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Low Frequency Volume Reverberation in the North East Atlantic

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1. Introduction

Experiments have recently been performed in the North East Atlantic to measure volume scattering strength down to depths of 1500 metres. Measurements of reverberation level were made using 2 kHz acoustic transmissions which were received with a vertical line hydrophone array. This had a beamwidth of 6^{o} and could be steered from the horizontal to a depression angle of 40^{o}. The measurements were normally taken at 3 depression angles at each of the 17 sites visited. Each set of measurements was transformed into a profile of volume scattering strength against depth. Six profiles at each depression angle were then averaged to produce a mean profile at the 3 depression angles at each station. In addition to the volume scattering strength level measurements, each transmission was recorded on a range-time display so that a "picture" of the reverberation was built up by visual integration over about 50 pulses.

2. General Results

The volume scattering strength versus depth profiles showed several interesting features. The most striking was a peak in scattering strength at about 1000 metres of about -70 dB. This is illustrated in Fig 1 which shows a typical profile taken in the Biscay area. A second peak in the profile was found at 500 metres in an area closer to the Azores as shown in Fig 2. The rapid rise in scattering strength above 300 metres is due to backscatter from the surface and is not therefore a volume scattering effect. These two peaks were the principal features of the profiles, and so scattering levels at these two depths were read from all of the results and used for comparison against temporal and geographical parameters.

Since the data set was limited, it was difficult to separate out the variations which were entirely geographical or temporal in origin. Thus in order to show the temporal variations at each depth the data have been averaged in two groups, night time (18-00 to 06-00 hours) and daytime (0600 to 18-00 hrs). and presented graphically in Fig 3 as a mean and standard deviation for each group. It may be seen that whilst there is a small variation at 1000 metres it is hardly significant in view of the size of the standard deviation, whereas at 500 metres there is clearly a significant variation in which the level after dark is some 2.5 dB higher than that in the daytime. This may be explained by the well-known vertical migration of fish in a diurnal cycle in which it has been shown that fish tend to move towards the surface at night in an attempt to remain in a region of constant illumination [1]. The lack of variation at 1000 metres is probably due to the fact that at this depth there is very little illumination from the surface and hence little variation in light level.

The volume scattering strengths at 500 and 1000 metres have also been compared with geographical parameters and are presented in Fig 4 in the form of maps. In this case it may be seen that there is little variation at 500 metres but at 1000 metres there is a tendency for the scattering strength to increase towards the north east. The same general tendency is exhibited by the column scattering strength estimated from the profiles to lie in the range -53 to -58 dB. The column strengths are also in agreement with those quoted in the literature [2, 3] in the North West Atlantic and North Pacific.

3. Further Work on the 1000 Metre Layer

The range-time displays mentioned in the Introduction exhibited small tracks which were to be seen over many transmissions in the time bracket from which the volume reverberation emanated. The densities of these tracks have been compared with the measured values of volume scattering strength at 500 and 1000 metres. The results are presented in Fig 5 and show good correlation at 1000 metres but poor at 500 metres. This fact taken together with the fact that the mean depth of the tracks was 1000 metres indicates that the scatterers responsible for the tracks on the range-time displays were also responsible for the high levels of scatter at this depth. The mean density of scatterers was about 3.2 in 10^8 metres^3.

It was assumed that all of the scattering from 1000 metres was due to tracks, and target strengths were then calculated for each measurement. The mean was -6.4 dB. This may be translated into a totally reflecting area of 2.8 metres^2 and so any partially reflecting scatterer would need to be many times this size.

A resonant spherical gas bubble at this depth would only have a target strength of -21 dB, and hence would not account for -6.4 dB observed. However there is evidence in the work of Chapman et al. [4] to show that this is a resonance phenomena and so it is possible that these are groups of gas bubbles or shoals of fish with swim-bladders resonant at 2 kHz. Further evidence for this may be found in the track densities themselves in which fish shoal densities have been shown to lie in the region of 3 in 10^8 metres^3 [5] whereas fish densities have values around 1-3 in 10^3 metres^3 [6, 7, 8].

Assuming then that these are shoals of fish it is possible to estimate the numbers of fish in a shoal. The difference between the observed target strength of -6.4 dB and the strength of a resonant gas bubble permits a calculation of the numbers in one shoal to be about 25 in dividuals, after making allowance for mutual impedance this might be increased to say 50. It is also possible to estimate the lengths of the individuals from a formula derived by Haslett [9] in which the volume of the swim-bladder is related to the length of the fish. This puts the length of the fish at about 44 cms.

4. Conclusions

It has been possible to demonstrate that the strong scattering layer to be found at 2 kHz and 1000 metres in parts of the North East Atlantic is due to shoals of about 50 fish, with resonant swim-bladders having a radius of 1.9 cms, and with a length of 44 cms. These have been shown to be more numerous towards the north east, and not to exhibit any variation with the time of day as do the better known scatterers at 500 metres. No relationship has been found between the density of scatterers or their volume scattering strength and the values of temperature, density, salinity and the amount of dissolved oxygen at this depth.

5. Acknowledgements

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6. References

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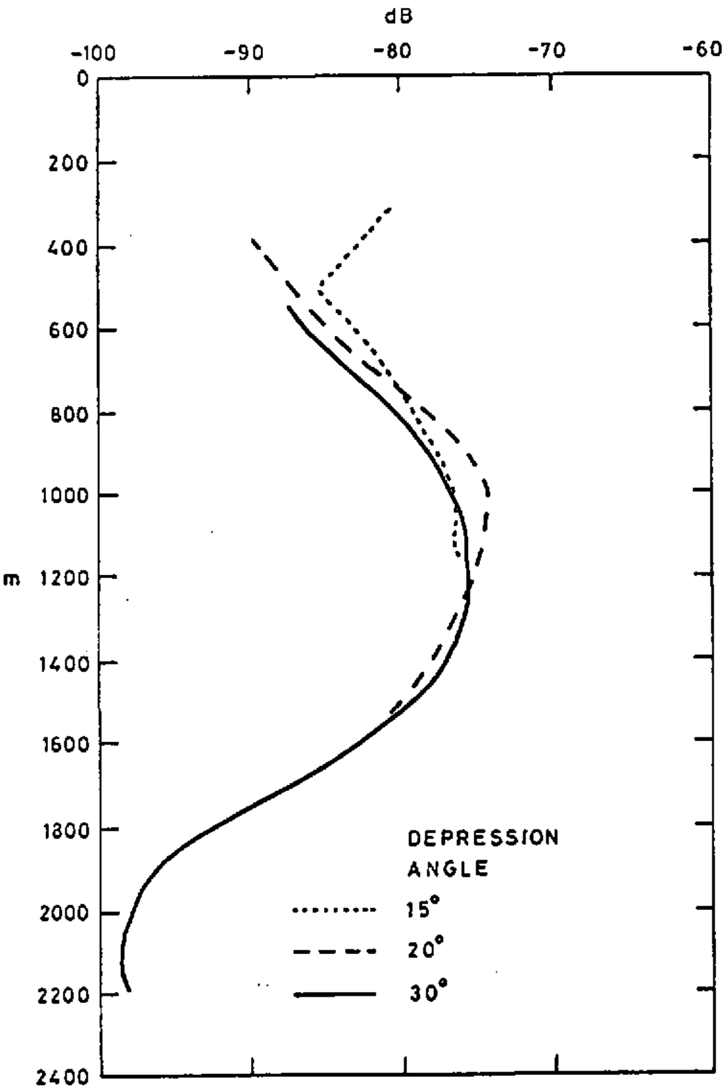


Figure 1. A typical plot of volume scattering strength against depth for a station in the Biscay area.

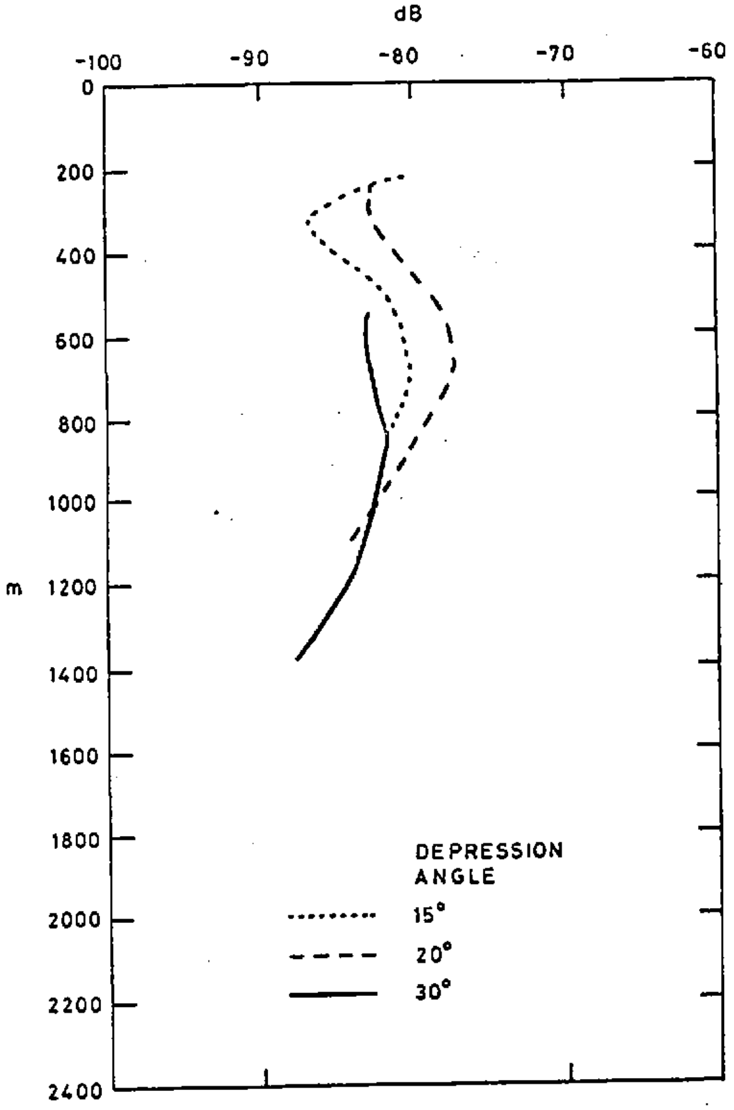


Figure 2. A typical plot of volume scattering strength against depth for a station to the north of the Azores.

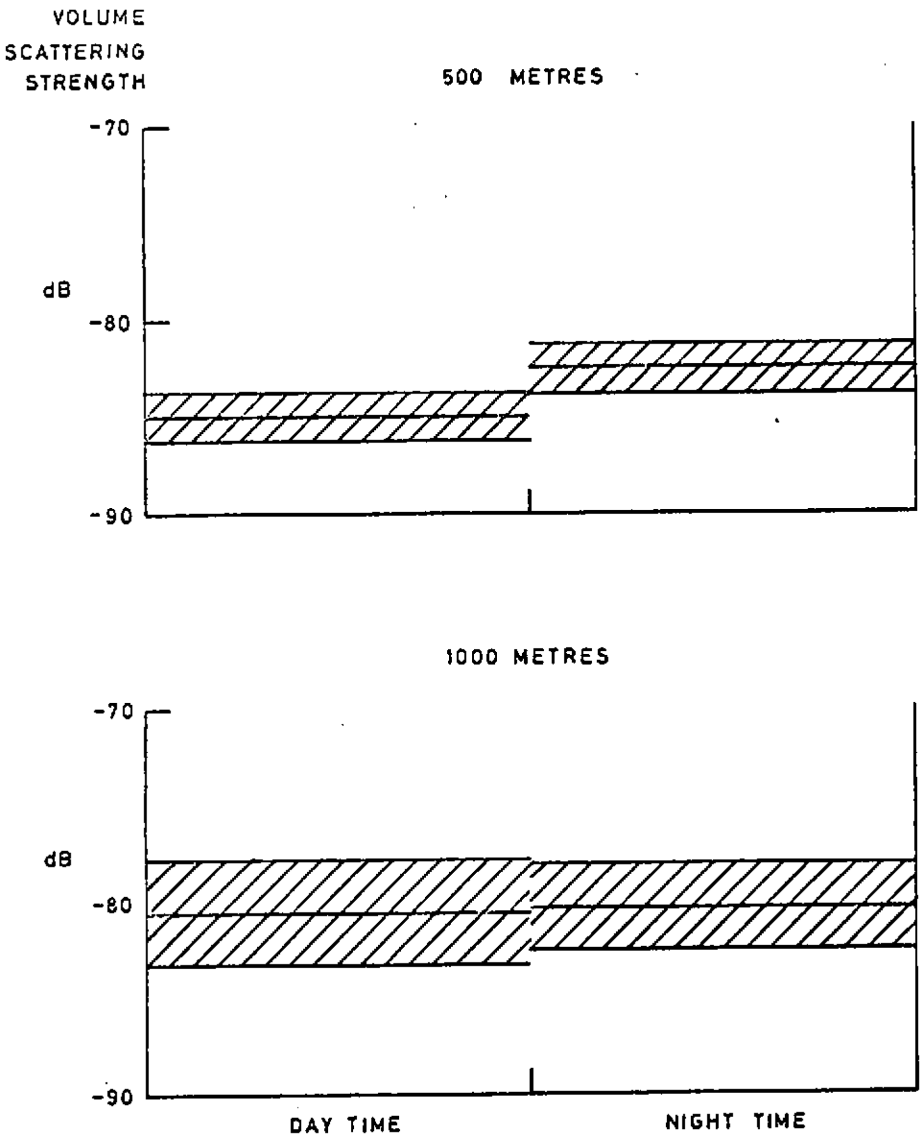
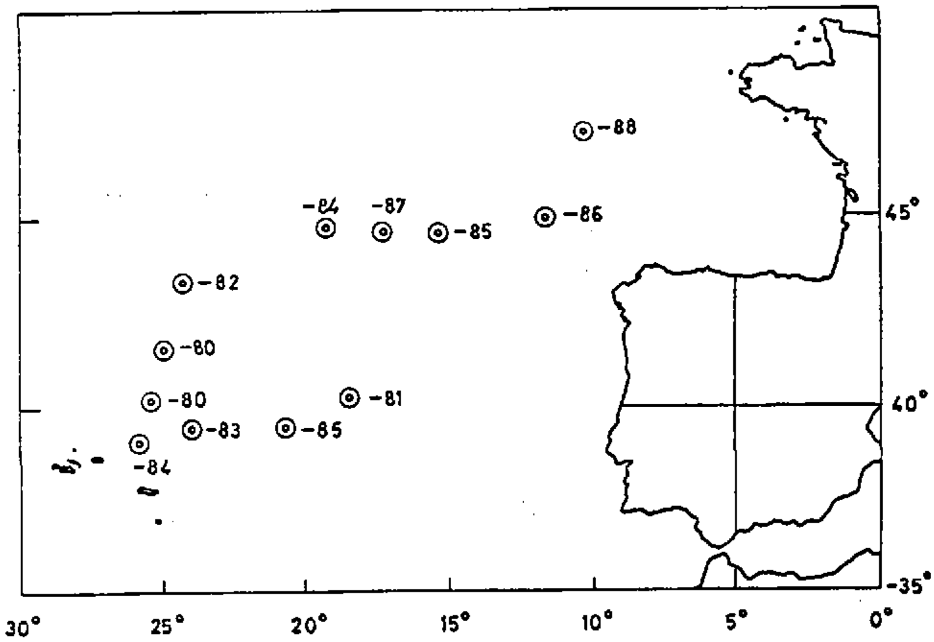
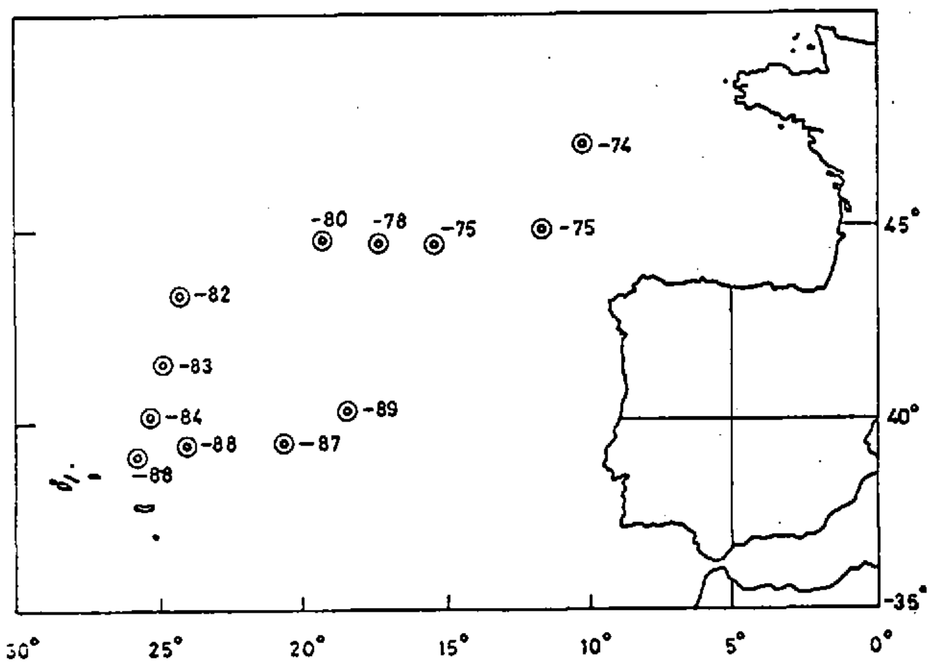


Figure 3. A chart showing the mean value of volume scattering strength at 500 and 1000 m during the day and at night.



Volume Scattering Strength at 500 metres



Volume Scattering Strength at 1000 metres

Figure 4. Maps showing the variation of volume scattering strength at 500 and 1000 metres with geographical position.

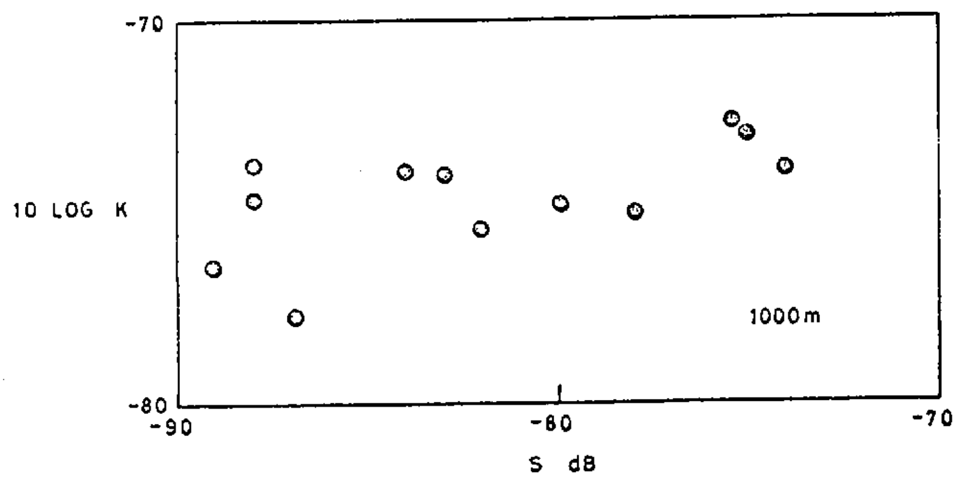


Figure 5. A plot showing the relationship between volume scattering strength at 1000m (S) and the density of scatterers (K).