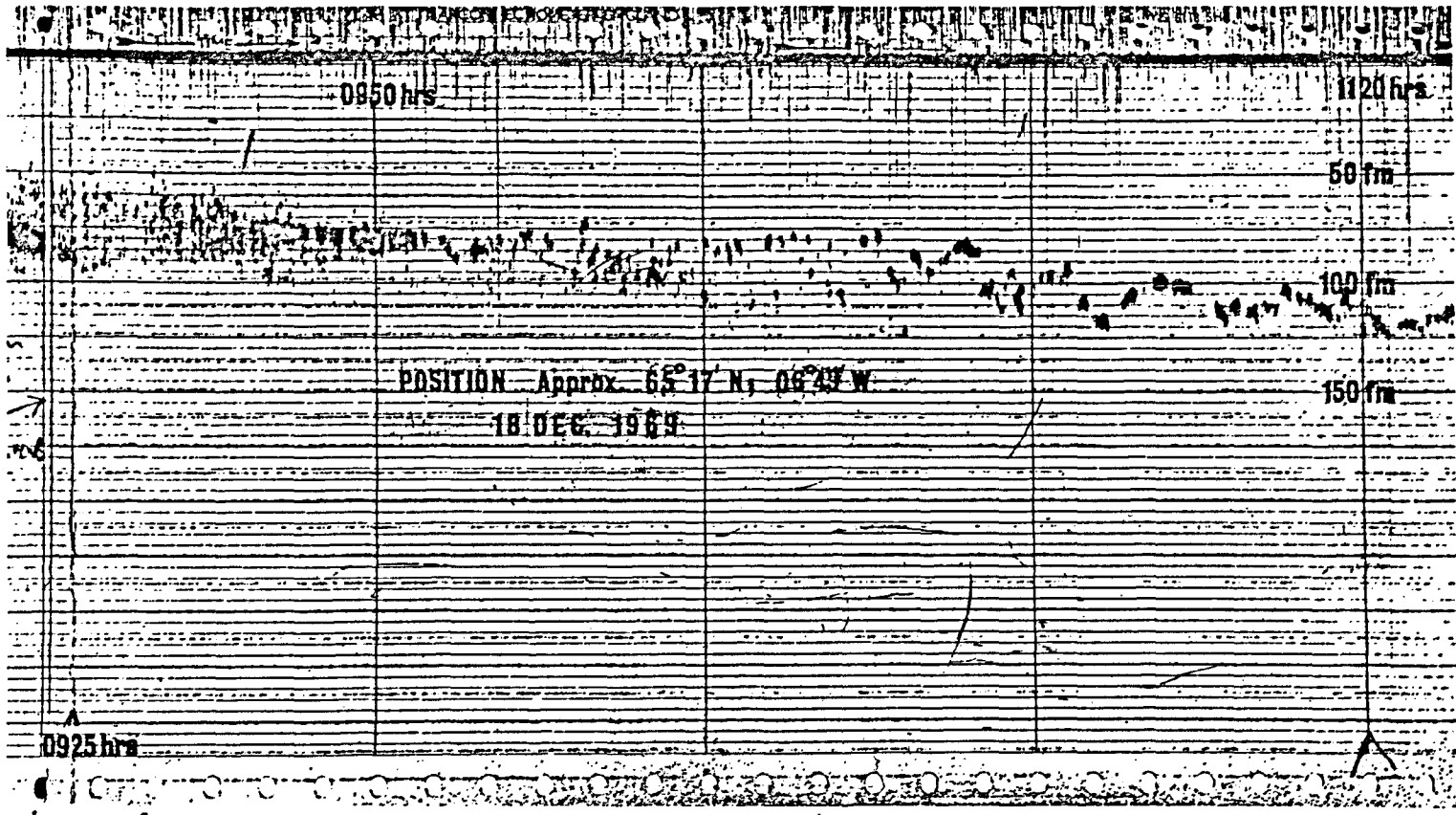

Fig.1

An echo-trace characteristic of those attributed to blue whiting

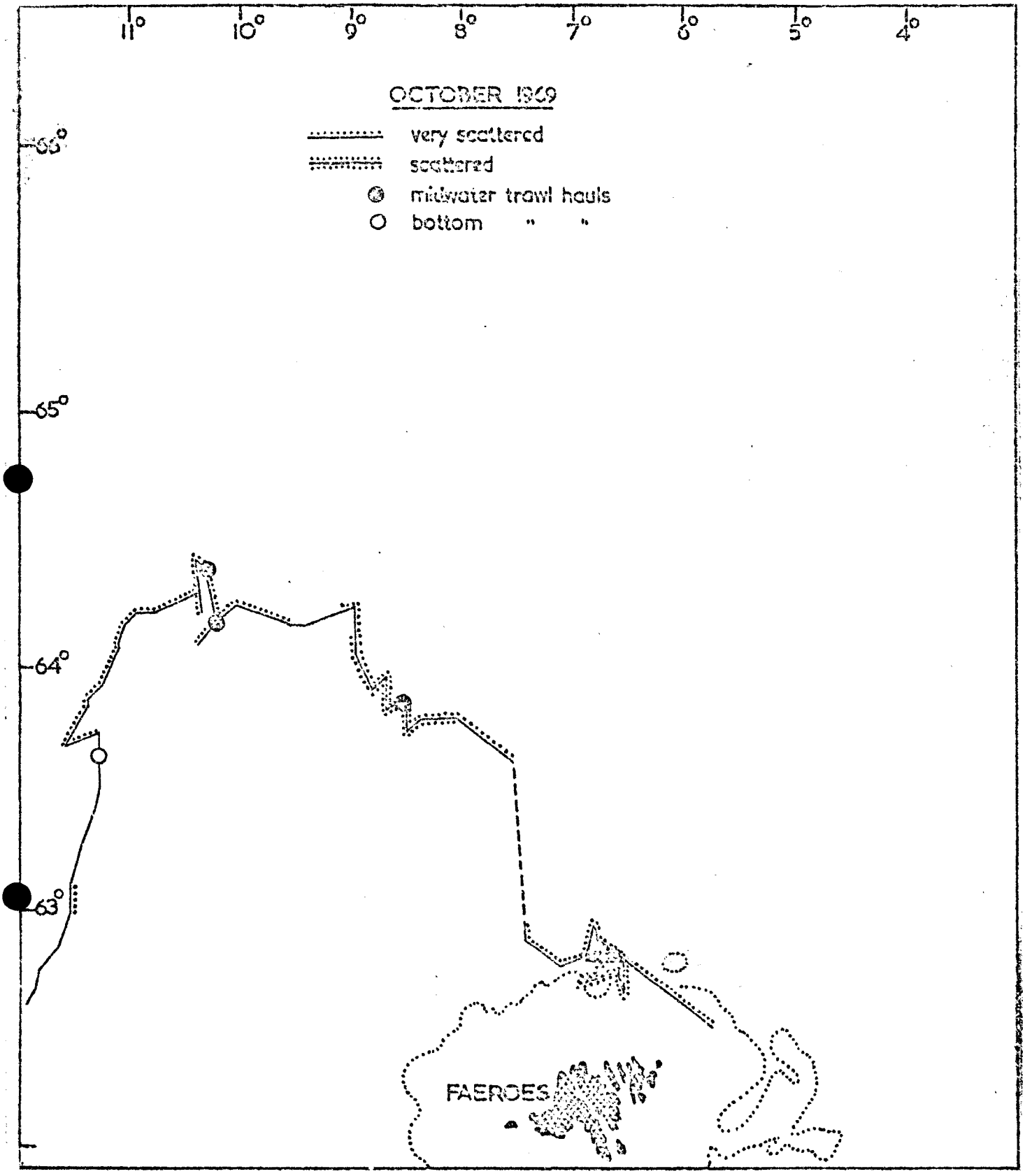

Fig. 2 Distribution of midwater echo-traces, trawl hauls and surface isotherms in October 1969.

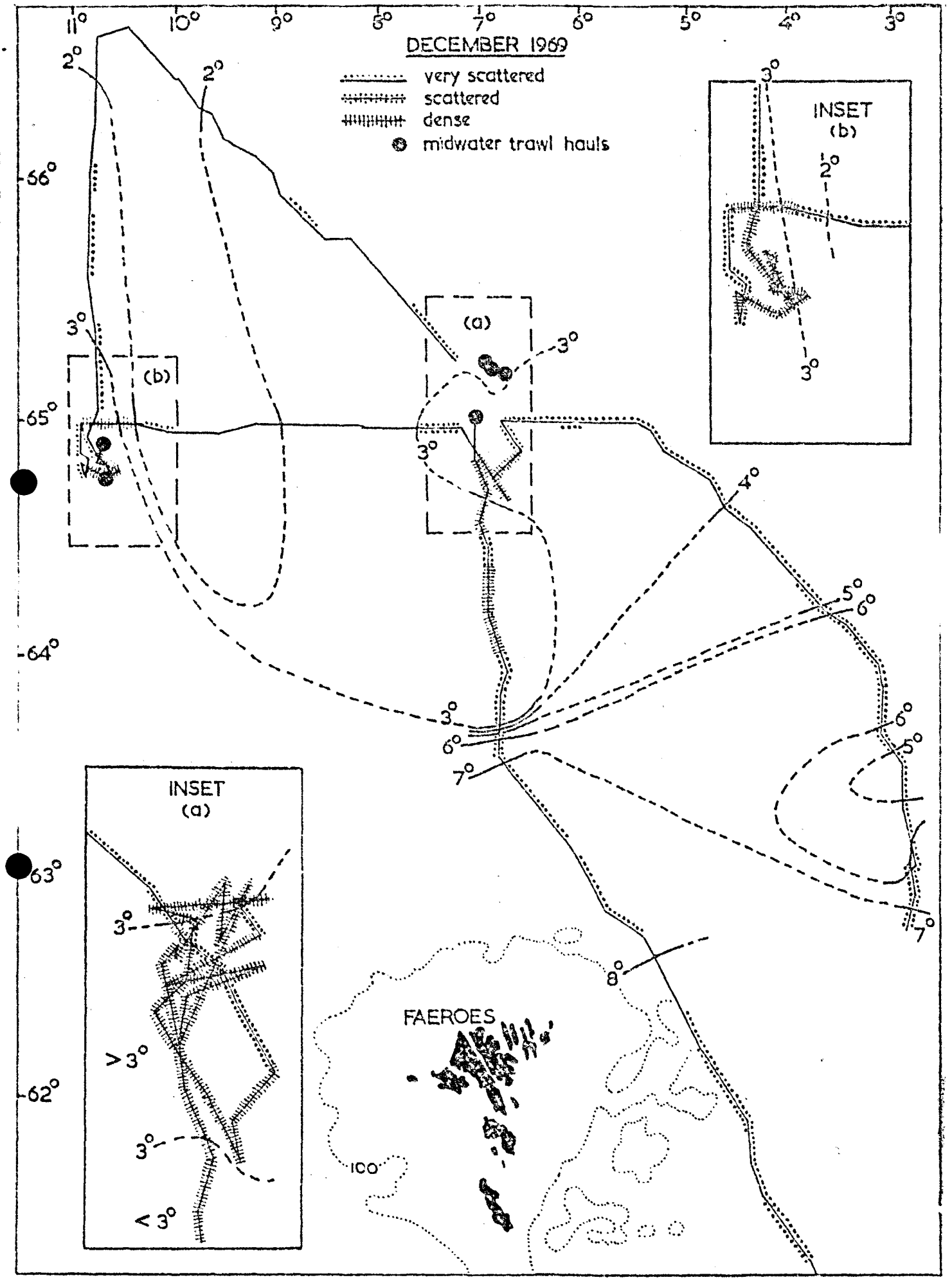

Fig. 3 Distribution of midwater echo-traces, trawl hauls and surface isotherms in December 1969.

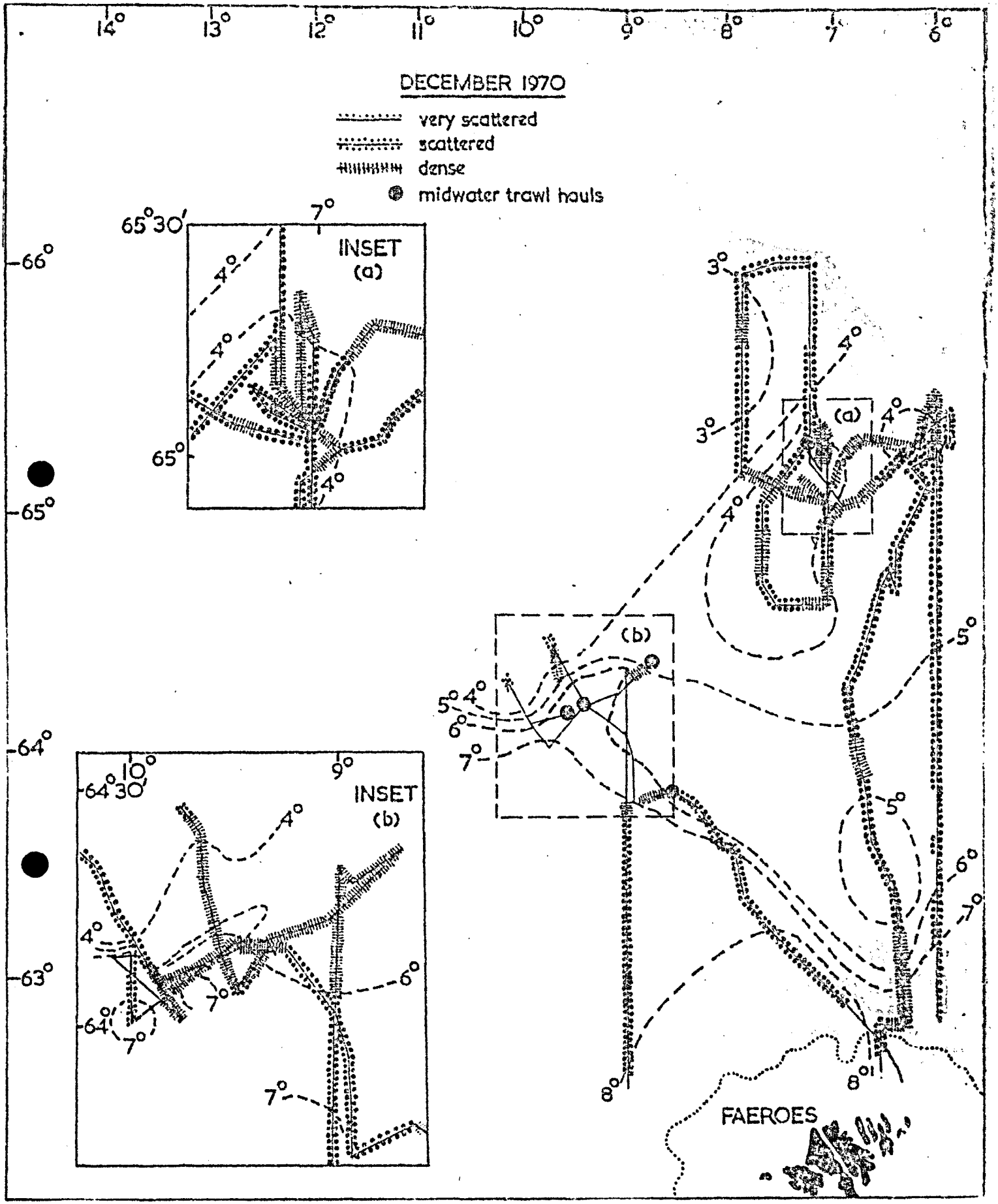

Fig. 4 Distribution of midwater echo-traces, trawl hauls and surface isotherms in December 1970.

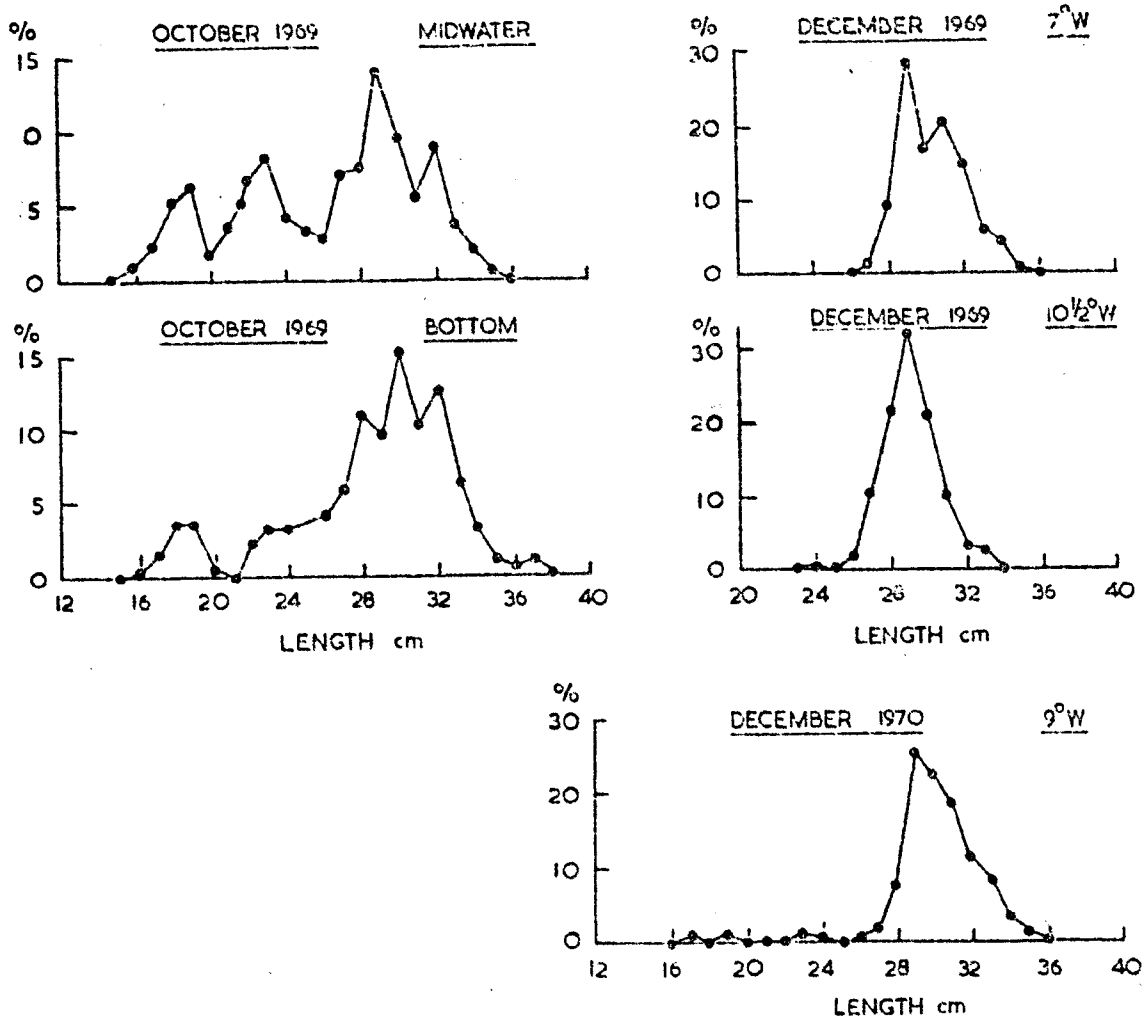

Fig. 5 Length distributions of samples of blue whiting from the Faroe-Iceland area.

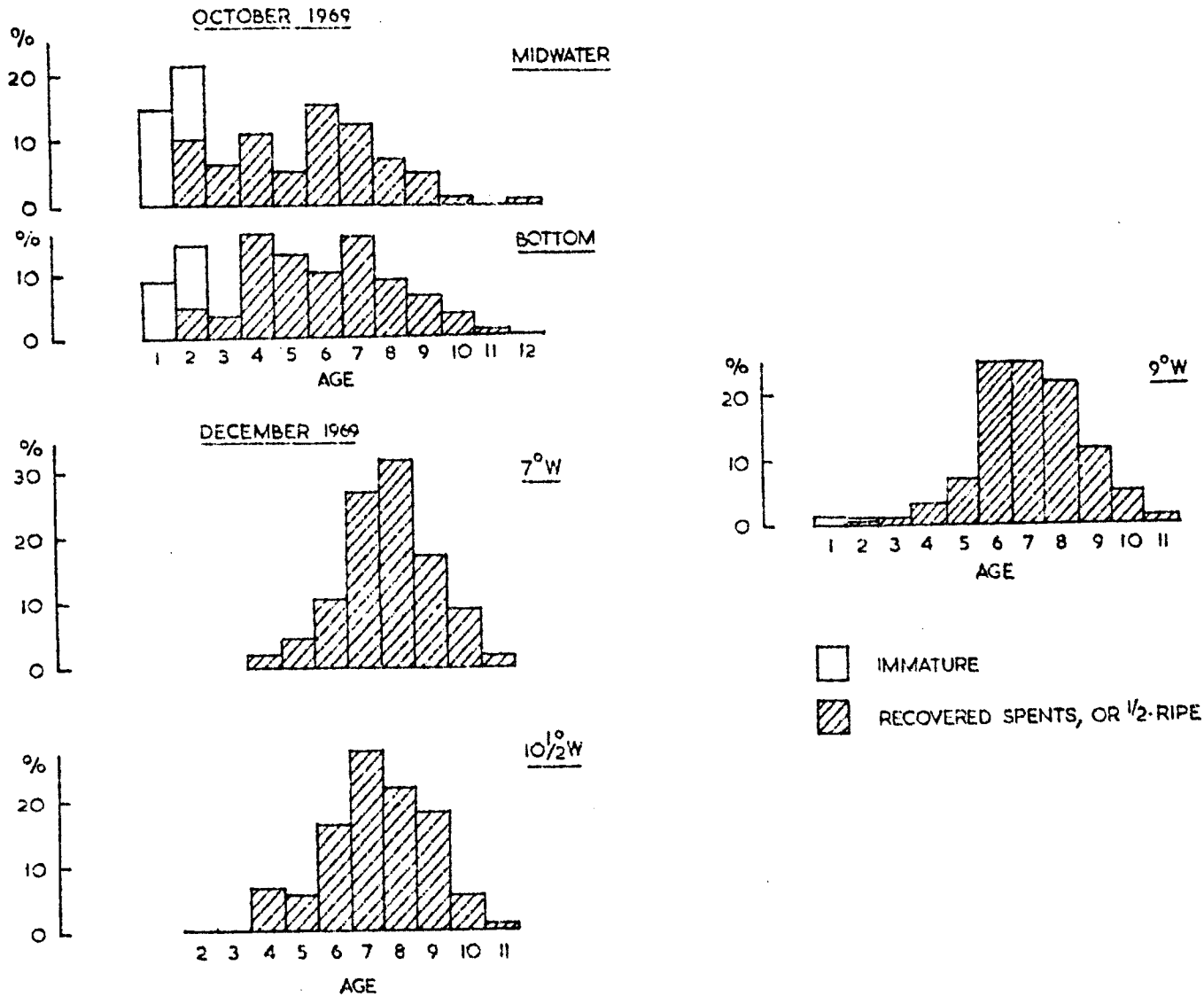

Fig. 6 Age composition of samples of blue whiting from the Faroe-Shetland area.