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SPAWNING OF *CALANUS FINMARCHICUS* RELATED TO MESO-SCALE ENVIRONMENTAL STRUCTURES IN A NORWEGIAN SHELF BREAK FRONT

by

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ABSTRACT

Calanus finmarchicus has been observed to spawn vigorously in Norwegian shelf break fronts in early July, but the duration and the associated environmental premises have not been known. From mid March to August in 1995, monthly research vessel transects were made over 40 n. miles, from the Lofoten Islands across the shelf break, to gain more knowledge. The average abundance of *Calanus* nauplii accumulated over 10 n. miles was used as an index for reproductive activity, obtained by the filtering of seawater pumped through the ship's hull at 3.5 m depth. The same water passed both a SBE25 CTD to locate frontal structures by salinity changes, and a Q300 fluorometer to observe how the copepod reproduction was associated with potential food for the spawners. From March to late May the abundance of *Calanus* nauplii was low across the entire shelf. However, reproduction seems to have started at a low rate near the shelf break in early May, associated with high fluorescence and low salinity over the slope. On later dates the *Calanus* reproduction occurred over the inner shelf, except for in late July when it also occurred over the outer shelf and slope waters, supported by high fluorescence all over the shelf. It may be concluded that fronts on the outer shelf were not strictly associated with the shelf break, and could develop over the inner shelf as well, providing conditions which probably favour spawning in *C. finmarchicus*. However, the conditions observed in 1995 may be rather particular, being due to an abnormally cold climate which may have interferred with the meltwater discharge which normally occur in June and July. However, the investigation supports that *C. finmarchicus* spawns over extended periods during summer, associated with mesoscale instabilities over the NW Norwegian shelf.

INTRODUCTION

Nauplii of the copepod *Calanus finmarchicus* is the prime prey of cod larvae of North-East Arctic cod spawning at the Lofoten Islands, north Norway (Wiborg 1948, 1960, Sysoeva and Degtereva 1965). The abundance of this prey, which influences the larval survival rate of cod (Ellertsen et al. 1987), is a function of the number of spawning female *C. finmarchicus* advected from their wintering habitats. Thus, it can be deduced that year-class strength in NE Arctic cod may be a function of *C. finmarchicus* production in the previous summer.

C. finmarchicus probably has two reproduction seasons in the neritic regime of the Norwegian west coast. One occurs mainly on the inner shelf and in fjords in April (Sømme 1934, Wiborg 1954,). Another is reported to occur along the shelf edge in mid summer (Ruud 1929, Skreslet and Rød 1986) and may be the one which produces recruits to the wintering habitats.

There is no information on how lasting the summer reproduction period may be, as there are only observations from the shelf edge habitat from late June to early July. Nor is there any available information that meso-scale geophysical processes may be involved in the reproduction of *C. finmarchicus* in this habitat. To gain more information on these two issues, field observations were carried out during the summer of 1995.

The present paper is a preliminary report on parts of the sampled material.

METHODS

To observe the duration of the spawning of *C. finmarchicus*, sampling was made at approximately monthly intervals from mid March to late August. The shelf outside the Lofoten Islands was selected for the study, due to the short distance to the shelf edge (Fig. 1). Observations were made from R/V Oscar Sund, along a course-line from N68°24.4', E14°04.7' outside the island of Gimsøy, to N68°51.0', E12°48.0' outside the shelf break, covering a distance of 40 n. miles.

To study mesoscale structures, continuous monitoring of environmental variables were obtained from seawater pumped through the ship's hull at a depth of 3.5 m. Parts of the water was by-passed into a chamber containing a Q300 fluorometer and supplying water to a SBE25 CTD at a rate of 1 l min^{-1}.

Water leaving the CTD was filtered by 100 micron plankton gauze to sample copepod nauplii which would indicate areas of reproductive activity. Samples were obtained every 10 n. mile and conserved in 4% formaldehyde. Counts of *Calanus* sp. nauplii were made by a Wild M8 stereo microscope, under shore-based laboratory conditions. Nauplii of other copepod genera were not included in the counts, but it was not assessed whether the counts may involve several *Calanus* spp, other than *C. finmarchicus*.

The bottom depth along the section was recorded by a Simrad EK500 echo sounder. All observations and sampling was made during the voyage from the Lofoten Islands to the shelf break.

RESULTS

The bottom depth was about 50 m in the landward end of the course-line, but it mostly varied between 120 and 190 m, to the shelf break at 31 n. miles, where the slope descenced to about 800 m at 40 n. miles (Fig. 2). On the mid-shelf, the course-line crossed the northern slope of a bank which is 83 m deep. The topography of the outer part of the shelf, situated between 25 and 31 n. miles, is characterized by a 120 m deep ridge, running along the shelf break.

The abundance of *C. finmarchicus* N1-2 was very low in March and May, but in early May there was a low, but noticable concentration in the outermost quartile, at 30-40 n. miles (Fig. 3). In June, July and August the abundance was highest in the innermost quartiles, and it decreased with time. However, the abundance was high in all quartiles in July.

The abundance of *C. finmarchicus* N3-6 was low in March, but in early May very high in the first quartile, and also conspicuous in the third (Fig. 4). The relative distribution between quartiles were rather similar in late May, but had declined markedly. The abundance increased with time at the first quartile (0-10 n. miles), being very high in August. In July, it was also high in the outermost quartiles.

The fluorescence was at its lowest in March. It was also lower than 100 mV in early May, except for the outer 10 n. miles, where it increased and varied between 200 and 600 mV (Fig. 5). In late May it varied between 100 and 200 mV in most of the section, but dropped to a minimum in the outermost 10 n. miles. It was a little higher in June, with a slight minimum near the middle of the course-line. In July, the fluorescence varied between 200 and 400 mV, with several modes. In August, the recording started at a minimum below 100 mV, but the fluorescence rapidly increased to maxima near 200 mV, then fell to a lower level in the outemost part of the course-line. In general, the fluorescence increased over the last nautical miles, on all dates except March.

In March the surface salinity was below 33.5 S°/oo over the innermost part of the shelf, but gradually rose to more than 35.0 S°/oo over the slope where it became stable (Fig. 6). In early May, the salinity was stable, below 33.8 S°/oo over most of the shelf, to about 25 n. miles. It then increased to about 34.7 S°/oo at the shelf break. In late May the surface salinity was mostly stable below 33.8 S°/oo over the first 25 n. miles, except for a maximum higher than 34.3 S°/oo over the inner shelf. The salinity was rather stable between 34.5 S°/oo and 34.7 S°/oo over the outer shelf, untill the break where it exceeded 35.0 S°/oo. In late June the surface salinity was about 33.9 S°/oo over the inner shelf, higher than 34.0 S°/oo over the outer shelf, and about 34.9 over the outer 10 n. miles. In late July the surface salinity was characterized by two minima and two maxima in the range between 33.5 and 34.0 S°/oo, over the innermost 20 n. miles. It then increased to about 34.7 S°/oo in the outermost part. In August the salinity was lower than 33.5 S°/oo in the innermost part of the shelf, but at 10 n. miles it increased to more than 34.0 S°/oo, followed by a minimum at about 33.7 S°/oo. Two maxima at 20 n. miles were succeeded by a minimum before the salinity increased to about 34.9 S°/oo at the end of the section.

DISCUSSION

During the investigation in 1995, information from early May seem to lend just little support that the shelf edge waters may be a particular reproduction habitat for *C. finmarchicus*. Then *C. finmarchicus* N1-2 were present in low, but noteworthy numbers at the shelf edge (Fig. 3). From this habitat the nauplii seem to have drifted onto the shelf where *C. finmarchicus* N3-6 had accumulated between 20 and 30 n. miles (Fig. 4). The spawning activity seems to have been supported by high planktonic primary production, as indicated by high fluorescence from the shelf break at 31 n. miles, to the termination of the recording at 40 n. miles. The highest fluorescence occurred outside 36 n. miles, where the surface salinity had stabilized. Lower fluorescence closer to the shelf break, may have been due to dispersal of algal cells due to turbulence in the front, or grazing, for instance by spawning *C. finmarchicus*. The productive area was characterized by low surface salinity indicative of freshwater influence.

The high abundance of *C. finmarchicus* N3-6 at the inner part of the shelf in early May, was probably not related to reproduction at the shelf break. The nauplii may have been produced on the shelf, closer to the Lofoten Islands, but may as well have been advected from the Vestfjord, which is a wintering and spring spawning habitat for *C. finmarchicus*.

On later occasions the shelf break system was not outstanding in terms of low salinity (Fig. 6), high fluorescence (Fig. 5) and high numbers of *C. finmarchicus* nauplii (Figs 3 and 4). This may be ralated to an exceptionally cold climate on the NW Norwegian coast from late May throughout the investigation period. It probably caused the vernal meltwater discharge to subside in May, causing higher surface salinity over the outer shelf and the continental slope than in early May. This is in contrast to the the normal period for meltwater discharge which usually culminates in June or July (Skreslet 1976).

It appears that in years with low freshwater discharge, like in 1995, *C. finmarchicus* may reproduce on the Norwegian shelf itself. In July it reproduced over the whole shelf (Fig. 3), possibly due to comparatively high primary production in all parts (Fig. 5). The cause for high production may be found in fluctuating surface salinity across the shelf, possibly indicating instabilities with up-welling of nutrients in areas with high salinity.

Similar features occurred in late August when low salinity was recorded near the Lofoten Islands, probably due to run-off caused by local precipitation. Frontlike haline gradients were associated with maxima in fluorescence and high abundance of *C. finmarchicus* N1-6 on the inner shelf.

The present investigation does not confirm that the shelf break frontal zone is a spawning habitat for *C. finmarchicus* over extended periods during summer. Rather, in periods with low freshwater influence the spawning may occur over different parts of the shelf. However, the investigation indicated that the spawning may start at the shelf break as early as in the beginning of May. Despite the climate in 1995 probably provided atypical premises regarding the meltwater discharge cycle, the spawning activity of *C. finmarchicus* occurred during most of the summer, but on the shelf itself.

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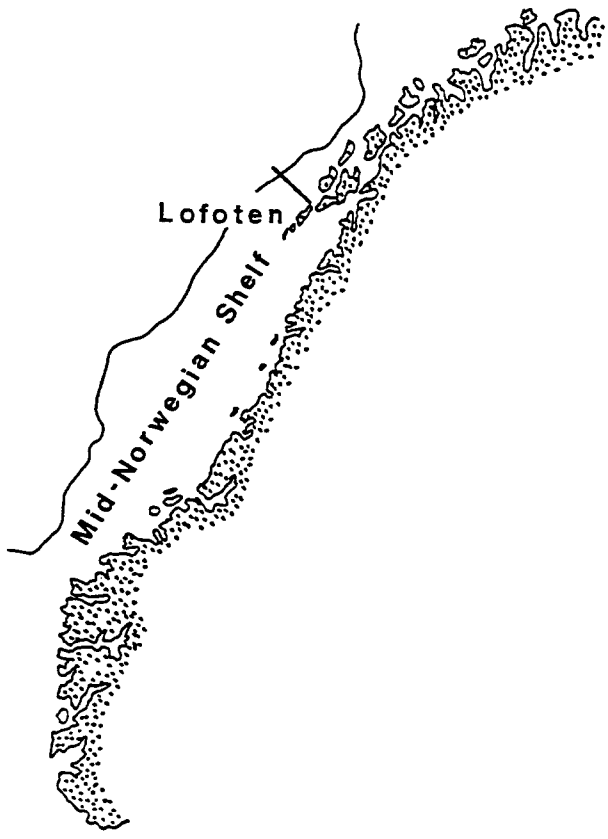

Fig. 1. Lofoten Islands with the repeated R/V Oscar Sund course-line.

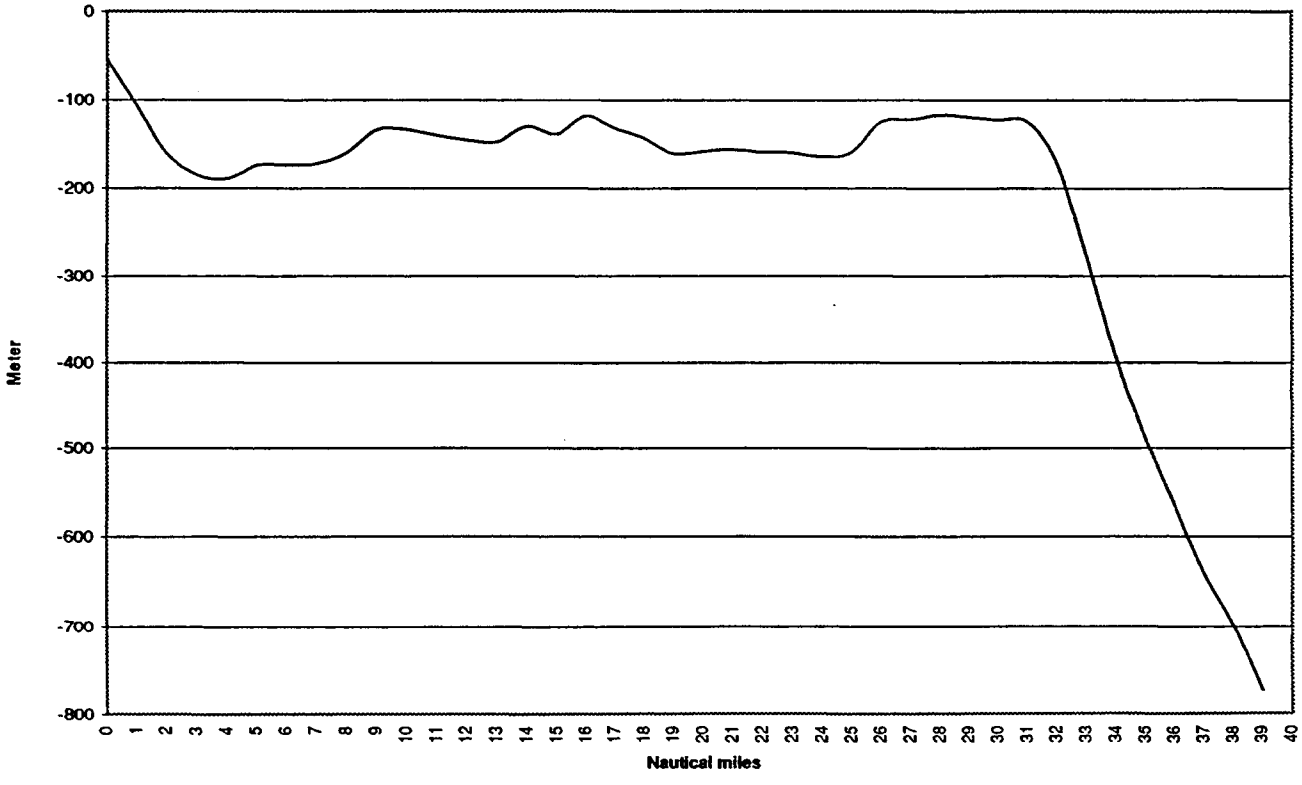

Fig. 2. Depth profile recorded by Simrad EK 500 echo sounder along the course-line.

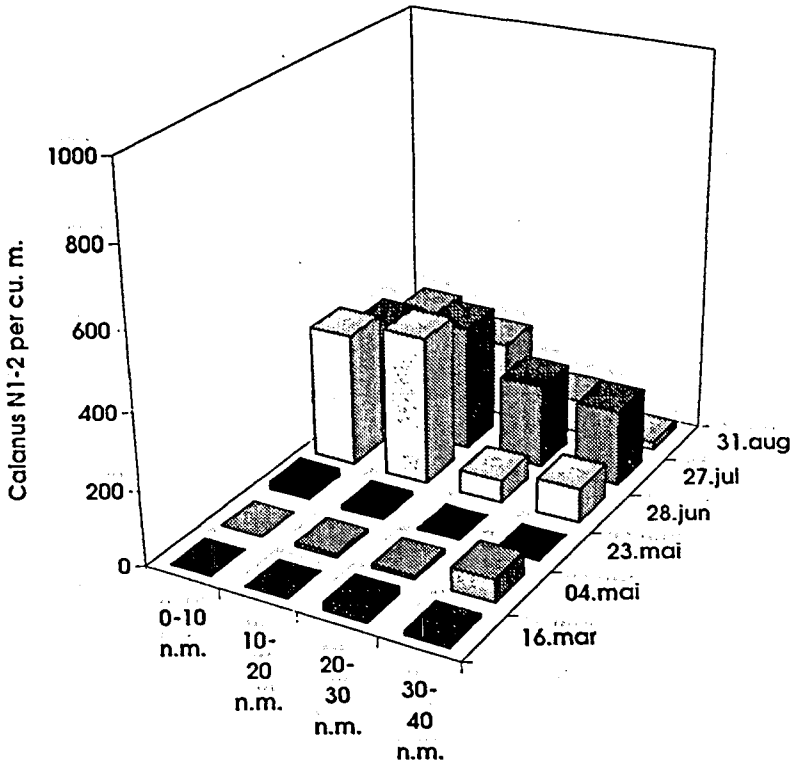

Fig. 3. Average abundance of *C. finmarchicus* naupliar stages 1-2 across the Lofoten shelf at different dates.

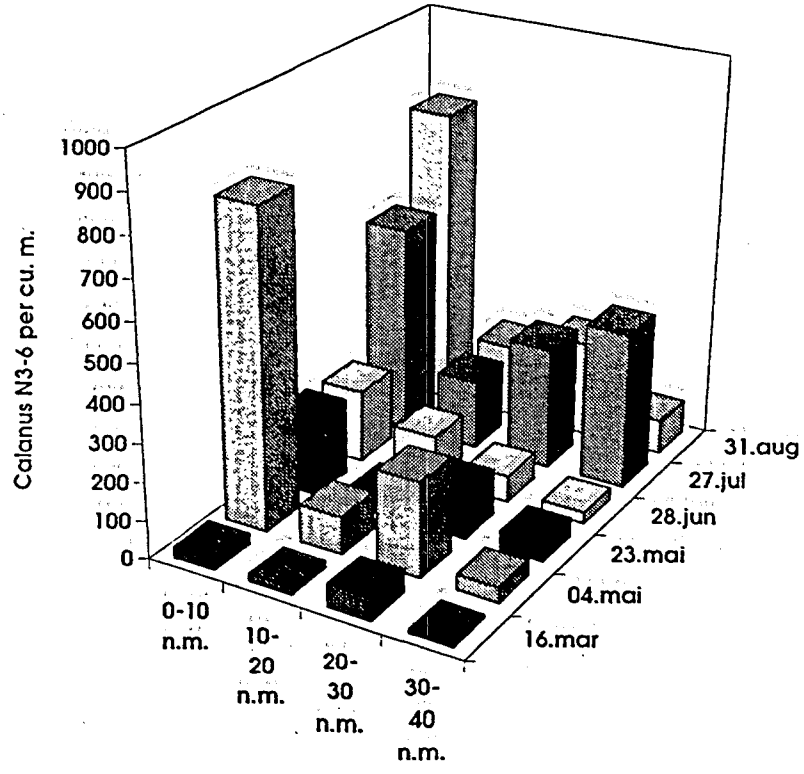

Fig. 4. Average abundance of *C. finmarchicus* naupliar stages 3-6 across the Lofoten shelf at different dates.

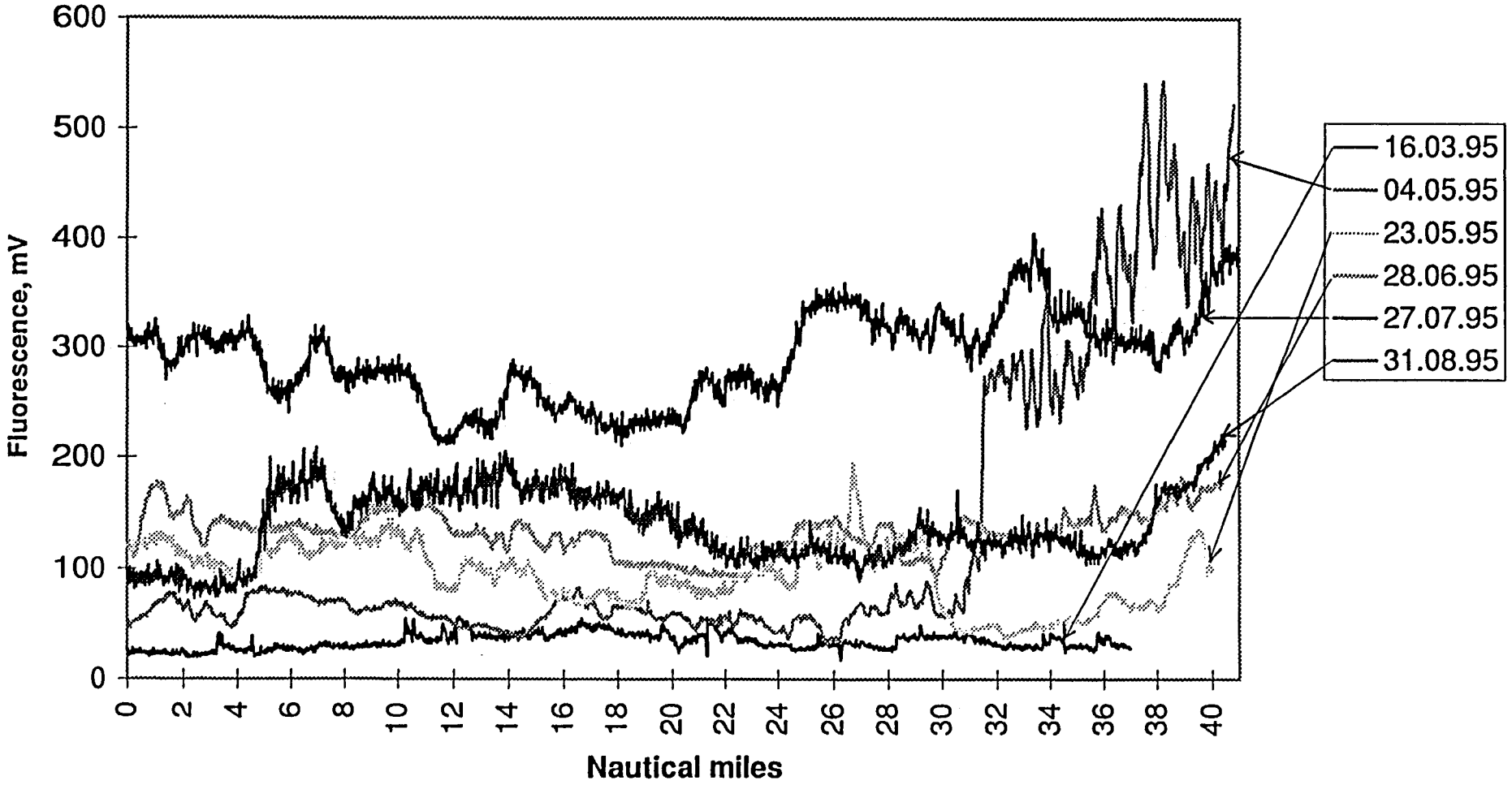

Fig. 5. Fluorescence recorded at 3.5 m depth every 10 second across the Lofoten shelf at different dates.

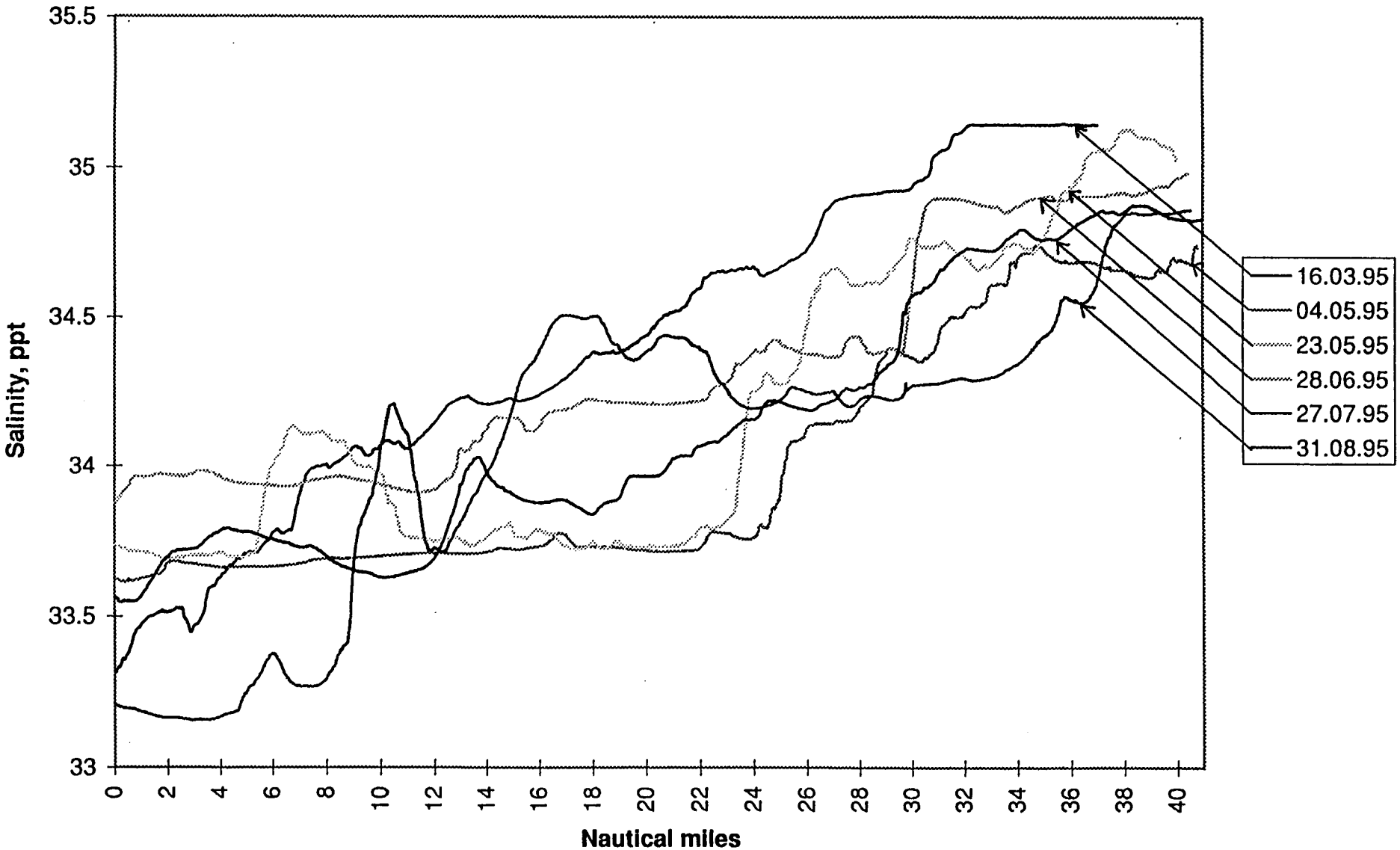

Fig. 6. Salinity recorded at 3.5 m depth every second across the Lofoten shelf at different dates.