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FREQUENCY DEPENDENCE OF HERRING AND COD TARGET STRENGTHS

by

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INTRODUCTION

Using echo integration to estimate the abundance of pelagic fish stocks can provide estimates of biomass or the number of fish. This method assumes that the average fish backscattering strength or target strength (TS) is predictable. Present procedures require that the TS does not depend significantly upon fish behaviour, and that echoes from species of interest can be easily distinguished from those of lesser importance. The identification is usually done either by visual inspection of echo traces or by partition of the echo integrator data in proportion to the composition of trawl catches. The target strength is usually assumed to be constant, or perhaps dependent on fish length but independent of fish behaviour. Unfortunately, this is probably too simple a model. Fish are known to have highly variable backscattering strengths which depend upon tilt angle (Nakken and Olsen, 1978; Foote, 1978). Moreover the size of the gas-filled swimbladder will change with the depth of the fish (Sands and Hawkins, 1974; Blaxter et al., 1979). At normal survey echo sounder frequencies the acoustic wavelength is generally of the same order as some of the dimensions of the fish. It is therefore expected that there will be some frequency dependence in backscattering strength resulting from both changes in tilt angle and swimbladder size.

By increasing the system bandwidth it might be possible to use frequency response information to help identify species or swimbladder size, or to smooth out differences in backscattering strength due to fish orientation changes. A wide band echo sounder has been produced to investigate these possibilities. A detailed description of the system and performance measurements can be found in Simmonds and Copland (1986). This paper presents results obtained using the system on caged aggregations of cod and herring.

METHOD

Measurements of the spectral response of fish were carried out at the Marine Laboratory's Loch Duich field station, on the west coast of Scotland. Fish were placed in a cage 2 m diameter and 1 m deep (Fig. 1). The cage was placed between two aluminium frames supporting stereo 35 mm still cameras and low light TV cameras below the cage (Edwards and Armstrong, 1983). The complete rig was suspended from a raft, the transducer at 15 m below the surface in a motorised gimbal table (Copland, 1984) with a 38.1 mm diameter tungsten carbide reference target positioned 10 m further down. The cage support frame was 12 m from the transducer which placed the fish at a range of 14 m from the transducer. This arrangement allowed the ball to be used as a reference target, with transducer position adjusted for maximum echo strength and the fish located in the region of the centre of the beam. The calculated TS of the reference target was used to calculate system performance.

Four experiments were carried out, two with cod and two with herring. The number of fish and size ranges are shown in Table 1. For all experiments the fish were removed from a surface holding pen and placed in the experimental cage, lowered to a depth of 29 m and left for several days. During this period stereo photographs were taken every ½ hour and acoustic data collected in 6 minute blocks of 40 transmissions per frequency, over 32 fixed frequencies placed linearly between 27 and 54 kHz. The acoustic data were averaged over one hour periods before further analysis. Herring, once lowered to depth produce relatively consistant results over several days with no indication of diurnal effects in the acoustic data. These experiments ran for three days. The first hour of data was ignored. In the case of cod, the fish slowly adapted to the higher pressure and produced stable results after three days. Clear differences occurred in the acoustic reflectivity between day and night. The data from the cod experiments were divided between four time categories: " day", from 0500 hours to 2100; "night", 2100 to 0500 GMT; "preacclimatised", less than 48 hours at experimental depth; and "acclimatised", more than 72 hours at experimental depth, the intervening 24 hour period was neglected. These criteria were selected purely on the basis of acoustic data, in particular the results of earlier single frequency work (Forbes, Simmonds and Edwards, 1983).

The 35 mm stereo photographs were examined for differences. In the case of cod a superficial analysis provided no clear behavioural differences between day and night and the slides were then analysed in groups defined by the acoustic data. For the herring there appeared to be clear behaviour differences between day and night defined as "day" from 0630 to 1900 and "night" from 1930 to 0600 GMT. As the choice of time indicates these experiments were conducted in September whereas the cod work had been carried out in May. The slide data from the herring experiments were analysed on this basis even though no clear acoustic division could be made between these time periods. Figure 2 shows the behavioural differences between herring in "day" and "night" situations.

RESULTS

In all cases no significant differences were found in the acoustic data between two experiments on cod or between the two on herring and in both species the data from the two experiments were combined.

Figure 3 shows the acoustic backscattering strength per kilogram for cod with mean weight of 204 g and mean length 27.0 cm. This figure illustrates the absolute differences in backscattering strength between the four categories. Differences between mean values day and night are 2.0 dB and 0.5 dB for acclimatised and preacclimatised states respectively, and 5 dB between the acclimatised and preacclimatised states. In addition there are other differences with frequency.

Figures 4a and b show plots of relative frequency response for day and night data, and separately for acclimatised and preacclimatised fish. These show no significant spectral difference between day and night; but there are statistically significant differences between acclimatised and preacclimatised fish. Figure 5 shows the relative response for herring, again showing significant differences from both acclimatised and preacclimatised cod.

In order to try to understand these results they need to be compared to the behavioural data from the four experiments. Vertical changes in distribution have been observed but these are removed by TVG function. Some horizontal distributional changes are also found, however these should not seriously affect the results and the similarity between night and day; in both herring and cod frequency responses indicates that this is so. Two major behavioural phenomenon remain that can contribute to the variation in acoustic data. These are swimbladder volume and tilt angle. Table 2 and Figures 6 and 7 shows tilt angle data for all four experiments. In the case of cod there are significant changes between acclimatised and preacclimatised fish with small changes between night and day. In the case of herring there is no significant change between night and day. Although the fish distribution and behaviour appears different from a superficial look at the slides (Fig. 2) there is no change in the tilt of these fish. The acoustic results from cod show clear differences from those of herring and even over a wide range of tilt angles (-11 to +5°) cod do not exhibit a falling frequency response whereas herring do. Even over a reasonably moderate range of swimbladder volume changes in cod, thought to be from 1/3 inflated to fully inflated there is no indication of a falling frequency response.

CONCLUSIONS

Herring exhibit a falling frequency response and cod exhibit a rising response. The exact causes of this phenomenon are not known but this appears to be true for a wide range of behaviour. This therefore has clear implications both for separation of species and probably for target strength length relationships.

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Table 1

Experiment	$\bar{L}$ cm	$\bar{W}$ g	Number
1 Cod	26.8	200	35
2 Cod	27.2	208	36
1 Herring	27.4	172	66
2 Herring	26.5	177	46

Table 2

Tilt angles of cod and herring

		Mean	Interquartile Range
Cod			
Preacclimatised	Day	+5°	54°
	Night	+4°	44°
Acclimatised	Day	-11°	64°
	Night	-8°	59°
Herring			
	Day	+7°	38°
	Night	+9°	37°

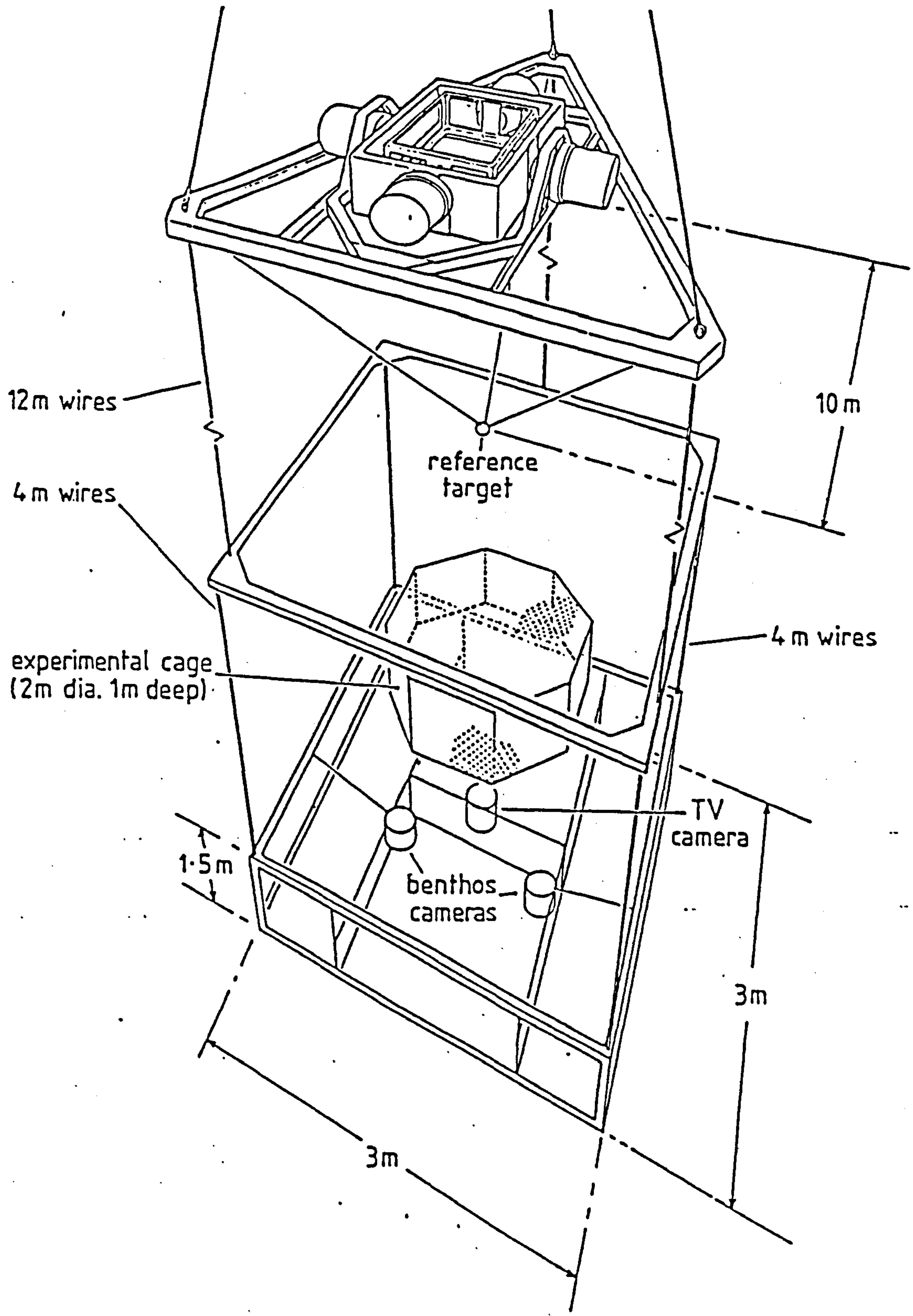


Fig. 1 Experimental Rig (not to scale)

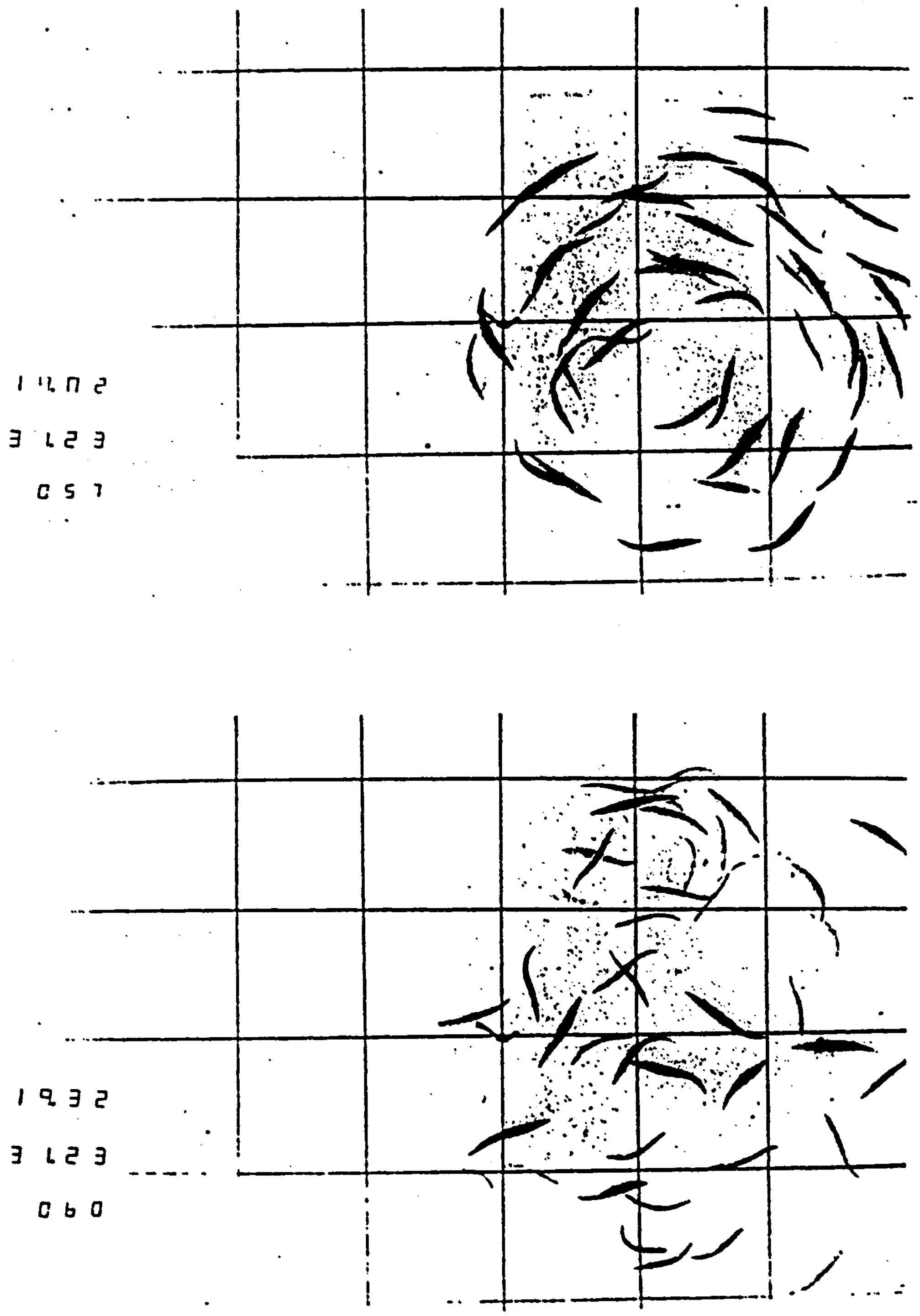


Fig. 2 Photographs of herring (and Calibration Grid) showing schooling behaviour during day light and more random orientation 1½ hours later after dark.

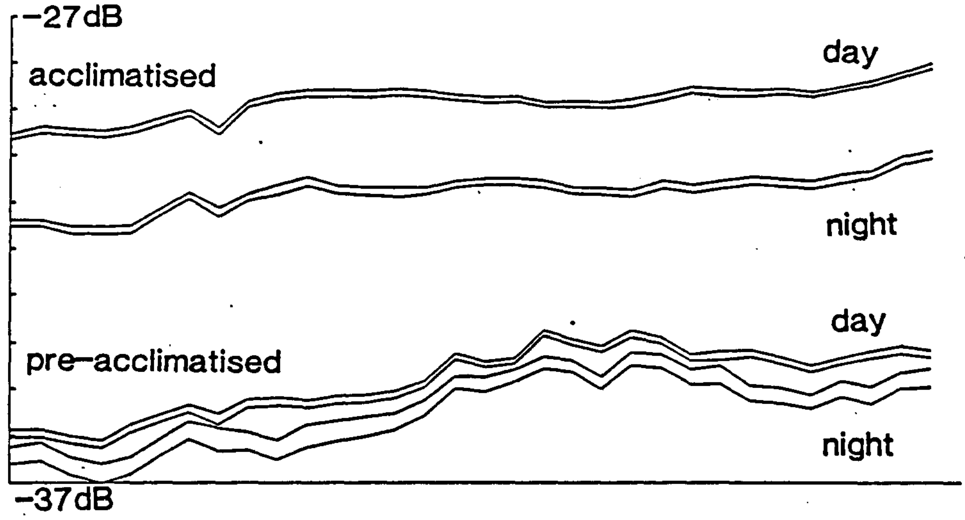


Fig. 3 Absolute target strength of cod (dB//kg) 95° confidence limits from 27 to 54 kHz.

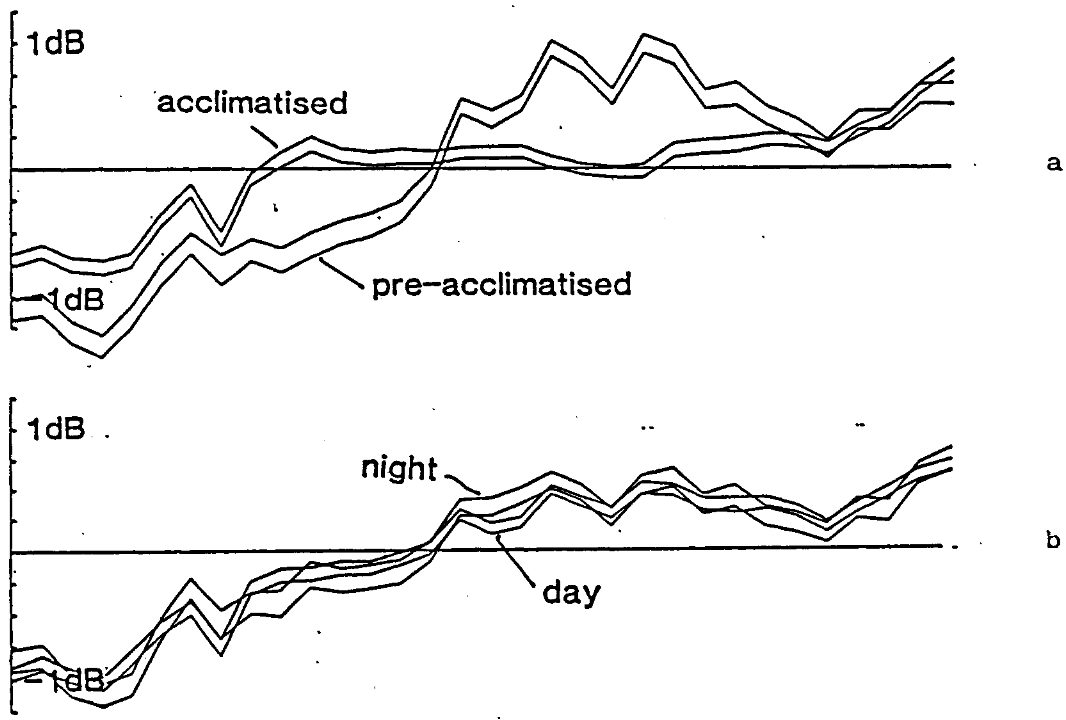


Fig. 4 Relative target strength of cod comparing
a. preacclimatised and acclimatised states
b. Day and Night

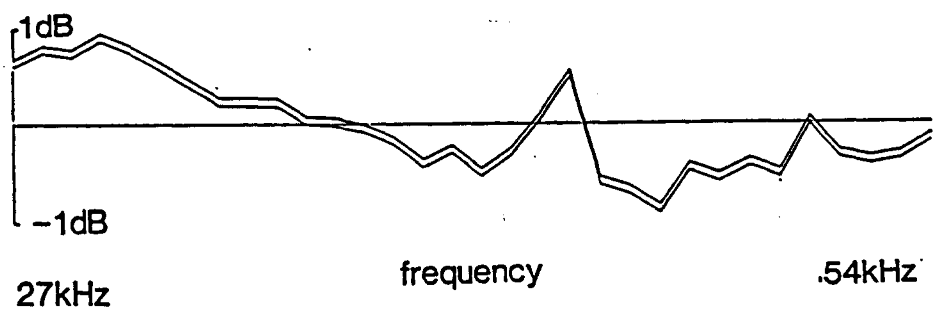
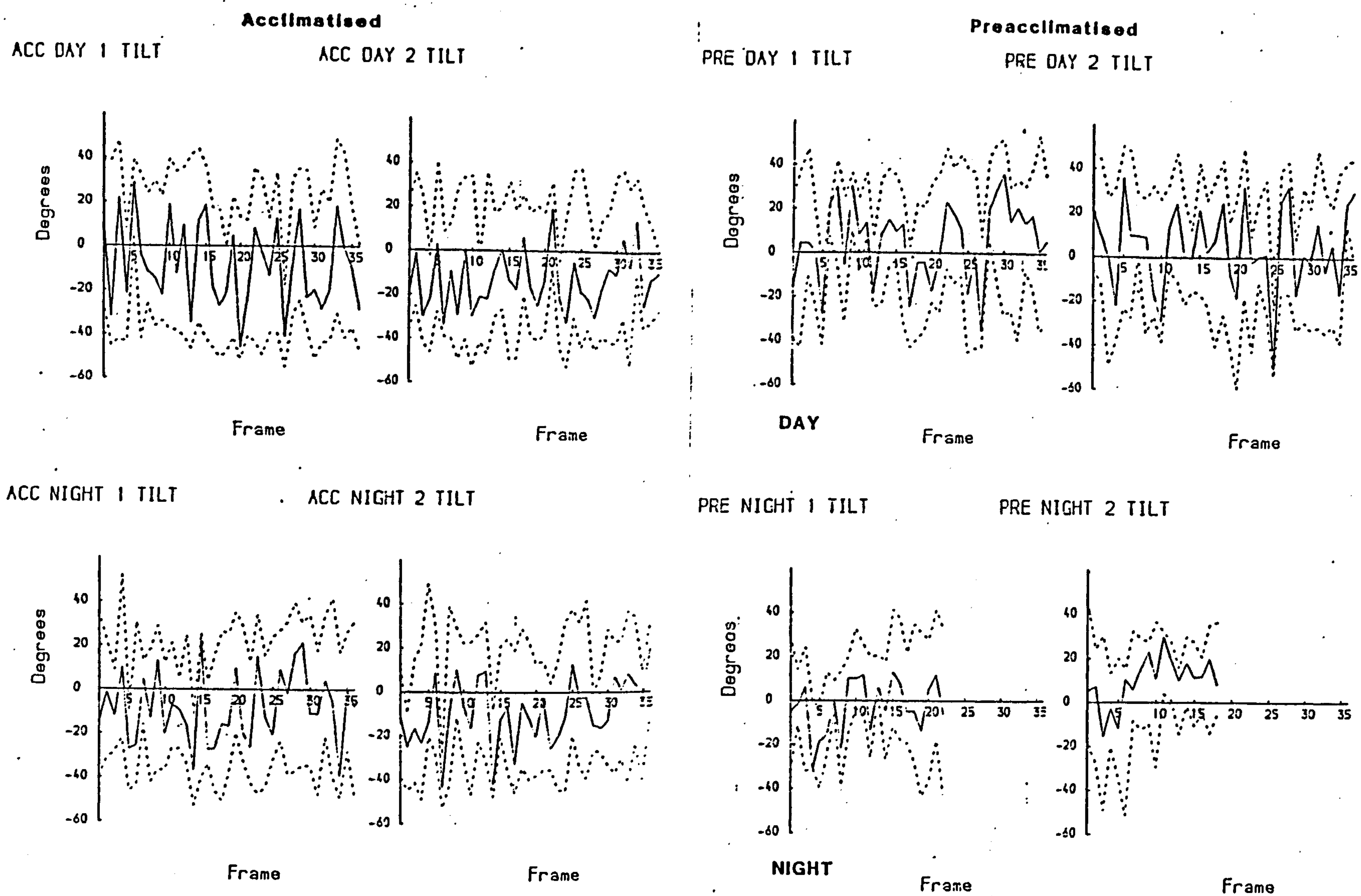


Fig. 5 Relative target strength of herring.

Fig. 6 Tilt angle of cod measured on successive slides comparing day, night, acclimatised and preacclimatised fish from two experiments. For mean values see Table 2.



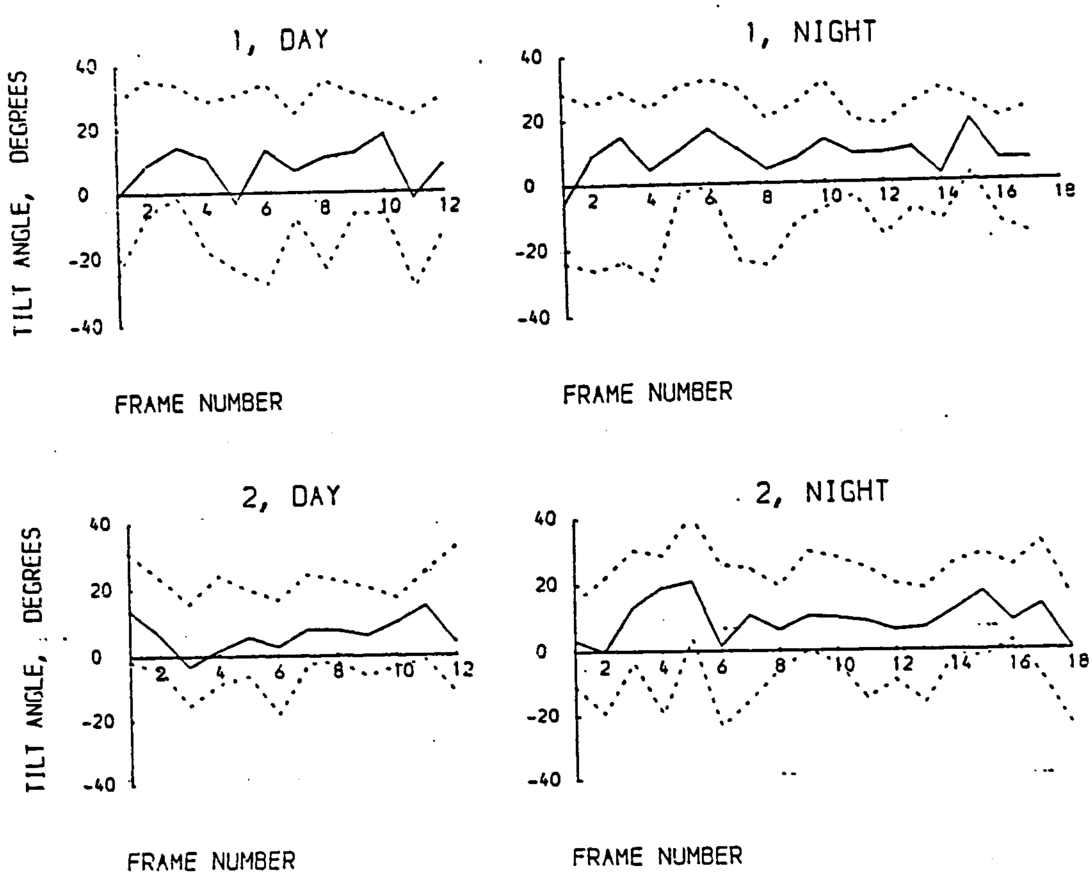


Fig. 7 Tilt angles of herring comparing day and night for two experiments. For mean values see Table 2.