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Northwest Atlantic Fisheries Organization

Serial No. N1387

NAFO SCR Doc. 87/84

SCIENTIFIC COUNCIL MEETING - SEPTEMBER 1987

Spawning of Atlantic Halibut (Hippoglossus Hipploglossus L.) in Deep Waters of the Continental Slope South West of the Faroe Islands

by

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ABSTRACT

From the appearance of fish with running gonads, and of pelagic eggs in the water column, it is evident that the Atlantic halibut, *Hippoglossus hippoglossus*, spawns in late winter in deep waters on the continental slope southwest of the Faroe Islands. Almost exclusively sexually mature specimens are present in the spawning area (mainly depths below 700 m), while in shallower areas around the Faroes, small immature halibut are quite abundant. Temperatures and salinities in the spawning area are, in February, c. 8^0C and 35.25 o/oo respectively. A possible significance of the cold deepwater current running north-westwards just north of the spawning area through the Faroe Bank Channel, as a clue for halibut to identify the spawning area, is discussed.

INTRODUCTION

In Norwegian coastal inshore waters, Atlantic halibut, *Hippoglossus hippoglossus* (L.), spawning in early winter in deepwater localities (300-700 m) in certain fjords has been well documented (see, e.g., Devold 1938, Kjørsvik et al. 1987). From the occurrence of planktonic eggs and larvae (Jespersen 1917, Rollefsen 1934, Vedel-Tåning 1936, McIntyre 1958) and the occasional presence of adult fish with running or spent gonads in commercial catches (Hjort 1905, Jespersen 1917, Devold 1938) it has been inferred that the species most probably also spawns at certain deepwater areas laying on the slope of the continental shelf in various parts of the North Atlantic.

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Congregations of adult halibut on definite continental slope spawning grounds were not documented, however, until late 1982 - early 1983 when a Faroese trawler made very good catches of large halibut in a restricted area at 800-1000 m depth on the south-western slope of the Faroe Bank (Fig.1) (Jakupsstovu 1986). Later research in this area has revealed that spawning commenced in January and intensified with a peak of activity probably occurring later in winter or early in spring (Jakupsstovu & Haug 1987). This paper presents further results from these investigations including variations in the frequency of mature fish and in the size/age distributions in relation to depth and time of the year, the occurrence of planktonic eggs, and the hydrographic regime under which the halibut spawns and eggs develop in the area.

MATERIAL AND METHODS

The fish were caught in bottom trawls by r/v "Magnus Heinason". Three different commercial bottom trawls were used: One four paneled and two two-paneled. There was no apparent difference in the trawls' ability to catch halibut. Trawling took place in 1983 (November and December), 1984 (January), 1985 (January and February), 1986 (January and February) and 1987 (February), mainly in the deep water halibut spawning area on the continental slope northwest of the Faroe Bank, but several hauls were also made in shallower waters on the banks and coastal waters around the Faroes (Fig.2). The material from all years was pooled, while fish from the shallower hauls (<700 m) were treated separately from those from the deepest (>700 m) hauls.

Fish were sexed and total lengths were measured to the nearest cm below in most cases. Pairs of sagittal otoliths were collected and stored dry in envelopes. Otoliths were prepared for age determination using the method outlined by Bedford (1983), and the ages were read as described by Devold (1938).

Gonad maturity was determined according to several gross criteria along the scale given by Jakupsstovu & Haug (1987) where fish in maturity stages I-IV were regarded as immature, while those in stages V-VIII were classified as sexually mature.

In February 1987 planktonic egg surveys were carried out using a Tucker trawl (mesh size 1.0 mm) which was towed horizontally in a number of hauls at different depths in two parts (north and south of $61^{0}30'$N) of the spawning area. A more detailed description of the Tucker trawl used is given by Hopkins et al.(1982). Due to the large depths involved and weather conditions the opening/closing mechanism could not be used and the trawl had to be lowered and raised open. The approximate volume filtered at the determined depth during each haul (2800 m^3 per hour) was calculated using the area of the trawl opening (1 m^2) and the cruising speed of the ship (1.5 knots).

Halibut eggs were identified by their diameters and morphology (Russell 1976) immediately upon arrival on deck. They were then fixed in a solution of 2.5 % glutaraldehyde and 2.5 % formaldehyde in 0.05 mol/l cacodylate buffer (pH=7.2, 350 mosmol/kg), for later determination of egg diameters, and, if possible, developmental stages according to Rollefsen (1934) and Lønning et al. (1982).

Hydrographical data were recorded in the centre of the two egg-survey areas using a Neil-Brown CTD-profiler connected to a Hewlett-Packard computer. During the 1987 bottom trawl surveys, bottom temperatures were also recorded at 20 minute intervals using a temperature sensor mounted on to the trawl.

RESULTS

Size composition

Fish caught in the depths shallower than 700 m were generally smaller than those taken in deeper waters (Fig.3). In the shallower depths, males seldom exceeded 100-110 cm in length, while in the deeper areas the length range of males was 50-180 cm. Females were generally larger than males, and individuals ranging in size from 50 to more than 200 cm were observed both above and below 700 m depth, but with most large fish in the deeper strata.

No apparent change seemed to occur in size composition from month to month, yet such comparisons are complicated by the low number of individuals recorded in certain months.

Age composition

From Fig.4 it is evident that while the shallow strata (<700 m depths) were dominated by young fish (mainly 3-7 years old for both sexes), the fish from the deeper waters (>700 m) were generally older with ages ranging from 2-3 years to more than 25 years. It also appears from Fig.4 that females caught at depths below 700 m were generally older than males.

Sexual maturity

In the shallow strata above 700 m depths, the catches were predominated by immature fish (males as well as females) in November-January, although the number of fish caught in December and January were rather small (Fig.5). In February, however, considerable numbers of mature fish (with ripe or running gonads) were captured above 700 m depths.

Below 700 m depths immature fish were rather scarce, and the catches were dominated by sexually mature fish whose spawning preparedness became more and more evident from month to month (Fig.5).

Hydrography

In February 1987 the hydrographical conditions in the middle of the protected spawning area (the southmost CTD-station in Fig.1) were very homogeneous with temperatures (c. 8^{0}C), salinites (c. 35.25 o/oo) and sea water densities (c. 27.5) varying only very little from surface to bottom (Fig.6). Further north (the northmost CTD-station in Fig.1), however, there was a strong vertical gradient between 450 and 700 m depth (Fig.7), where the temperature changed from c. 8^{0}C to below 0^{0}C, the salinity from c. 35.3 o/oo to 34.9 o/oo, and the sea water density from 27.5 to 28.1 with increasing depth.

Usually, the bottom temperatures, as measured during the whole February 1987 cruise by the temperature sensor on the bottom trawl, ranged between 7-8^{0}C. On 16 February, however, when two bottom trawl hauls were carried out in the northern parts of the protected spawning area (Fig.1), very sudden changes occurred in temperatures during the hauls (Fig.8). During the first of these hauls (from north to south, Fig.8A), the temperature was below 0^{0}C when the trawl hit the bottom, but increased to c. 8^{0}C over a very short time interval and within a distance of less than 1 nautical mile. During the second haul (from south to north, Fig.8B), the temperature decreased from a little over 7^{0}C to less than 2^{0}C during the haul.

Egg-surveys

In the egg surveys, 21 and 7 Tucker Trawl hauls were carried out south and north of 61^{0}30'N respectively at depths varying between 10 and 900 m (Table 1). The hauls lasted between 45 and 130 minutes and filtered between 2100 and 5600 m^{3} sea water at the sampling depths. 5 halibut eggs were captured. South of 61^{0}30'N, 2 eggs were found at 800 m depth. In the northern area, 1 and 2 halibut eggs were found at 50 and 100 m depth respectively. The latter gives the largest egg concentration observed at any depth with 0.48 eggs per 1000 m^{3} filtered sea water. The average diameter of the halibut eggs was 3.22 ± 0.12 mm. Unfortunately, all halibut eggs were dead and cytolized after capture, such that their developmental stages could not be determined.

Additional to the halibut eggs, 3 small eggs (two with diameter less than 2.0 mm, and one with diameter 2.7 mm, species unknown) and 20 larger eggs with average diameter 3.60 ± 0.08 mm, segmented yolk, and a single yellow oil globule (average diameter 0.97 ± 0.12 mm), were captured during the surveys.

DISCUSSION

Apparently, some differentiation exists in the distribution of halibut with respect to age/size during winter in the investigated area. Most of the fish in deep water were mature, while in shallower strata small, imature fish were more abundant. This is consistent with observations made in the Nova Scotia/New Foundland area in North America (McCracken 1958). Furthermore, the almost complete absence of immature fish below 700 m depth, which from the appearance of fish with running gonads and pelagic eggs in the water column clearly should be considered a spawning area for the species, is consistent with observations from spawning areas on the coast of Norway (Devold 1938, Mathisen & Olsen 1968, Haug & Tjemsland 1986). The occurrence in February of some mature fish with running gonads at depths above 700 m, indicate that some spawning must also take place at these depths.

The apparent sexual difference in age distribution in the deeper strata, with a large proportion of males being younger, must be attributable to the lower size and age at which the males attain sexual maturity (Jakupsstovu & Haug 1987), and, thus, recruit to the spawning stock.

Based on data from the coast of North Norway, Olsen (1969) suggested that old fish which had spawned in previous years arrived on the spawning grounds earlier than first time spawners. The present size composition data give no evidence for such conclusions in the Faroe area.

Our hydrographical observations of extremely cold bottom water in the northmost part of the protected area are consistent with the fact that this is a part of the Faroe Bank Channel which runs north-westwards between the Faroe plateau and the Faroe Bank and is the deepest channell through in the Greenland-Scotland ridge. Through this channel is a continuous overflow of cold water masses from the Norwegian Sea to the North Eastern Atlantic; this cold subsurface current then follows the western flank of the Iceland-Faroe ridge, westwards along the deep parts of the southern Icelandic slope before it turns southwards to the southwest of Iceland (Hansen 1985). There also is some evidence for another branch of this flow descending westwards along the northern slope of the Faroe Bank (Hansen loc. cit.), i.e., just north of the spawning area. The extremely narrow front between this cold-water current and the warmer (8^0 C) water further south in the protected spawning area might represent a clue for halibut to identify the spawning area, although there is no evidence from tagging experiments in North Norway that halibut navigate in relation to currents when on migration (Godø & Haug in press). The potential deep-water current navigation of halibut in Faroese waters should be studied further.

The number of halibut eggs found during our February surveys was rather low. However, according to Jakupsstovu & Haug (1987), the sampling probably took place before the peak in spawning and more planktonic eggs could probably have been expected later in the year. This is supported by previous surveys in areas near or just above the continental slope between the Faroes and Iceland (Vedel-Tåning 1936) and south west of Iceland (McIntyre 1958), in April and early May, which yielded considerable numbers of eggs, clearly in excess of our present results.

The rather homogeneous hydrographical conditions observed from the surface to bottom south of 61^{0}30'N, and from thesurface to c. 400 m depth north of 61^{0}30'N may have contributed to an even vertical egg distribution, thereby lowering their relative abundance at all depths and reducing their chances of being caught in horizontal hauls with the type of gear/filtering capacity used. All eggs were found in temperatures and salinities of respectively 8.0-8.1^{0}C and 35.0-35.2 o/oo. They were found at large depths in the south, whereas in the north, they were only found in the upper layers. This apparent difference may indicate an influence of physical factors upon the vertical distribution of the eggs similar to those seen in Norwegian fjord areas by Haug et al. (1986). Further verification is needed, preferably later in the year when more abundance of planktonic eggs can be expected to be found.

The observed egg diameters of the halibut eggs found is consistent with previous measurements of pelagic halibut eggs (Vedel-Tåning 1936, Haug et al. 1984, Kjørsvik et al. 1987). According to Russell (1976) the larger eggs found which had segmented yolk and a single yellow oil globule were most probably from Argentinus silus, a species whose planktonic eggs were found in this area also during the previous surveys of Vedel-Tåning (1936).

ACKNOWLEDGEMENTS

Thanks are due to the crew and field assistants, A. Henriksen in particular, on board r/v "Magnus Heinason" for help during field work, B. Hansen for help with the hydrographical recordings and constructive criticizm, M.S. Nilsen and A. Svendsen for technical assistance, S. Sundby for criticizm of the manuscript and R.T. Barrett for corrections of the English. Financial support was received from the Norwegian Council of Fisheries Research (NFFR), project no. I.405.003.

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Table 1. Summary of the Tucker-trawl hauls and the number of fish eggs caught at various depths north and south of $61^0 30'$N in the halibut spawning area.

Depth (m)	North of $61^0 30'$N				South of $61^0 30'$N			
			No.of eggs				No.of eggs	
	No.of hauls	Vol. filtered (m^3) at depth	*Hippoglossus hippoglossus*	*Argentinus silus*	No.of hauls	Vol. filtered (m^3) at depth	*Hippoglossus hippoglossus*	*Argentinu silus*
10	1	2800	0	0	2	8400	0	0
50	1	4200	1	2	2	7000	0	0
100	1	4200	2	1	2	8400	0	0
200	1	4200	0	1	2	7000	0	0
300	1	4200	0	3	1	4200	0	0
350					1	5600	0	0
400	1	4200	0	0	1	4200	0	2
500					2	10000	0	1
600	1	4200	0	0	2	7700	0	1
700					2	8400	0	4
800	1	4200	0	1	2	8400	2	3
850					1*	4200	0	0
900					1**	4200	0	1

* Also two eggs with diameter <2.0 mm

** Also one egg with diameter 2.7 mm

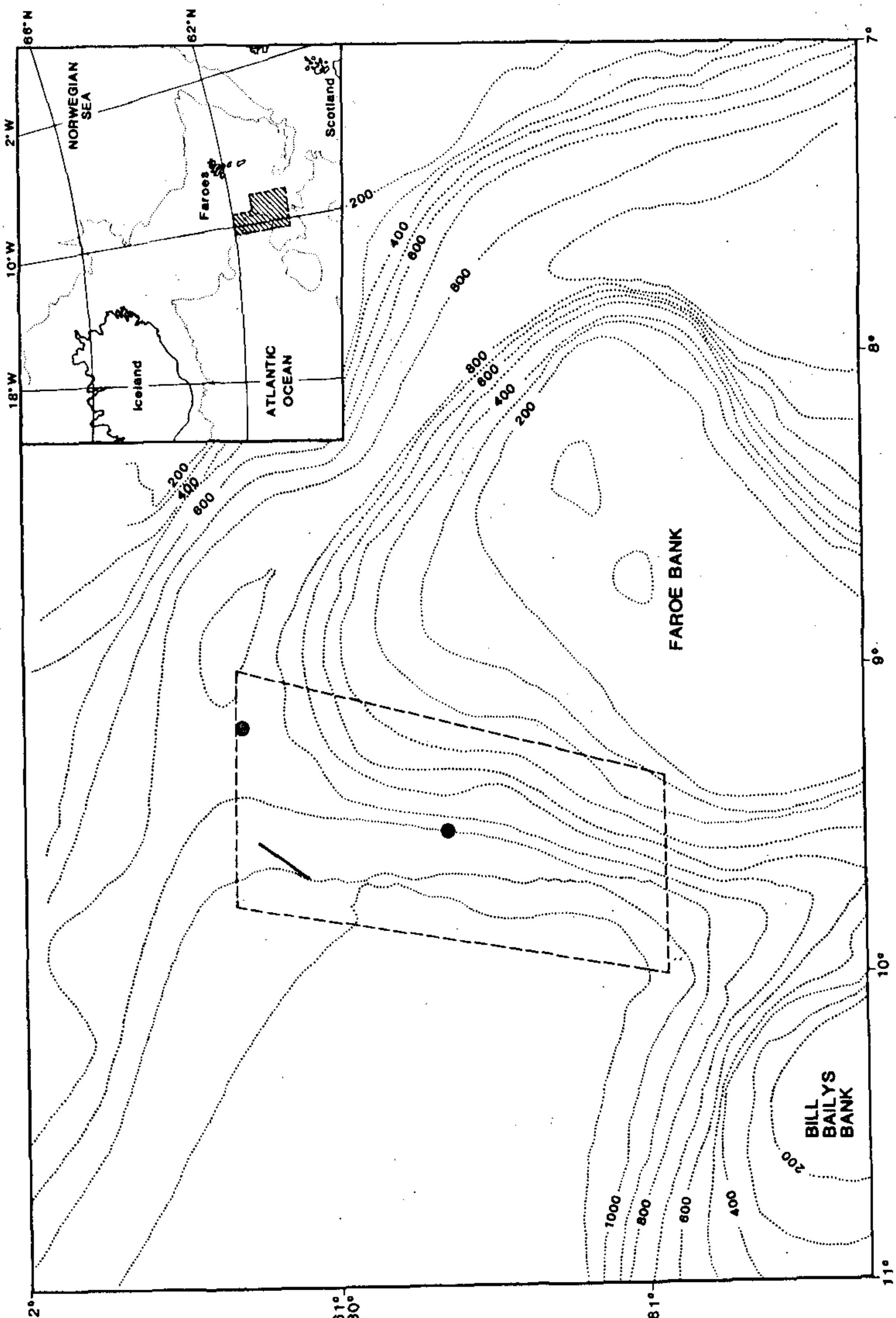

Fig. 1. The main research area (hatched) south west of the Faroes. On the detailed map are shown bottom topography, the protected halibut spawning area (stipled), the CTD-stations (black dots), and the track of the trawl on 16 February when large variations in bottom temperatures occurred (Fig.8).

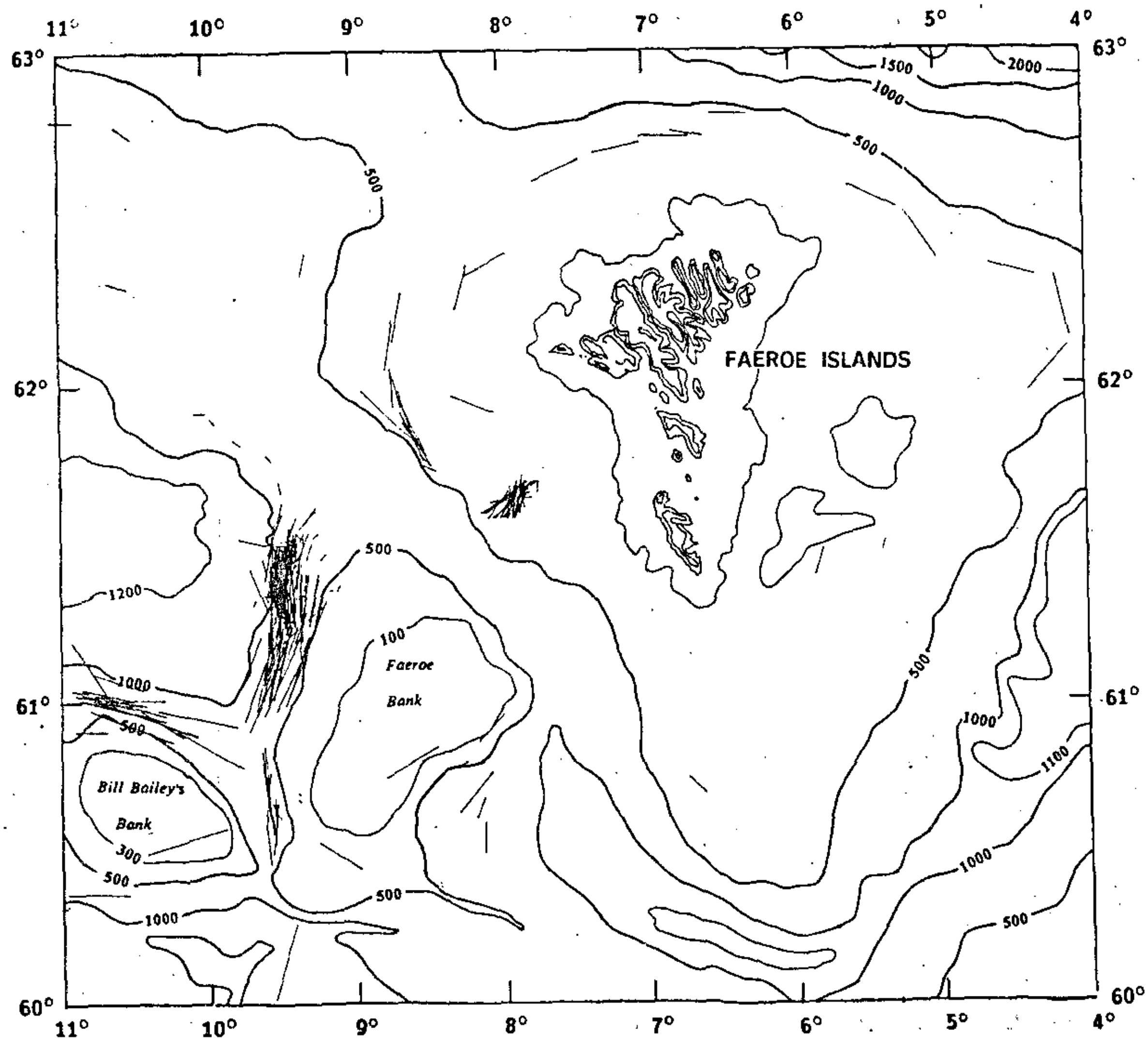

Fig. 2. Map showing the position of bottom trawl hauls in Faroese waters. Various depth strata are indicated, showing that both deep and shallow water hauls were included.

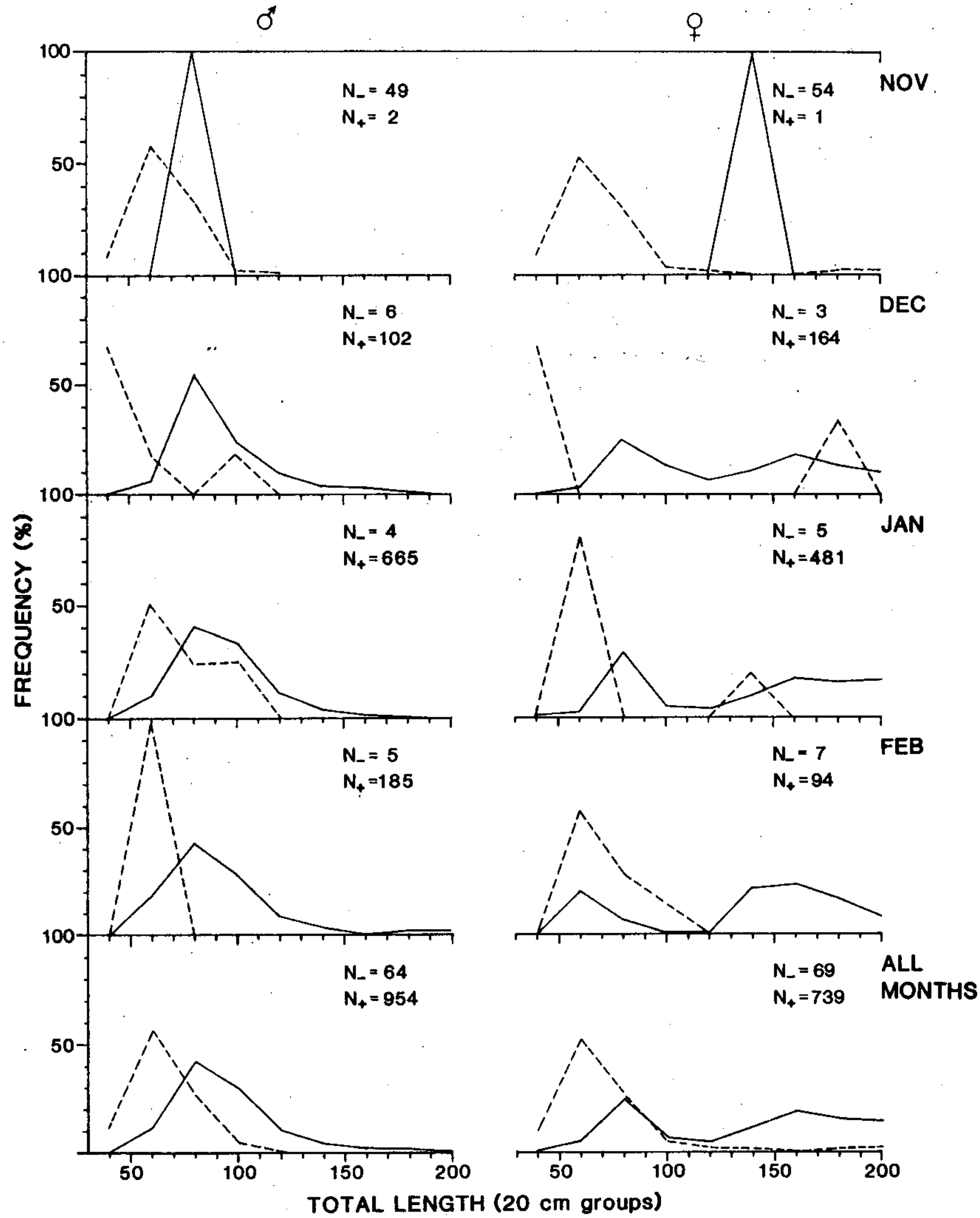

Fig. 3. Size composition (% frequency) of male and female halibut caught SW of the Faroes in November-February 1983-1987, above (stipled line) and below (solid line) 700 m depth. N_- and N_+ are number of fish caught above and below 700 m depth respectively.

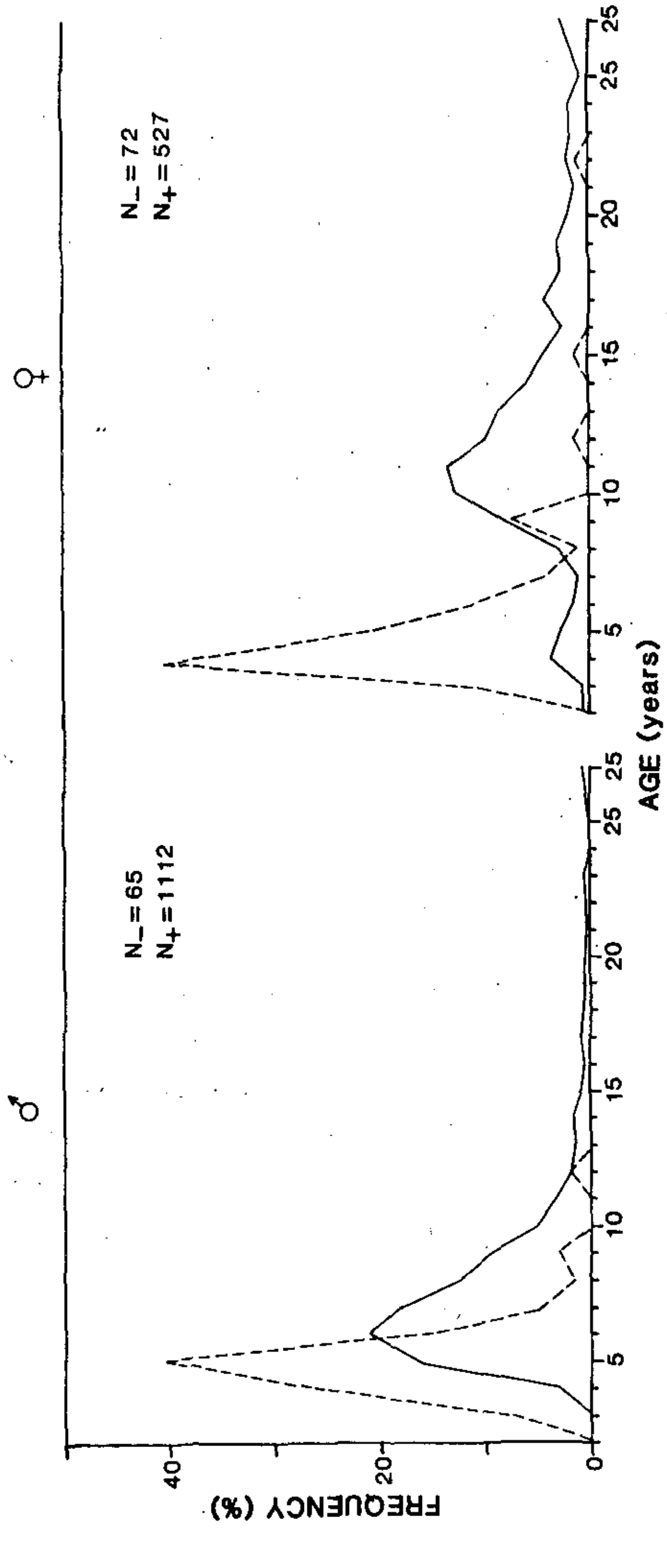

Fig. 4. Age composition (% frequency) of male and female halibut caught above (stipled line) and below (solid line) 700 m depth southwest of the Faroes in 1983-1987. N_- and N_+ are number of fish caught above and below 700 m depth respectively.

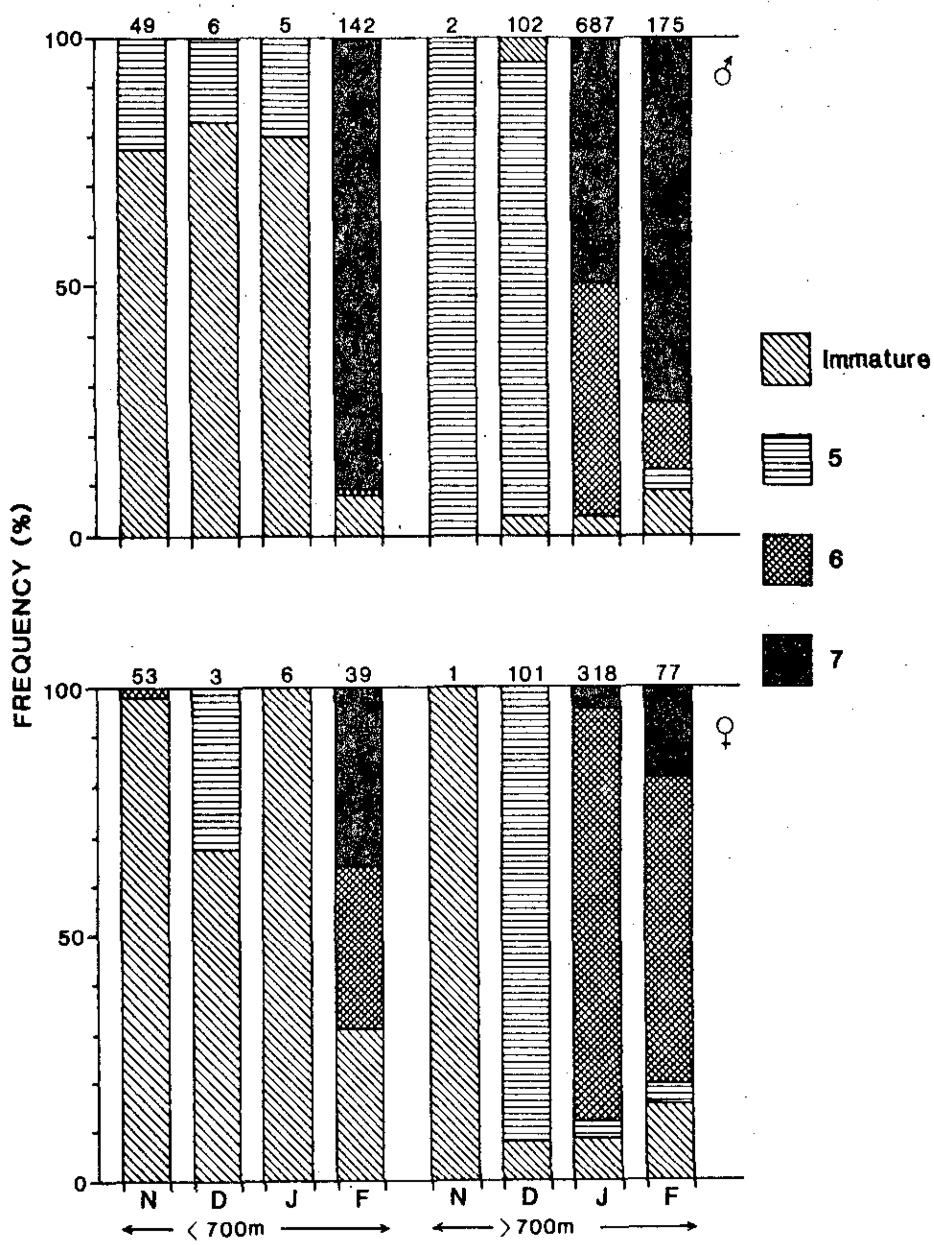

Fig. 5. Frequency of immature and mature male and female halibut caught above and below 700 m depth south-west of the Faroes in 1983-1987. Number of fish caught each month (Nov.-Feb.) are given above each column. For description of maturity stages 5-7, see Jakupsstovu & Haug (1987).

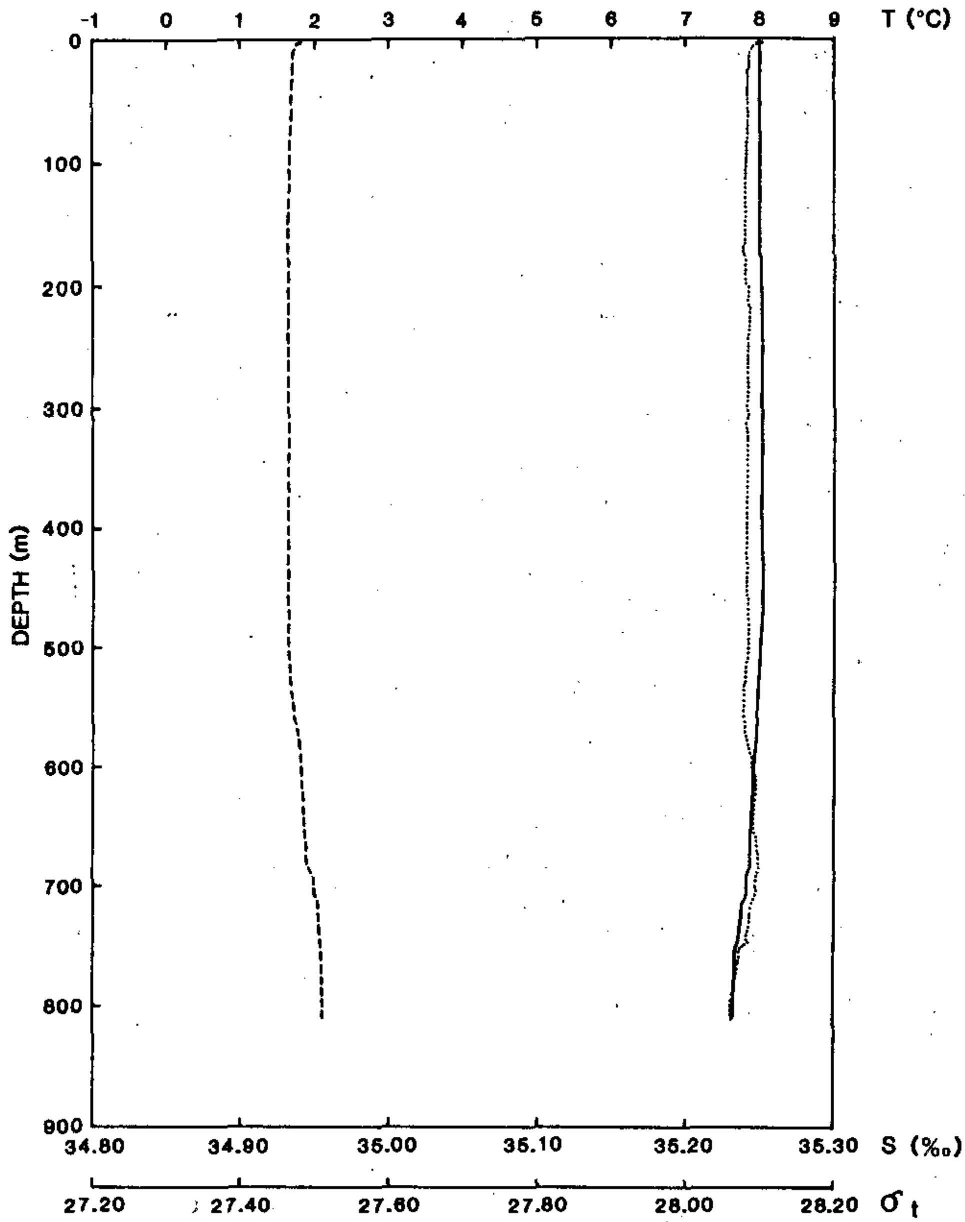

Fig. 6. Temperatures (T, solid line), salinities (S, dotted line), and sea water density (σ_t, stipled line) at various depths as recorded at the southernmost CTD-station (Fig. 1) on 6 February 1987.

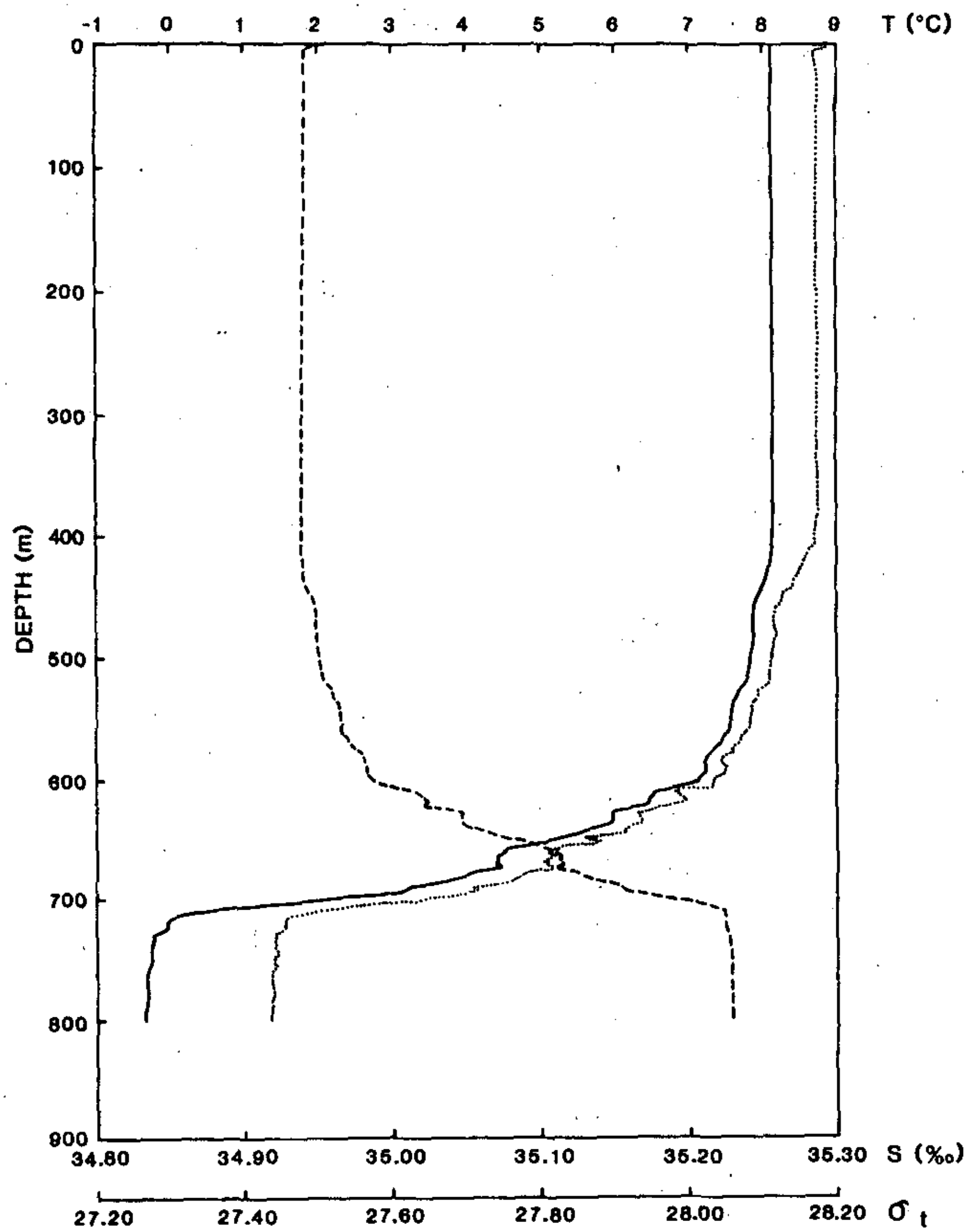

Fig. 7. Temperatures (T, solid line), salinities (S, dotted line), and sea water density (σ_t, stipled line) at various depths as recorded at the norternhmost CTD-station (Fig. 1) on 17 February 1987.

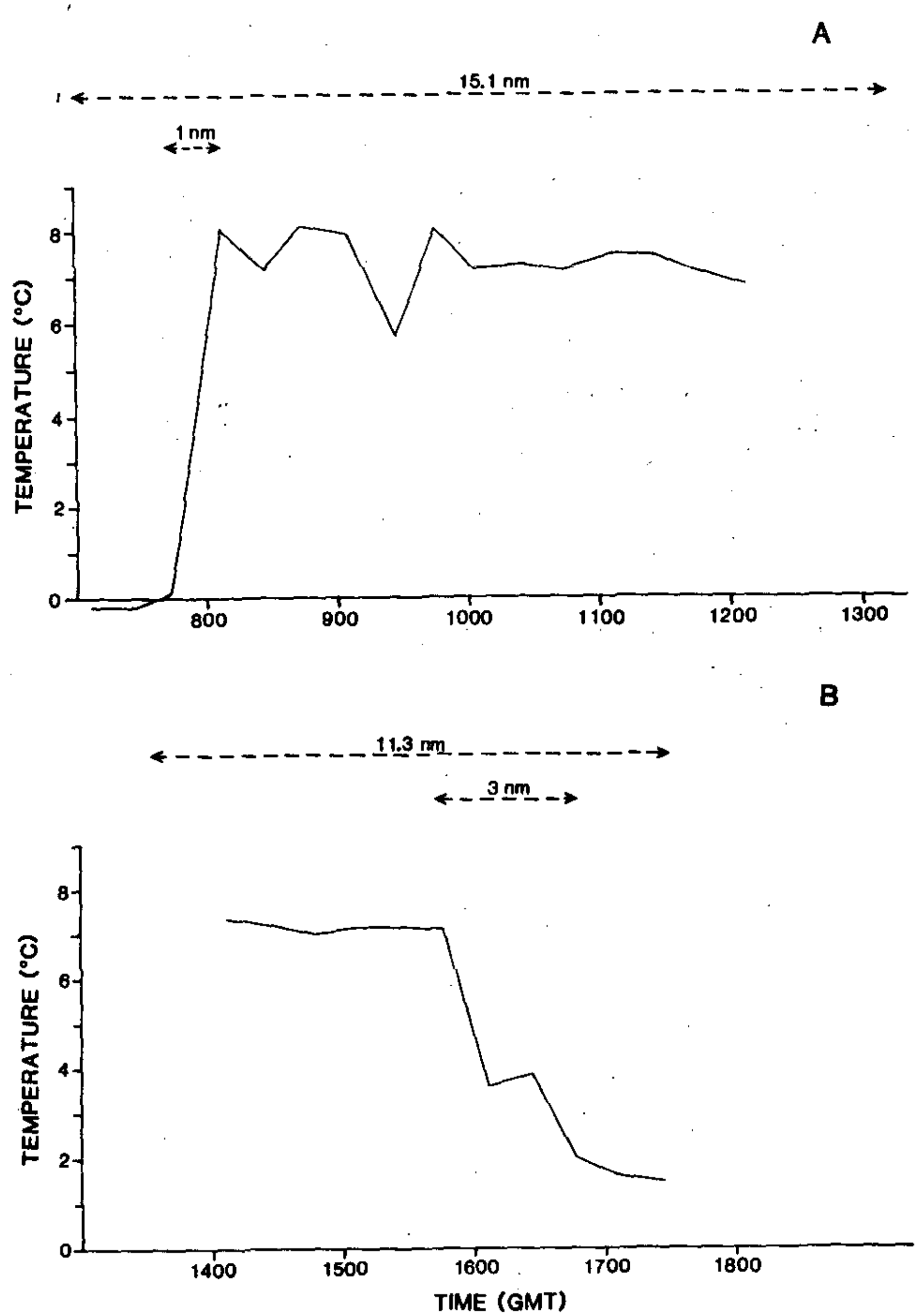

Fig. 8. Variation with time in bottom temperature as measured by temperature sensor during two bottom trawl hauls on 16 February 1987 (trawling position given in Fig. 1). A) is a north-south haul, B) is a south-north haul. Approximate distances travelled within different time intervals are also given.