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ORIENTATION MEASUREMENTS OF COD IN LOFOTEN OBTAINED FROM UNDERWATER PHOTOGRAPHS AND THEIR RELATION TO TARGET STRENGTH

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INTRODUCTION

The reflection of ultra sound by a fish has been shown to depend greatly on the orientation of the fish in the sound beam (Midttun and Hoff 1962, Shibata 1970). The detection of a fish within the beam of an echo sounder will consequently not only be a question of where in the beam the fish is situated, but depends also on its actual swimming position. An illustration of this is shown in Fig. 1 by a polar plot of back-scattering pattern in the pitch plane of a 69.5 cm cod (illustration from other recent investigations). Maximum reflection of the sound is shown to occur when the head-tail axis through the fish has an inclination 11-13° head down. A small change in the inclination (i.e. 10-15°) will result in a reflection loss of the order of 10-12 dB.

Electronic integration of fish echoes obtained when surveying areas in Lofoten, have been applied in a method of estimating the present stock in the area (Midttun and Nakken 1970). It is assumed in this method that inclination of the fish relative to the horizontal plane is approximately uniformely distributed. A wide spread in inclination will result in underestimation of numbers of fish in the areas. A similar result will be obtained if the method is applied to relatively dense fish concentrations (shading effects).

In order to obtain some more precise information about behaviour of cod in the spawning area, observations have been made by underwater photography on a survey by our research vessel "Peder Rønnestad".

METHODS

A self-contained underwater camera with an electronic falsh unit and with remote exposure control was lowered on a wire into the fish consentrations. In rough weather the camera was suspended by attaching the wire to three partly submerged plastic floats in order to suppress unwanted motions of the camera.

Observed changes in fish consentrations because of the descending camera were made on the echo sounder. Very often the fish seemed to avoid the approaching camera (even in the dark), but a few minutes after the camera had reached its operating position a complete adaptation seemed to occur and photographing could commence.

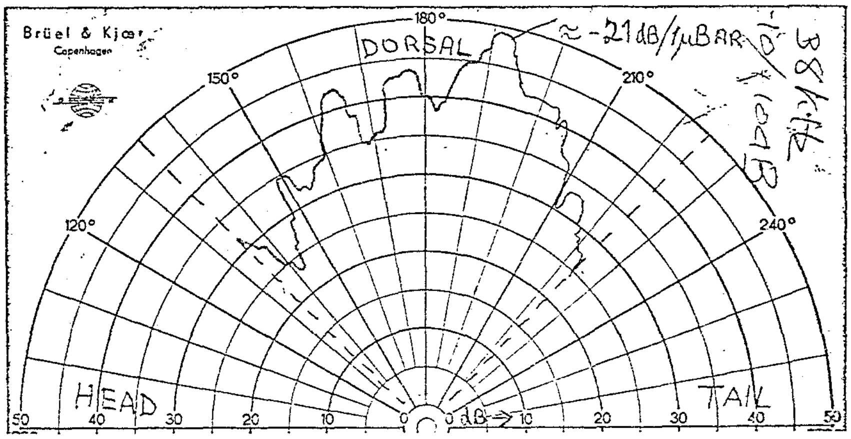

Fig. 1. Back-scattering directivity pattern of 69.5 cm cod. Rotated in the pitch plane (38 kHz).

In order to obtain information about fish passing the camera's field of view at a reasonable distance, a separate echo sounder and transducer was mounted close to the camera lense, looking approximately in the same direction. Any echoes of fish could then be observed on an oscilloscope onboard the ship. Due to the limited photographic range, a sweep time on the oscilloscope giving 15 m observation range was generally used, and most of the photographs were taken when the fish were 2-10 m away from the camera. Although the observation distances were easily read from the oscilloscope, a permanent photographic record of the display was made, syncronized with the exposure control of the underwater camera.

In general, however, the observation system had some tendency to overestimate the number of fish being in the camera's field of view. This was caused by the poor directivity of the available transducer, receiving echoes form fish at wider angles than the camera ($\approx 45^{\circ} \times 25^{\circ}$ compared to $30^{\circ} \times 25^{\circ}$). Fig. 2 shows a block diagram of the underwater camera and the instrumentation.

In order to reduce any possible disturbances caused by the flashing light, the time interval between each exposure was a minimum of one minute.

The photographs obtained have been classified as day and night photographs, according to the usual diurnol variation in behaviour of the fish. For measurements of the inclination of the fish relative to the horizontal plane, those photographs showing fish with their long axis in a plane ($\pm$ 10-15°) normal to the photographic axis have been used. The horizontal inclination is defined as the angle between the horizontal plane and a line drawn through the front of the upper jaw and the root of the tail.

Photographs of fish having an apparent greater inclination than 10-15°to the plane normal to photographic axis, have been used only if the fish is also swimming at approximately the same depth as the camera. On these occasions a correction formula on the measured inclinations have been applied:

$$\text{Sin } V = \text{Sin } V'\left(\frac{L'}{L}\right) = \text{Sin } V'\left(\frac{L'}{\alpha B}\right)$$

V = true horizontal inclination
V´= observed horizontal inclination
L = true lenght of the fish
L´= measured length of the fish
B = heiht of the fish head, measured half way between eye and pectoral fin
α = estimated mean of L/B from measurements of fish with their axis in the plane normal to the photographic axis.

The correction formula has been applied to photographs of 30 of the 230 fish measured (15%). The formula is estimated to give an increase in confidence interval compared to a direct measurement from $\pm 0.5^{\circ}$ to $\pm 1.5^{\circ}$.

RESULTS

Fig. 3a and Fig. 3b show histograms of the distribution of fish inclinations relative to the horizontal plane, obtained by plotting numbers of observations against angle of inclination in 5° intervals.

The fish photographed in daytime (Fig. 3a) have a calculated mean inclination of 3.8°, head down. The fish photographed at nighttime have a mean inclination of 5.5°, also head down. Tests for normality of the distributions have been worked out (χ^2-tests), and show significance at 50% and 25% levels for the day and night photographs respectively.

A comparative test of the two observed means of the distributions (t-tests) shows no significant difference. Thus, a mean horizontal inclination of all the 230 fish measured can be calculated. This mean inclination is 4.5° head down.

Observations of fish densities from the photographs show great variations. Approximately 3/4 of the photographs show at least two fish or more, and occasionally 10-15 fish can be counted.

The sampling volume covered by the camera's field of view at its optimum range of about 10 m, is calculated to approximately 50 m^3 (from camera lens specifications and observed average fish length). This corresponds to a fish density of the order of 1 per 4 m^3 of water, or 1 per 2 m^2 of surface area.

The photographs show that the predominant behaviour is for all fish to orientate in the same direction. This pattern is maintained even in the hours of darkness.

DISCUSSION

The reliability of the data obtained will depend greatly upon the presumption of an undisturbed environment and on the assumption that the longitudinal axis of the camera housing remains vertical.

The photographs themselves show that the fish apparently ignore the presence of the camera, as there is no apparent tendency to swim towards or away from the camera.

The heavy weight of the camera housing (≃ 50 kg) together with the suspension arrangements give a very stable vertical position under normal conditions of wind, tide and current.

The effect of the spread in horizontal inclinations on the distribution of target strength of fish when echo-surveying the area, may be estimated or analysed by comparing the directivity pattern in Fig. 1 with the distributions shown on Fig. 3. Bearing in mind that Fig. 1 shows a directivity pattern obtained from only one fish, some valuable comparisons may be made.

The particular aspect when maximum reflection of sound is obtained differ to some extent from the average horizontal inclination (appr. 7^{O}). It is believed that this is due to the inclination of the long axis of the swimbladder in cod, compared to the long axis of the fish (Midttun and Hoff 1962). The result of the deviation gives a probability estimate of 60% of the fish to give a target strength of at least 6 dB below their maximum target strength and 25% to give a loss of 20% or more.

The total variation in target strength when taking into account the sound beam directivity pattern and the variation in the size of the fish will exceed the dynamic range of an echo sounder. The ultimate effect of this will be a loss in number of targets observed.

SUMMARY

1. Cod in Lofoten have been photographed and their inclination relative to the horizontal plane has been measured.

2. The horizontal inclination is shown to be normally distributed with a mean inclination of 4.5°, head down. No significant differences exist between day and night.

3. The spread in horizontal distribution is shown to give a considerable increase in the variation in target strength. This may result in underestimation of targets in echosurveys.

4. The relative dense fish consentrations observed will result in shading effects.

5. The photographed fish were all orientated in the same direction, and this behaviour pattern was maintained both during day and night.

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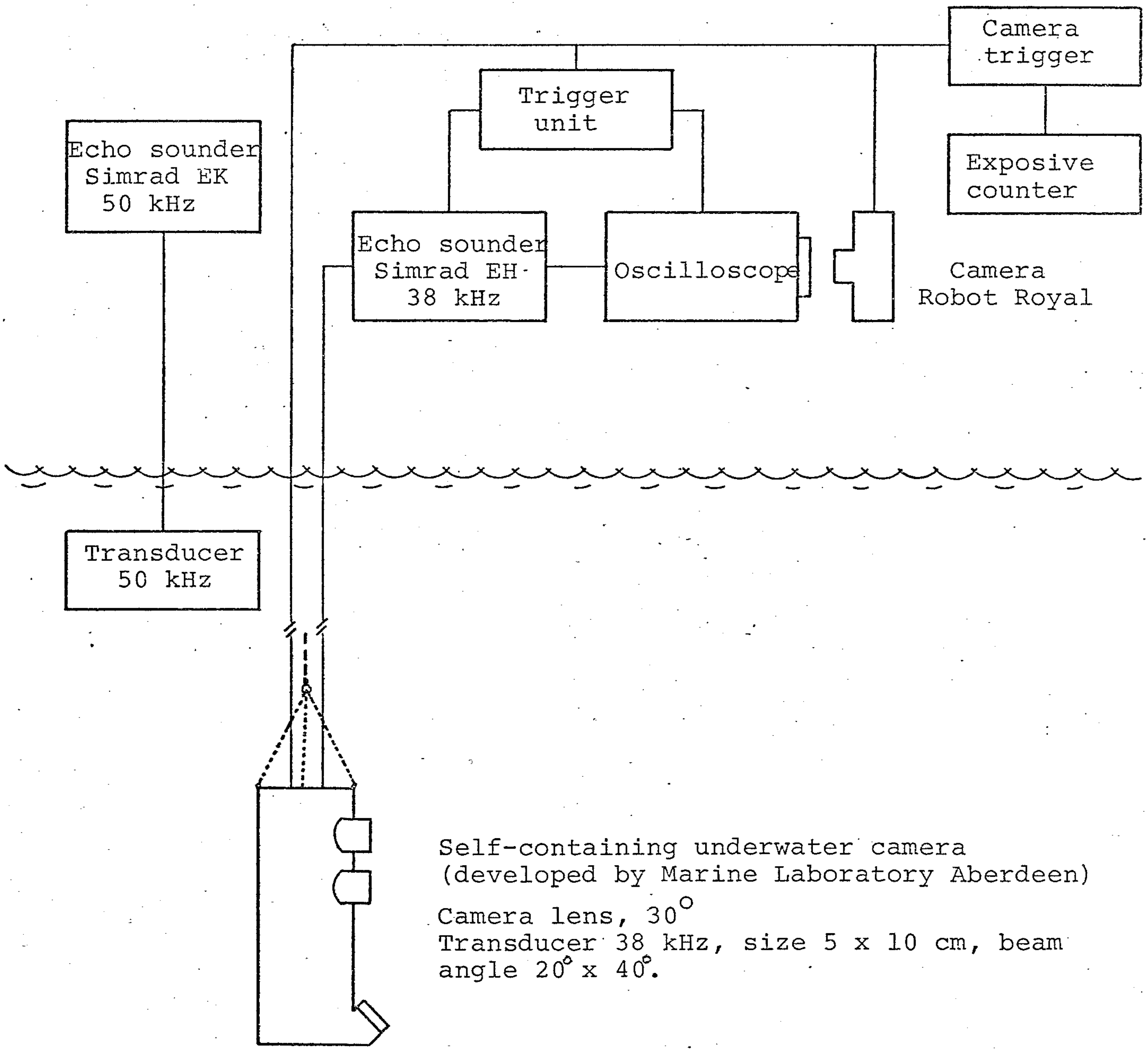

Fig. 2. Block diagram of instrumentation set up.

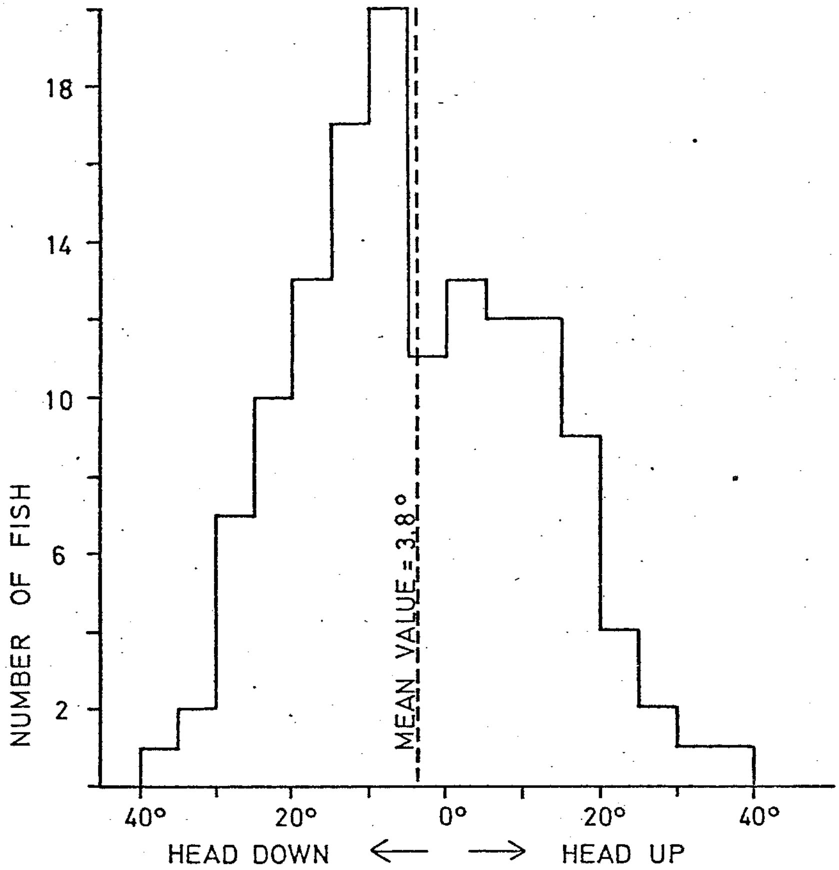

Fig. 3a. Distribution of fish inclinations measured relative to the horizontal plane, day-photographs.

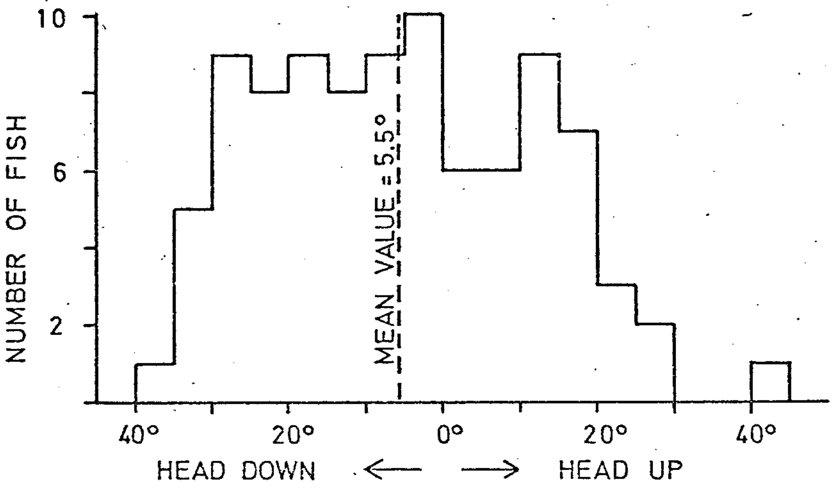

Fig. 3b. Distribution of fish inclinations measured relative to the horizontal plane, night-photographs.