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# INVESTIGATIONS ON DIEL VERTICAL MIGRATION OF 0–GROUP FISH IN THE BARENTS SEA

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ABSTRACT

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In August—September diel vertical migration of 0-group fish was studied in the Barents Sea. Redfish and capelin had different vertical migration patterns. 0-group redfish were found at the surface at dark and spread in the upper 50 m during the daylight period while the unpigmented 0-group capelin stayed in small schools close to the surface by daylight and dispersed into a weak scattering layer at the depth of the thermocline (20—30 m) at dark. This behaviour might introduce large errors to the abundance indices of 0-group capelin.

Comparative fishing with a pelagic trawl and a purse seine were carried out. The samples showed no significant differences in the length distributions of each species of 0-group fish caught with the two gears.

## INTRODUCTION

During late summer and early autumn fish fry of many species occur pelagically in the Barents Sea. Since 1965 joint international surveys have been carried out annually in this area during 12—15 days in late August and early September. The primary aim of these surveys has been to map the geographical distribution and to obtain estimates of yearclass strength of the different species of 0-group fish. Preliminary results have each year been reported to the International Council for the Exploration of the Sea (ANON. 1965—1974 a).

The distribution and density of the pelagic layers of 0-group fish have been observed with echo sounders, echo integrators and small meshed pelagic trawls. Details of the technique applied are given in DRAGESUND, MIDTTUN and OLSEN (1970), and a thorough description and discussion of the method was made by ANON. (1974b).

The main results from these surveys are indices of yearclass strength (HAUG and NAKKEN 1973). These indices might be influenced both by the sampling efficiency of the pelagic trawls and by the behaviour of the fish. The vertical migration of the different species may thus effect observations both with echo sounders and pelagic trawls.

Diel vertical migration is a well known feature of the behaviour of most pelagic fishes. WOODHEAD (1966) and BLAXTER (1970) have reviewed the literature on the subject. Normally, pelagic fishes are found at intermediate depths during the day, they move towards the surface at dusk and descend at dawn. This general pattern will probably vary with fish size, species and environmental factors. Although a few investigations have been carried out on redfish larvae (KELLY and BAKER 1961 a, KELLY and BAKER 1961 b, MAGNUSSON, MAGNUSSON and HALLGRIMSSON 1965), the diel vertical migration pattern of the 0-group fish in the Barents Sea was considered to be insufficiently known. During the survey in 1974 experimental work was therefore conducted to study this subject, and the results from the experiments are reported here.

## MATERIAL AND METHODS

The investigations were carried out with the 600 tons purse seiner «Havdrøn» which is also fitted for pelagic trawling and equipped with Scientific sounder, EK 38, two echo integrators, QM, and a net sonde. Observations were collected in three different localities (Fig. 1). The periods of observations were as follows:

Area 1: 27—29 August  Area 2: 1— 3 September
Area 3: 4— 5 September

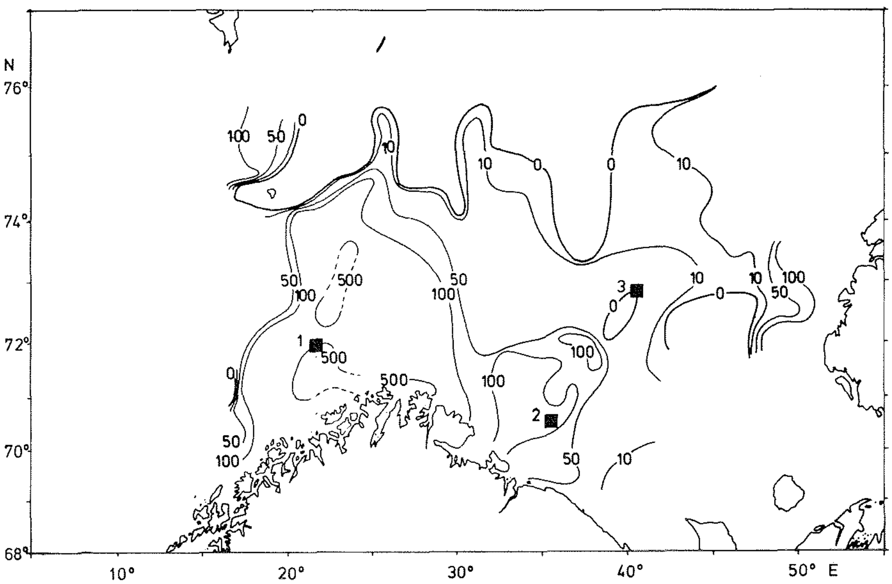


Fig. 1. Localities where diel vertical migration pattern of 0-group fish were studied in August—September 1974. 1) Area 1, 2) area 2, 3) area 3. Isolines indicate the echo integrator deflections observed during the international 0-group survey.

The selection of the areas were made on basis of information from the other vessels which participated in the survey. A standardized sampling procedure was followed in all three areas. An anchored bouy was used as a fixed position. Another bouy, attached to a free floating drogue in 25 m depth, was used as the point of reference for a small scale survey (Fig. 2). The grid of the small scale survey was continuously adjusted to keep the drogue at point A (Fig. 2). The arrows in Fig. 2 indicate «Havdrøn»s courses, and during one small scale survey the ship sailed 32 nautical miles. Between each completed survey one trawlhaul, one hydrographic station, one plankton haul and one series of light measurements were taken (Fig. 2). In each of the areas 1 and 2 ten small scale surveys were carried out while five completed surveys were found to give sufficient information in area 3.

When the weather conditions permitted, the 0-group fish scattering layer was observed by scuba divers. The divers observed the water column from 0 to 30 meters once by daylight and once at dark in area 2, and once at dark in area 3.

The four echo integrator channels were continuously monitoring the following depth intervals: 6—15 m, 15—30 m, 30—60 m, 60—200 m.

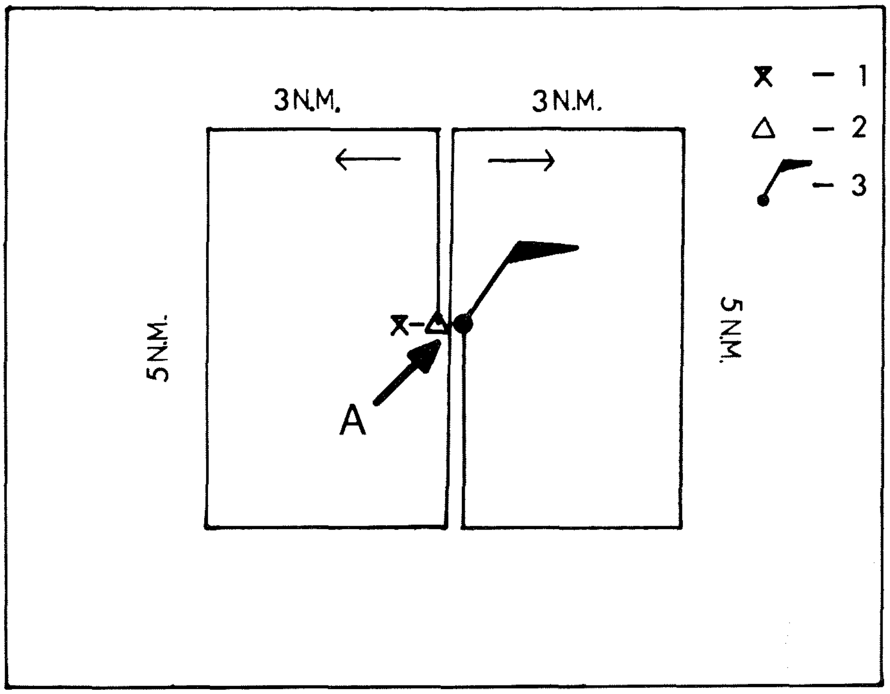


Fig. 2. The small scale survey conducted in the three areas. A) Start and end. 1) Hydrography and plankton station, 2) pelagic trawl and purse seine station, 3) drogue.

Their outputs were read for each nautical mile and then averaged for each half completed small scale survey. The values were converted to R.V. «G. O. Sars» values in order to be directly comparable to the figures in Fig. 1 (BUZETA *et al.* 1974).

The fishing gears, which were used, were of commercial sizes with minor modifications for sampling of 0-group fish. The purse seine was a capelin net 470 meter long and 112 meter deep with a mesh size of 20 mm. In the very end of the bunt a piece of webbing, 28 meter long with mesh size 5 mm, was inserted to prevent the smallest fishes to escape. The pelagic trawl was a capelin trawl, 1000 meshes in circumference with a mesh size of 400 mm, giving an approximate vertical opening of 10—14 meters at 3.5—2.5 knots towing speed. An inner net of mesh size of 12 mm was used in the codend.

The hydrographic stations were worked with Nansen bottles and bathythermograph. Plankton samples were collected with a 180 $\mu$ Juday net, hauled vertically from 50 meter to the surface. The light measurements were made at 1 m depth.

## RESULTS

### *HYDROGRAPHY*

Fig. 3 shows the drift of the current cross in area 1 and 2. The average velocity of the drogue was 0.1 knot in both areas. In area 3 the displacement of the drogue was less than the error of the positioning.

Fig. 4 shows the vertical temperature distribution in the three areas. In all areas there was a thermocline between 25 and 40 meters, the vertical temperature gradient being more pronounced in area 3 than further west.

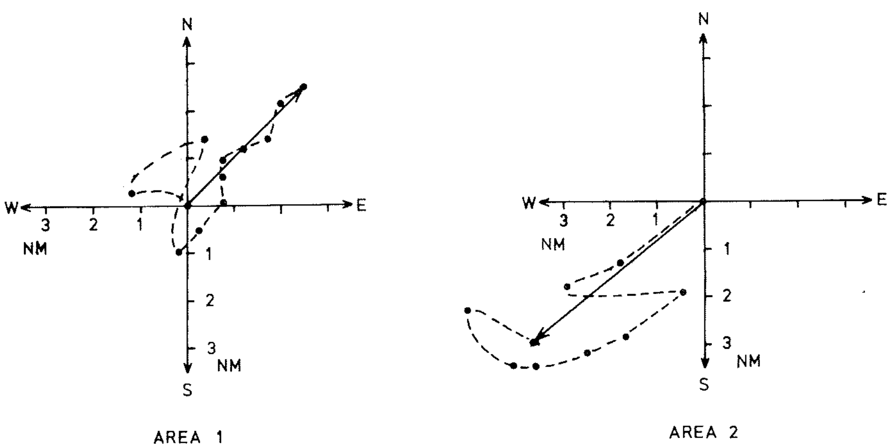


Fig. 3. Drift of drogues during the period of the small scale survey.

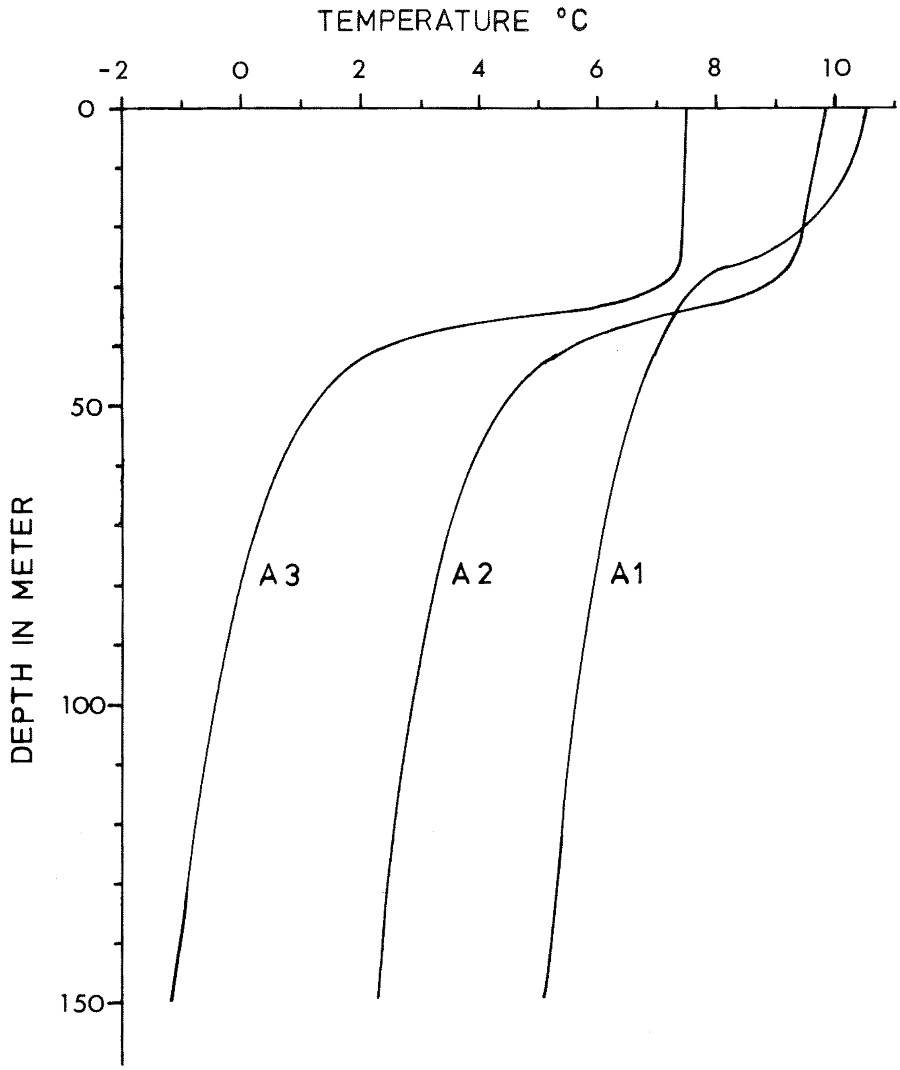


Fig. 4. Vertical distribution of temperature in the three areas.

## *DISTRIBUTION OF 0—GROUP FISH*

The composition of species in the catches are given in Table 1, 2 and 3. According to these tables the distribution of 0-group fish in the three areas can be characterized as follows:

Area 1 was a «pure» redfish area. In area 2 redfish and capelin were mixed while area 3 was a «pure» capelin area. The contribution from other species was quite low compared to the contribution from capelin and redfish.

Table 1. Composition of trawl and purse seine (PS) catches of 0-group fishes in area 1.

| St. No. | Date | Hrs. (GMT) | Depth Meters | Redfish | | Haddock | | Cod | | Long Rough Dab | | Mackerel | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | No. | % | No. | % | No. | % | No. | % | No. | % |
| 1 ..... | 27 Aug. | 1930 | 35—48 | 8 000 | 100 | 3 | + | 2 | + | — | — | — | — |
| 2 ..... | 28 » | 0040 | 25—38 | 3 000 | 100 | 6 | + | — | — | — | — | — | — |
| 3 ..... | 28 » | 0547 | 22—34 | 1 300 | 98 | 9 | 1 | 6 | + | 2 | + | 14 | 1 |
| 4 ..... | 28 » | 1014 | 10—22 | 13 750 | 100 | 42 | + | 5 | + | — | — | 1 | + |
| 5 ..... | 28 » | 1510 | 25—38 | 6 000 | 100 | 1 | + | — | — | — | — | — | — |
| 6 ..... | 28 » | 2108 | 10—40 | 1 000 | 99 | 8 | 1 | — | — | 2 | + | — | — |
| 7 ..... | 29 » | 0300 | 20—40 | 4 300 | 100 | 6 | + | — | — | 1 | + | — | — |
| 8 ..... | 29 » | 0754 | 10—40 | 5 600 | 99 | 30 | 1 | — | — | — | — | 11 | + |
| PS 1 ..... | 29 » | 1814 | 0—60 | 25 800 | 99 | 181 | 1 | 4 | + | — | — | — | — |
| PS 2 ..... | 29 » | 2055 | 0—60 | 52 000 | 99 | 460 | 1 | 20 | + | — | — | — | — |

Table 2. Composition of trawl and purse seine (PS) catches of 0-group fishes in area 2.

| St. No. | Date | Hrs. (GMT) | Depth Meters | Redfish | | Capelin (Unpigmented) | | Capelin (Pigmented) | | Haddock | | Cod | | Long Rough Dab | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | No. | % | No. | % | No. | % | No. | % | No. | % | No. | % |
| 11 | 31 Aug. | 2045 | 25—37 | 91 | + | 46 300 | 99 | 337 | 1 | 6 | + | 52 | + | 2 | + |
| 12 | 1 Sep. | 0027 | 22—42 | 850 | 3 | 28 800 | 97 | 102 | + | 5 | + | 16 | + | 6 | + |
| 13 | 1 » | 0316 | 15—37 | 190 | 95 | — | — | — | — | 1 | + | 2 | 1 | 6 | 3 |
| 14 | 1 » | 1509 | 25—42 | 125 | 51 | 110 | 45 | — | — | — | — | 1 | + | 8 | 3 |
| 15 | 1 » | 1919 | 22—40 | 135 | + | 122 400 | 99 | 780 | 1 | 8 | + | 24 | + | 1 | + |
| 16 | 1–2 » | 0003 | 30—42 | 73 | + | 71 250 | 95 | 3 900 | 5 | 2 | + | 10 | + | 4 | + |
| 17 | 2 » | 0410 | 10—32 | 260 | 22 | 600 | 51 | 271 | 23 | 10 | 1 | 37 | 3 | 1 | + |
| 18 | 2 » | 0848 | 10—25 | 450 | 59 | — | — | 267 | 35 | 5 | 1 | 35 | 5 | — | — |
| 19 | 2 » | 0957 | 0—12 | — | — | 5 000 | 100 | 36 | + | — | — | 1 | — | — | — |
| 20 | 2 » | 1544 | 30—42 | 7 | 12 | 8 | 14 | 40 | 70 | 1 | 2 | — | — | 1 | 2 |
| 21 | 2 » | 2217 | 10—40 | 445 | + | 127 500 | 99 | 170 | + | 3 | + | 21 | + | — | — |
| 22 | 3 » | 0220 | 30—42 | 9 | 45 | — | — | — | — | 5 | 25 | 6 | 30 | — | — |
| 23 | 3 » | 0312 | 0—12 | 8 100 | 45 | 10 000 | 56 | 1 | + | 4 | + | 2 | + | — | — |
| PS 3 | 3 » | 1305 | 0—60 | 4 200 | 92 | 176 | 4 | 135 | 3 | 34 | 1 | 4 | + | — | — |
| PS 4 | 3 » | 1612 | 0—60 | 8 700 | 99 | — | — | — | — | 41 | + | 18 | + | — | — |
| PS 5 | 3 » | 2250 | 0—60 | 2 700 | 72 | 1 000 | 27 | 6 | + | 47 | 1 | 17 | + | — | — |

Table 3. Composition of trawl catches of 0-group fishes in area 3.

| St. No. | Date | Hrs. (GMT) | Depth | Capelin (Unpigmented) | | Capelin (Pigmented) | | Cod | | Long Rough Dab | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | No. | % | No. | % | No. | % | No. | % |
| 24 | 5 Sept. | 1526 | 0—12 | 49 000 | 100 | 151 | + | — | — | — | — |
| 25 | 5 Sept. | 1919 | 0—12 | 10 000 | 100 | 33 | + | — | — | — | — |
| 26 | 5 Sept. | 2255 | 20—35 | 13 800 | 86 | 2 120 | 13 | 100 | 1 | 2 | + |

Fig. 5 shows selected typical echograms from the areas. It appears from the paper record that the redfish in area 1 had a rather wide spread vertical distribution in daylight, but concentrated in the upper layer at dark. This is also clearly demonstrated in Fig. 6 where the contributions from the different echo integrator channels are presented as a function of time. During the dark 80—100% of the reflecting scatterers were observed in the upper channel, 6—15 m. The total echo abundance showed no significant diel variation.

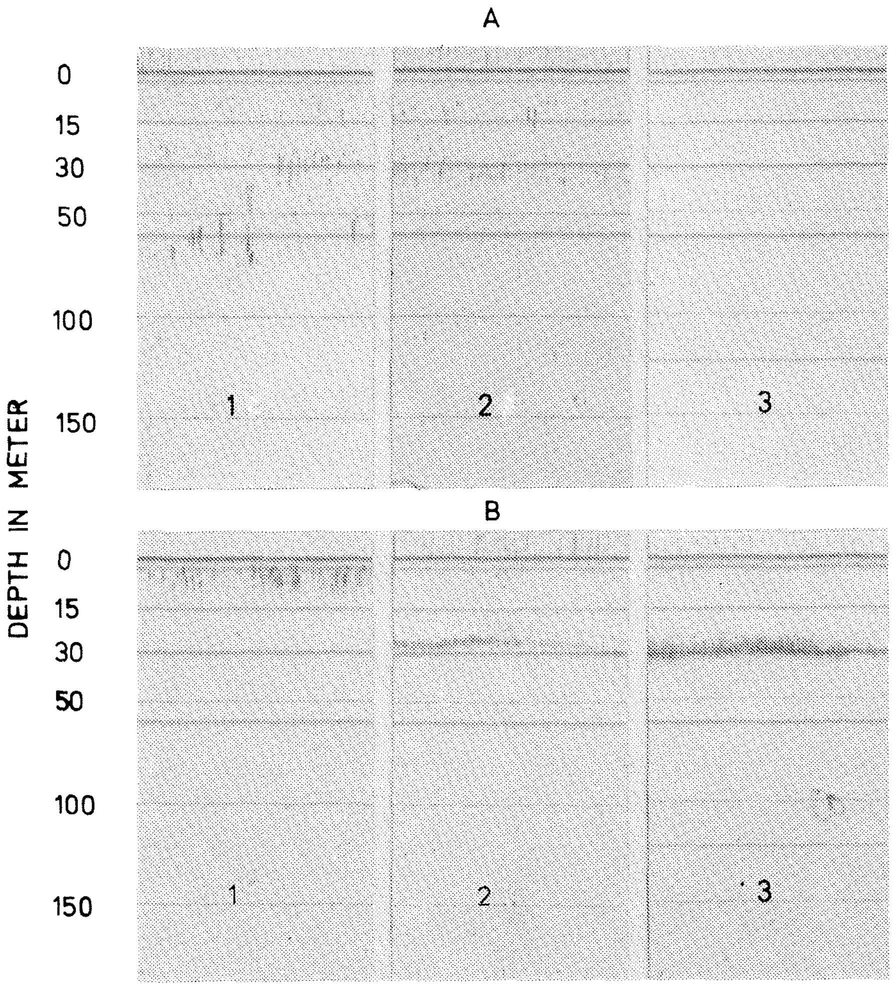


Fig. 5. Typical echo recordings from the three areas. A) Daylight, B) at dark. 1) Area 1, 2) area 2, 3) area 3.

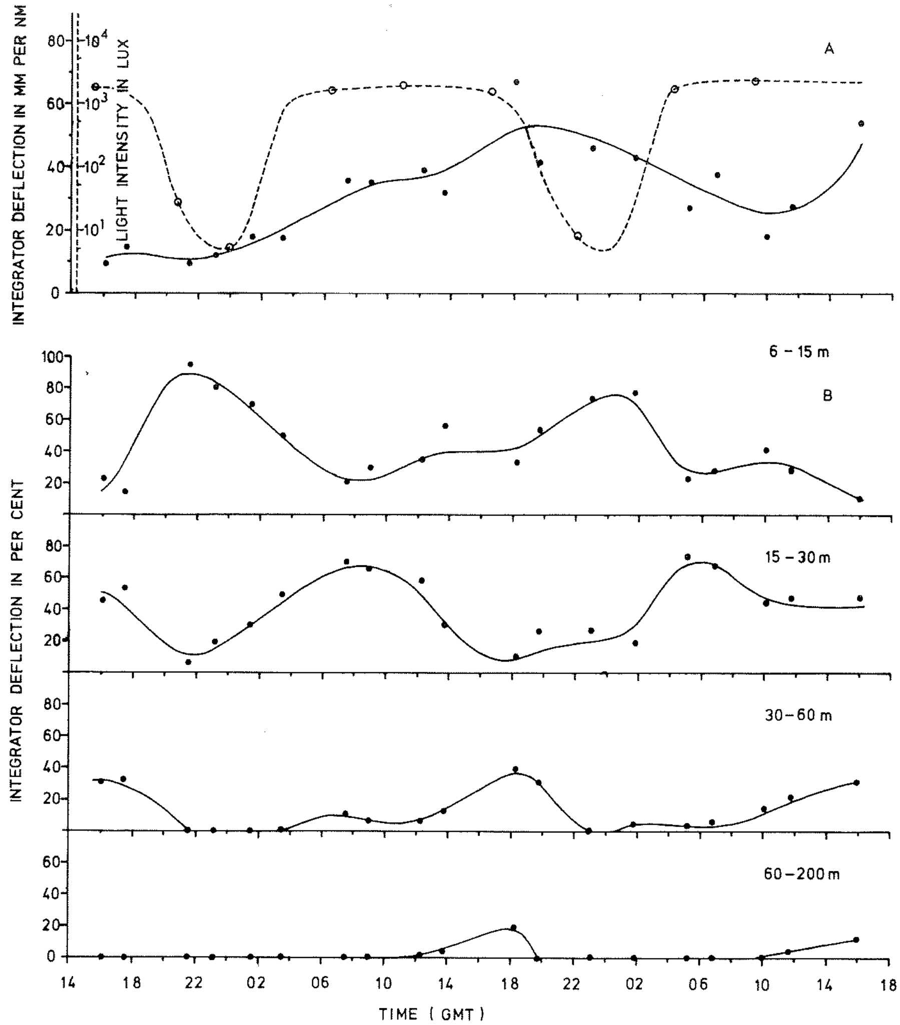


Fig. 6. A) Total echo abundance and light intensity according to time in area 1. B) The contribution to the total echo abundance from various depths according to time.

In area 2 a significant diel variation in echo abundance was observed (Fig. 7). The integrator deflection was significantly higher at dark than in daylight. There was also a periodic variation in species composition in the catches from the 10—30 m depth layer (Table 2, Fig. 8). In this layer the redfish were caught in daylight while at dark the catches consisted of capelin and krill. Capelin were also caught at the very surface (0—12 m) in daylight. The observations made by the scuba divers verified these observations. At dark they found a scattering layer of krill and capelin in 20—30 m while the redfish were observed very close to the surface, 0—2 m. In daylight they saw no 0-group fish at all.

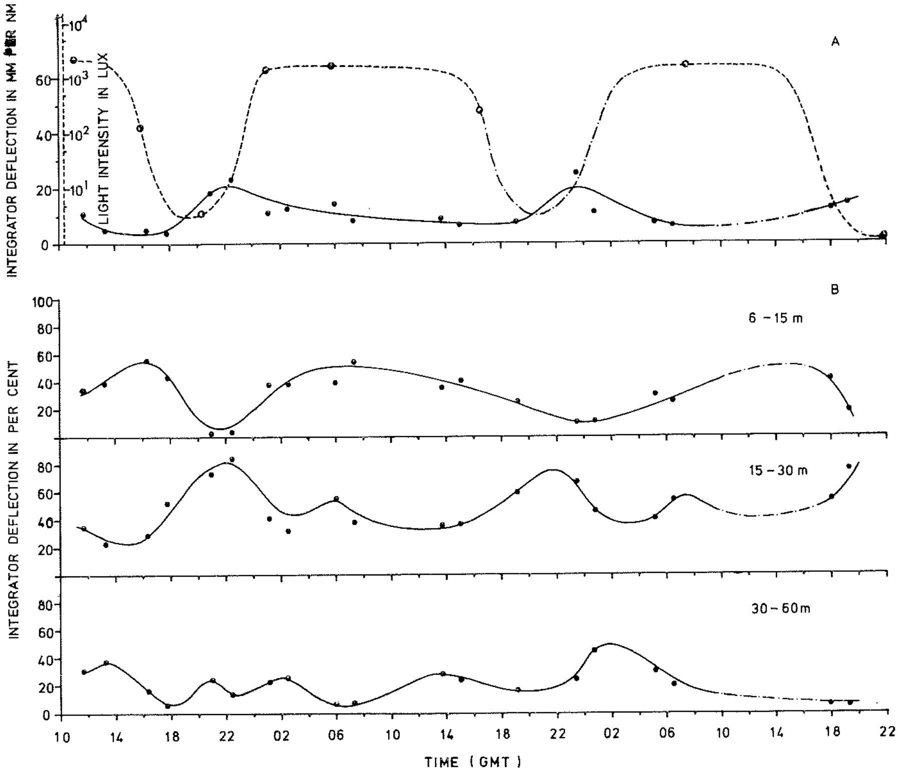


Fig. 7. A) Total echo abundance and light intensity according to time in area 2. B) The contribution to the total echo abundance from various depths according to time.

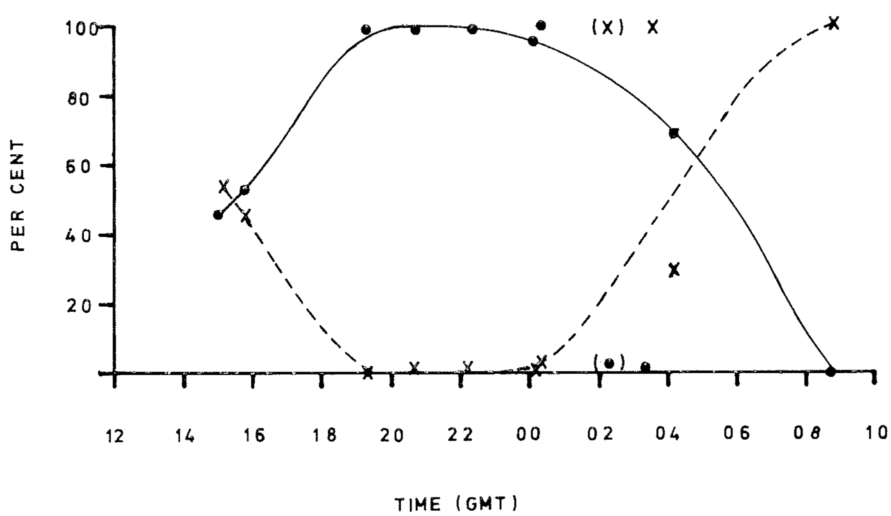


Fig. 8. The fish composition of trawl catches from 10 to 30 m depth in area 2. Solid line) capelin, broken line) redfish.

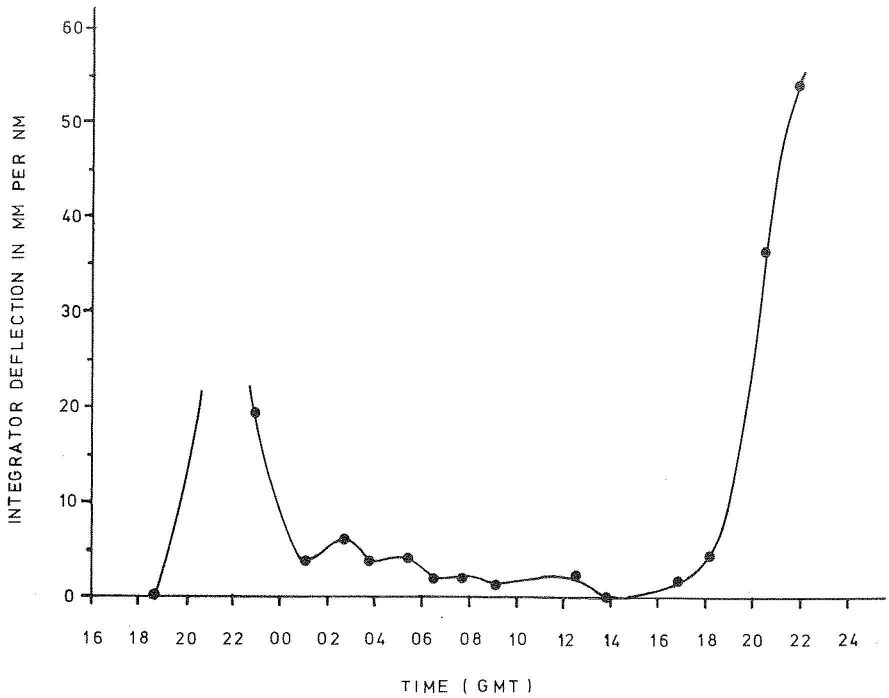


Fig. 9. Total echo abundance according to time in area 3.

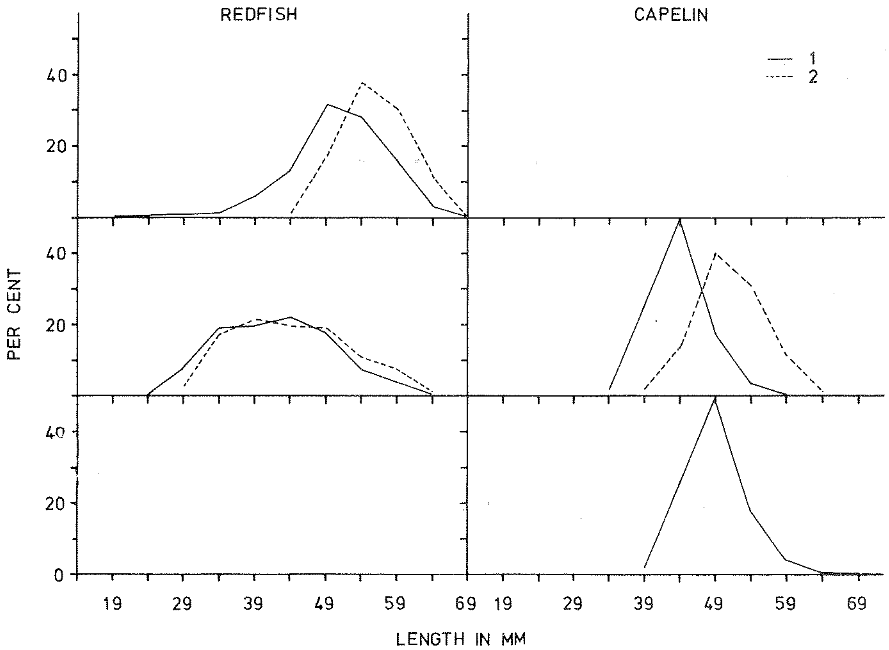


Fig. 10. Length distributions of 0-group redfish and capelin in the different areas. 1) Pelagic trawl, 2) purse seine.

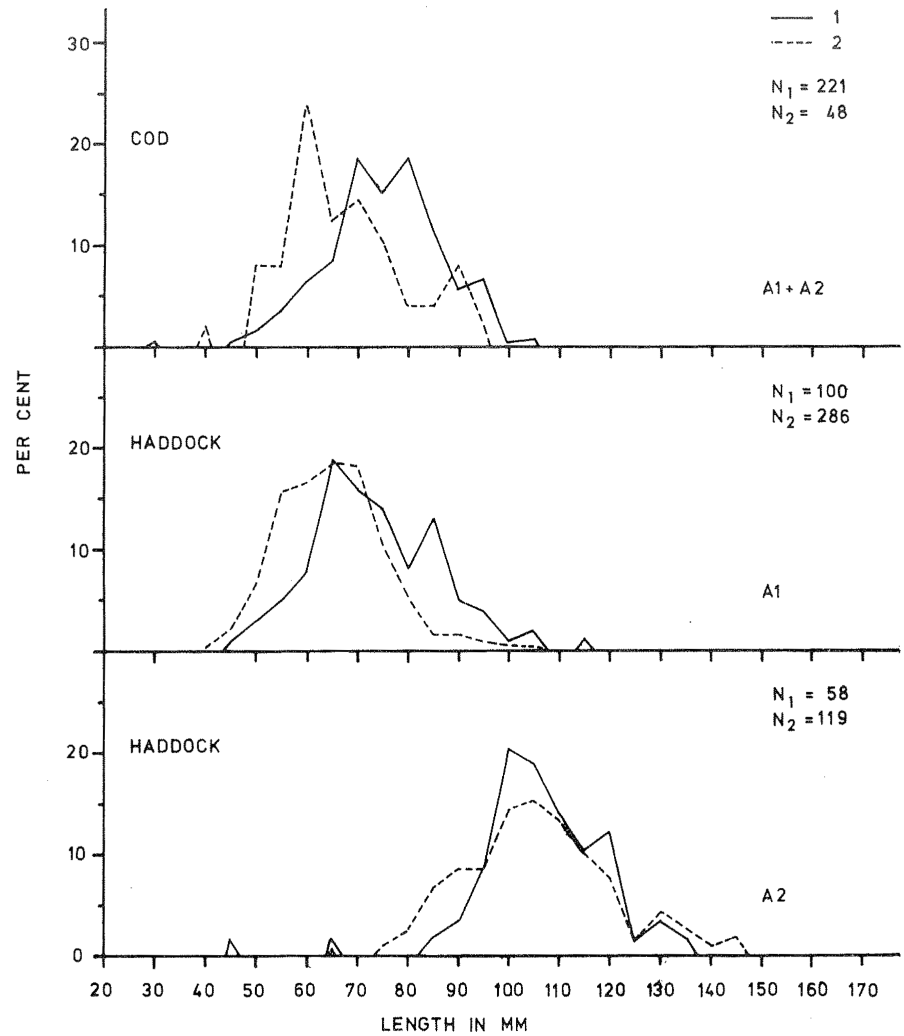


Fig. 11. Length distributions of 0-group cod and haddock in the different areas. 1) Pelagic trawl, 2) purse seine.

In area 3 there was practically no contribution to the echo abundance in daylight (Fig. 9), but great numbers of 0-group capelin were caught in surface hauls (Table 3). At dark the scattering layer in 20—30 m depth consisted of capelin and krill (Fig. 5.3 and Fig. 9) which was sampled with pelagic trawl and observed by scuba divers.

Nearly all the observed 0-group capelin were unpigmented while the 0-group redfish, cod and haddock were pigmented. Fig. 10 and 11 show the length distributions of these four species according to area and gear.

The krill, mainly *Thysanoessa sp.*, were only caught at dark in the pelagic trawl, sometimes in quantities up to 80 kg per haul in area 2. It had an average length of about 2 cm.

## DISCUSSION

Table 1, 2 and 3 show that 0-group redfish and capelin dominated the catches completely. Fig. 5, 7 and 8 show that 0-group redfish and unpigmented 0-group capelin had a different vertical migration pattern. The redfish showed a normal diel vertical migration and were found in the surface layer at dark while the capelin stayed in the surface layer during the daylight period and descended to deeper water at dark. According to BREDER (1962) the light radiation in the upper water layers may have deleterious effects on pigmented organisms while unpigmented organisms to some extent are protected against the light radiation. This may explain why capelin was found at the very surface in broad daylight. By staying in the uppermost water layer the unpigmented larvae can feed almost undisturbed by fish predators during most of the daylight period. However, the radiation theory cannot explain why the capelin descended and consentrated at the thermocline at dark (Figs. 4 and 8). A possible explanation may be that in the dark period, when feeding is difficult, the larvae save energy by staying in layers of higher water density. This behaviour will also be of advantage if the predators migrate to the surface layer at dark. It is known that 0-group cod feed on capelin larvae, and it is also likely that 0-group haddock do so, but the data at hand on the diel vertical migration of the two latter species are insufficient.

The observations of krill indicated that it stayed in depths below 40 m in daylight while it mixed with the 0-group capelin in the thermocline at dark (Fig. 5.3). The higher integrator deflection at dark in area 2 and 3 (Figs. 7 and 9) are thus caused by this mixture.

Although the observations on the horizontal distribution pattern (patchiness) of 0-group redfish and capelin are limited, some main features were found. Fig. 5 shows that 0-group redfish gathered in small groups during the daylight period. Some observations indicated a similar grouping of 0-group capelin. A lot of small sonar echoes in the uppermost water layer in daylight and the fact that the scuba divers did not observe 0-group capelin, in daylight supports this view. When the fishes form schools, the propability of detecting them with echo sounders is less than when they are evenly distributed, and dispersed distributions at dark are therefore easier to detect than dense schools in daylight. At dark the capelin dispersed in 20—30 m depth. The redfish, which at dark were observed by eye in the surface layer, appeared also to be dispersed although

Fig. 5.1 indicates that a certain grouping was maintained even in the most dark period. The differences in fish length between purse seine and trawl catches, which occur in Fig. 10 and Fig. 11, are not significant. From the present investigation we must thus conclude that the trawl catches were representative samples of the length distributions of 0-group fish.

The 0-group capelin, which in broad daylight is found above the depth of the hull mounted transducers, will not be recorded by the echo sounder (Fig. 5.3). Neither will it be representatively fished by a pelagic trawl unless special care is taken to haul the trawl at the very surface. Therefore errors of unknown magnitude might be introduced to the indices of abundance for 0-group capelin.

The redfish, which is spread in the water column during the daylight period, will be detected by echo sounders most of the time (Fig. 5.1). Although there might be areas where this species is not seen by echo sounders during a small part of the dark period, like area 2, it is felt that the error introduced to the abundance indices are negligible in comparison with the 0-group capelin.

To get a better understanding of the observed vertical diel migration pattern of 0-group capelin more detailed information is needed both on the distribution of plankton and the distribution and stomach contents of fishes in the upper 50 m depth layer in the Barents Sea.

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