

## Day and night fish distribution pattern in the net mouth area of the Norwegian bottom-sampling trawl

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A high-frequency scanning sonar, mounted as a net sonde, was used to study fish behaviour in the mouth area of the Norwegian bottom-sampling trawl. Fish distribution patterns were significantly different by day and night. At night the fish entered the middle of the trawl, close to the bobbins, and no fish were observed escaping over the headline. During daytime the fish entered more irregularly, using the whole opening of the trawl, and haddock were lost over the headline. The daytime sonar observations were confirmed visually with an underwater vehicle with video camera. The observations indicate that the herding process during bottom trawling may be equally efficient by day and night, and that hearing must play a significant role in this process under non-visual conditions.

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### Introduction

The Institute of Marine Research, Bergen, Norway, has carried out combined bottom-trawl and acoustic surveys on the stocks of Northeast Arctic cod and haddock in the Barents Sea and Svalbard areas since 1981. The results indicate that the trawl catches do not provide representative estimates of the density ratios between cod and haddock, and that the numbers of young fish are underestimated compared with older fish (Høyen *et al.*, 1986). Direct observations of cod and haddock during trawling in daylight in the North Sea (Main and Sangster, 1982), as well as in the shallow shelf areas of the Barents Sea, prove that cod and haddock react differently when entering the mouth of the trawl. When haddock become exhausted and drop back, they frequently rise high above the fishing line into the top part of the trawl, or even above the headline, whereas cod remain low near the seabed.

The main conclusion from observations in the North Sea is that vision is the predominant sense used in avoidance reactions when a fish is approached by a trawl (Wardle, 1986). Data on the reaction pattern and leading stimuli at reduced light levels are, however, still scarce. Flash photos taken inside the mouth of the trawl (Parrish *et al.*, 1962; Parrish, 1969; Beamish, 1966; Wardle, 1986) indicate a reduced orientation under

non-visual conditions, with the fish showing less orientation relative to the ground gear than in the daytime. If the reaction to the trawl varies with the ambient light level, this may also affect the sampling efficiency of the trawl. Direct observations have so far been limited to shallow water, but for the Barents Sea and Svalbard areas, similar observations are needed in deeper water and by night in order to evaluate the effect on the abundance estimates of cod and haddock.

New experiments with high-resolution scanning sonars mounted as a net sonde (Ona and Eger, 1986, 1987) indicate that this type of instrumentation could be used in investigations of fish behaviour in connection with trawling. This paper presents a first analysis of the position of fish in the mouth area of a bottom trawl at different levels of ambient light. The observations are made in relatively shallow water in order to evaluate the method by simultaneous use of visual observations.

### Materials and methods

The trawl experiments were performed in October 1986 off the east coast of Finnmark, Norway, at depths of 70 to 80 m, from the Norwegian research vessel RV "Eld-jarn". The standard Norwegian sampling trawl for demersal fish and shrimp in northern areas, the Campelen

1800, was used with slightly modified rigging. Instead of the standard rubber ground gear, the trawl was equipped with a rockhopper ground gear (Engås and Godø, 1989). The vertical opening and wingspread of the trawl were measured by sonar and SCANMAR sensors as 4.0–4.5 m and 17.5–18.5 m, respectively. The vertical opening could be changed to a certain extent by regulating the tension of the sonde cable.

The duration of a tow was set to half an hour from the time bottom contact was indicated by the sonar. Towing speed was standard at 1.5 m/s (3.0 knots).

The head of the Simrad FS 3300 trawl surveillance sonar, working at 330 kHz, was connected to a 1200-m net-sonde cable. Full specification of the sonar and cable is found in Ona and Eger (1987). In this study, the sonar was mounted inside the trawl, just behind the centre of the headline. The sonar beam thus scanned the mouth area of the trawl in a  $360 \times 2.7$  degree slice, transverse to the towing direction, and approximately 3.5 m in front of the centre of the ground gear. The sonar data were stored on high-quality videotape for further analysis. From replays of the sonar scans, the fish distribution pattern was established by drawing an outline of the trawl on transparent paper and dividing the mouth area into 16 different sections (Fig. 1). For regular 180° downward scans, the playback was stopped

and the number of individual fish echoes counted within each section. Upward scans were used to observe fish escaping over the headline.

During daytime, the net-sonde sonar observations were supported by visual observations from the towed remote-operated vehicle "Ocean Rover", equipped with a sensitive UTV-video camera and a still-photo camera.

Three typical hauls, representing different light levels, were used in the analysis, starting at 0300, 0700, and 1130 hours (GMT). The indicated light levels were estimated from the US Navy Natural Illumination Charts (Anon., 1952), with the weather conditions during the hauls as input. Only navigation lights were used during the night-time hauls.

During trawling, the fish abundance and vertical distribution were monitored on the acoustic instruments, the Simrad EK 400 (38 and 120 kHz) and further quantified using the ND-10 echo integrator with 4 pelagic and 8 bottom-locked integrator channels.

The catch consisted mainly of haddock (*Melanogrammus aeglefinus* L.), cod (*Gadus morhua* L.), and saithe (*Pollachius virens* L.), with mean lengths of approximately 40, 55, and 35 cm, respectively. More specific catch data are found in Figure 2.

## Results

The respective accumulated distribution patterns of the fish in the net mouth area of three typical hauls are shown in Figure 3, together with the estimated ambient underwater light levels (Table 1). At night-time, 98 % of the registered fish entered the lower half of the trawl opening, all in front of the central part of the ground gear. 80 % of the fish actually entered within 1 m of the seabed.

In the dawn haul the fish also entered close to the bottom, with only 3.3 % recorded above the vertical centre of the trawl. A slight horizontal displacement to starboard seemed to be correlated with the distance to the sand clouds from the trawl doors, passing the wings, or the trawl panels at the sonar section at 5.0 and 7.5 m, port and starboard, respectively.

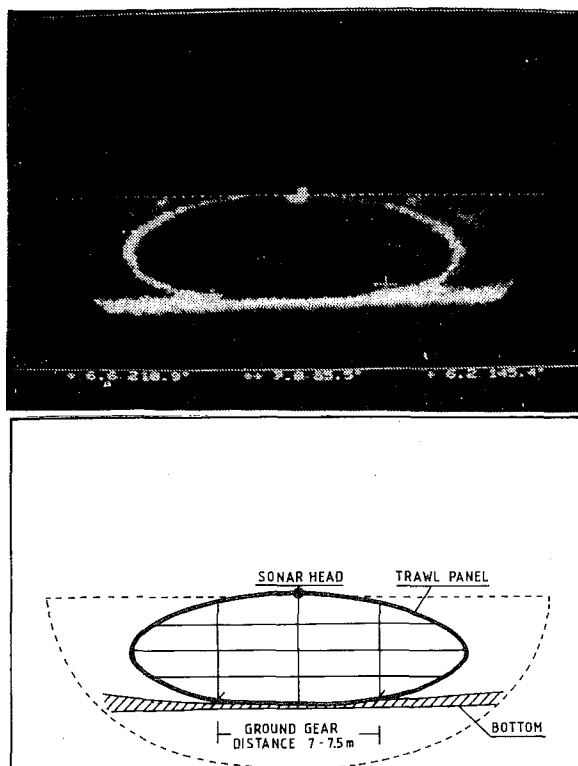


Figure 1. Sonar monitor with a 180° scan, showing the trawl panels and bottom. The sections used in the counting procedure are indicated below.

Table 1. Basic results from the three comparative hauls, with estimated light intensity at 75 m, and catch composition.

	Night	Dawn	Day
Hour (GMT)	0300	0700	1130
Light intensity (lux)	$2 \times 10^{-6}$	0.01	5
Fish counts	141	655	267
Sonar scans (180°)	139	169	325
No. of saithe	327	966	372
No. of haddock	700	1331	702
No. of cod	118	88	87

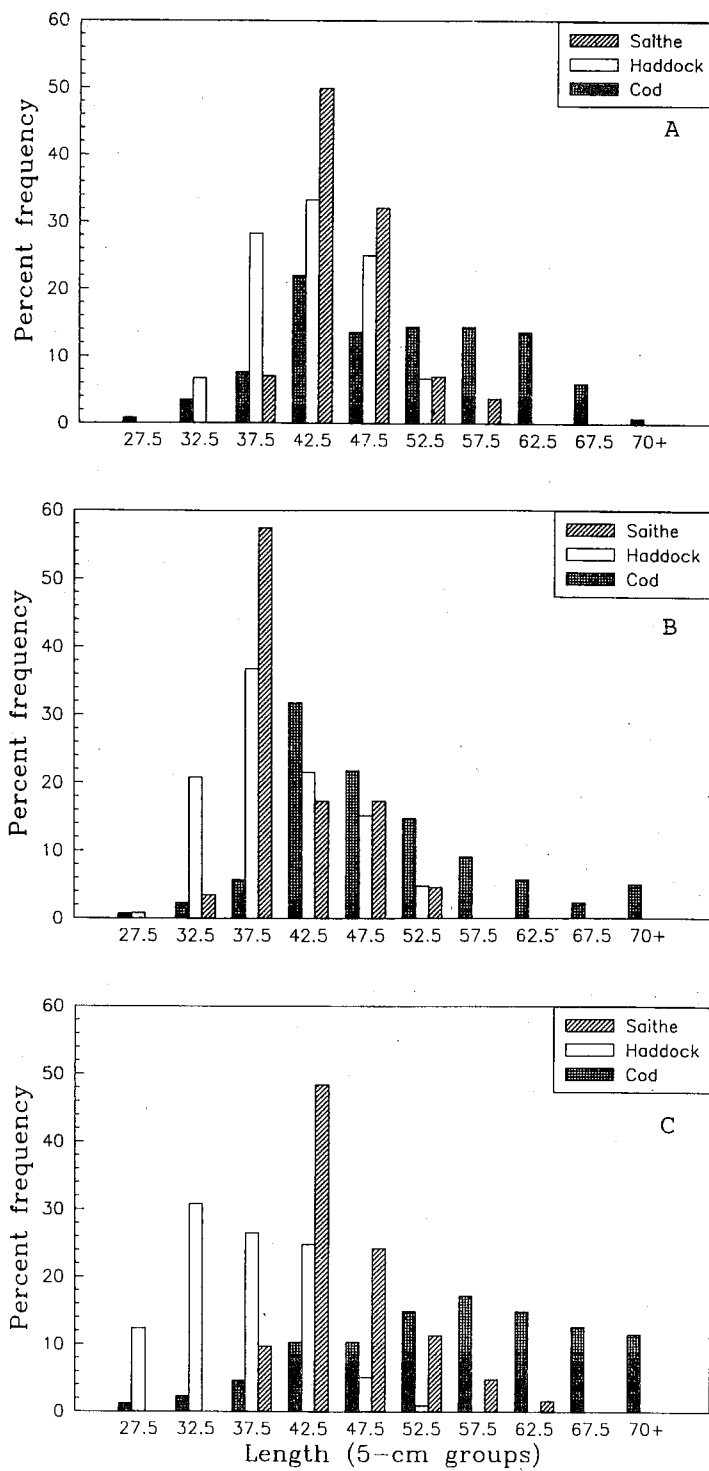


Figure 2. Length distribution of fish in the three comparative hauls. (A) - night, (B) - dawn, (C) - day.

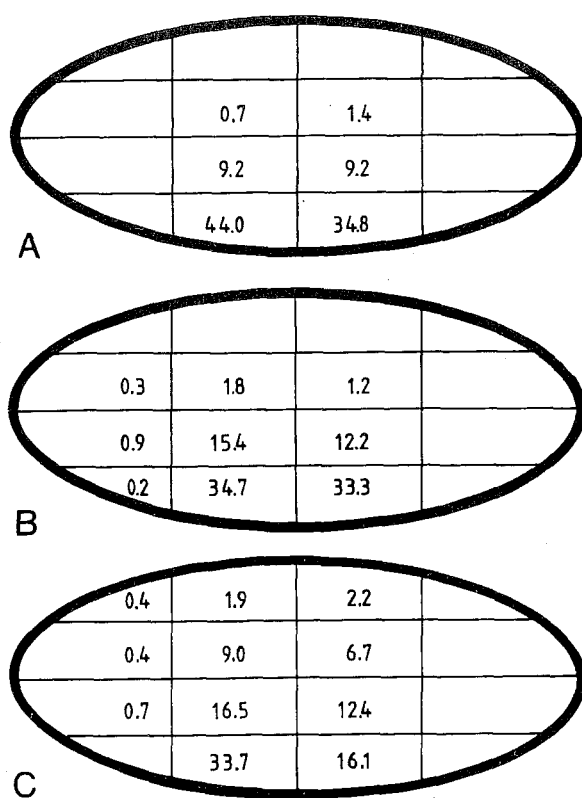


Figure 3. Fish distribution pattern in the mouth area of the trawl at different levels of ambient light (Table 1). Percentage of total counts are shown. (A) – night, (B) – dawn, (C) – day.

In the daytime, the distribution pattern was clearly different, with more than 20% of the fish entering the upper half of the trawl. The starboard displacement is even more distinct than in the dawn haul.

Using the sonar to scan the 180° sector above the trawl, fish echoes were registered close to the headline only by day. During the visual observations, only had-dock were seen escaping over the headline. These events were registered simultaneously by the sonar.

Echo-sounder observations beneath the trawling vessel (Fig. 4) show a moderate vertical migration of the fish during night-time, but indicate a trend opposite that observed in the mouth area of the trawl, with the fish more concentrated near the bottom during daytime than at night.

## Discussion

The results clearly show that high-resolution scanning sonars mounted as a net sonde can be used to observe the reaction pattern of fish during trawling.

From the apparent vertical migration pattern (Fig. 4) a more dispersed entrance pattern during night-time

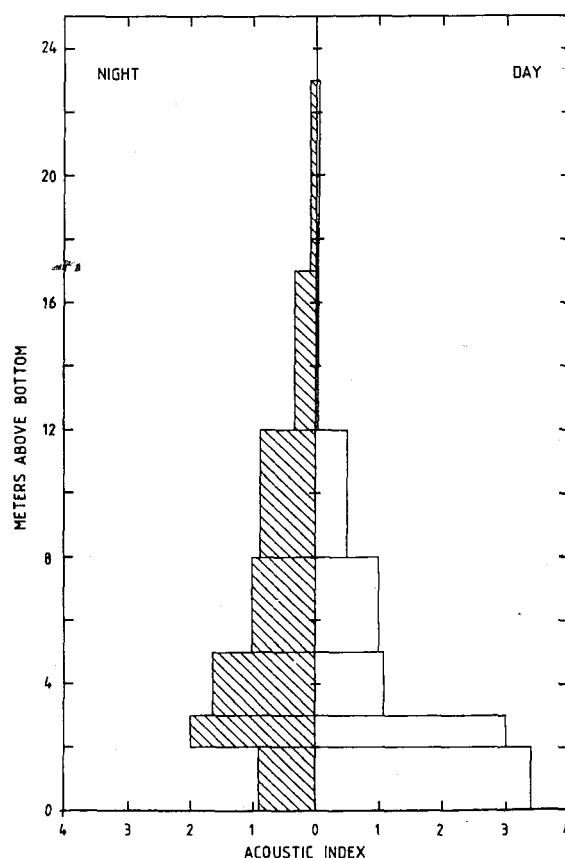


Figure 4. Vertical distribution of fish during the day and night stations. Acoustic index is proportional to volume density.

was expected. The fish were, on the contrary, well positioned near the seabed in the centre of the trawl, which indicates that stimuli other than visual ones must be effective. The centre of gravity of the distribution suggests that the fish were positioned at the maximum distance from the trawl panels as well as from the ground gear.

If the fish cannot see the trawl, they can certainly hear the noise from the propeller of the vessel, the otterboards, and the ground gear. Recent experiments (Sand and Karlsen, 1986) show that cod are very sensitive to infrasound (0.1–10 Hz) as well as to sound in the 30–500 Hz region (Chapman and Hawkins, 1973). Considering this new information on infrasound sensitivity, it seems plausible that the low-frequency vibrations generated by the warps and bridles, as well as turbulent noise from the panels, can be detected by the fish.

Under approximate non-visual conditions, Bagenal (1958) also observed a surprisingly strong herding effect at night, and attributed the greater catch with sweeps to the non-visual stimuli generated by them. Underwater observations using flashphoto techniques in the mouth

area of the trawl (Parrish *et al.*, 1962; Beamish, 1966; Wardle, 1986), however, show a variable and more random reaction pattern to the trawl at night.

In the present study, the fish were registered as being tightly organized with respect to the trawl panels and ground gear. Even if the light levels are somewhat underestimated, the reaction distance would be insufficient for the fish to assume the observed position by vigorous swimming after sensing parts of the trawl, like the headline. The level of entrance must have been determined 10 m or more in front of the headline. The predominant stimulus under the prevailing light conditions, excluding the possibility of bioluminescence in this area and season, is acoustic.

In the daytime haul, the behaviour pattern of haddock entirely supported the observations from the North Sea. Occasionally, the same tendency as earlier reported by Wardle (1984), of an increased escapement with increasing number of haddock piling up in the mouth area, was also observed. A moderate effect of a cross-current on the sand cloud, passing non-symmetrically toward the trawl, is also seen to affect the entrance pattern in these two hauls. Both the pattern of entrance and the reaction to the sand clouds support the general view of vision as the principal stimulus when the fish react to the approaching trawl in the daytime.

With the sonar oriented upwards, a weaker registration of haddock passing above the headline was observed. When dropping back, the haddock often displayed the tail aspect relative to the transducer. The speed of passage and the low target strength at this aspect may have caused an under-representation of the actual number of escaping haddock. However, as this problem is the same during day and night, the main conclusions are not affected.

The intention of this investigation was to evaluate the sonar method by comparison with direct visual observations in shallow water. Allowing for the unfavourable aspect when haddock pass above the headline, the sonar observations were fully confirmed in the daytime. It must also be mentioned that although we have called this an entrance pattern, the correct interpretation is rather the product of entrance position and the pattern made by fish moving through the slice on their way forward again.

The analysis of these data shows that this method can be used to study fish behaviour under non-visual conditions, at night or in deep water. This will be the main subject of future investigations with this method.

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