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A twenty-three day twenty-mile echo record of fish behaviour

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The long-range sonar bottom-laid in the Bristol Channel was run continuously for twenty-three days in June 1964, displaying the changing structure in a 4° beam out to 37 km. The occasion was a cooperative fish investigation experiment involving mainly the Fisheries Laboratory, Lowestoft and the Admiralty Research Laboratory. The echo displays of fish are reproduced, and show character changes every few days. The advantage of continuity in such records is demonstrated, both in general and as a trials monitor. Special features include markings associated with anchoring, with a midwater trawl, and with a very simple artificial target.

Introduction

Some long-range sonar studies of fish echoes were introduced by Weston and Revie (1971). The investigations employed experimental echo-ranging equipment laid on the sea-bed in the shallow waters of the Bristol Channel. Mention was made of some early comparisons with echo-soundings taken from a ship, using ACS "St Margarets" in Autumn 1963. It is intended to present here the results taken during a much more ambitious collaborative venture in June 1964. Several different groups of workers were involved, as described in the following section. The general objective was to tie together the different types of observation on fish possible with the variety of equipments available.

The June 1964 fish investigations

(a) The long-range sonar was operated continuously from 1500 BST on 1 June till 0925 BST on 24 June, and the main object of the paper is to present and discuss the records taken over this long period. Accounts of most of the other investigations have already been published, and the sonar records provide the continuous background to all this other work.

(b) Another group from the Admiralty Research Laboratory operated the ARL sector scanning sonar from PAS "Gossamer", as reported by Voglis and Cook (1966). It is interesting to note that the working frequency of 300 kHz is greater than of the long-range sonar by the large factor of 300. The main object was to look at the fish shoals, found to be typically several metres across and with a wide variety of shapes. It was particularly convenient that Fisheries scientists from Lowestoft could be present during these trials, and Cushing and Harden Jones (1967) assessed the potential of the scanning sonar in fisheries problems. It has since been installed in RV "Clione" and extensively used in fisheries research.

(c) The RV "Clione", from the Ministry of Agriculture, Fisheries, and Food Fisheries Laboratory, Lowestoft took part, her main contributions being echo-sounding and fishing with an Engel pelagic trawl. Cushing and Harden Jones (1967) report the catch as mainly pilchards, with mean length 23·5 cm.

(d) RV "Platessa" from the Fisheries Laboratory, Lowestoft also participated.

(e) The Survey Vessel HMS "Egeria" spent several days in the area measuring the tidal streams, and this was backed up by a large variety of other current observations.

(f) A team from the National Institute of Oceanography sailed for part of the trial in RV "Clione" making "boomer" measurements on fish shoals. McCartney, Stubbs and Tucker (1965) report estimates of acoustic cross-section near 1·5 kHz.

(g) In the same area, over the same period, propagation experiments reported by Weston et al. (1969) showed acoustic attenuation effects caused by the presence of pilchards.

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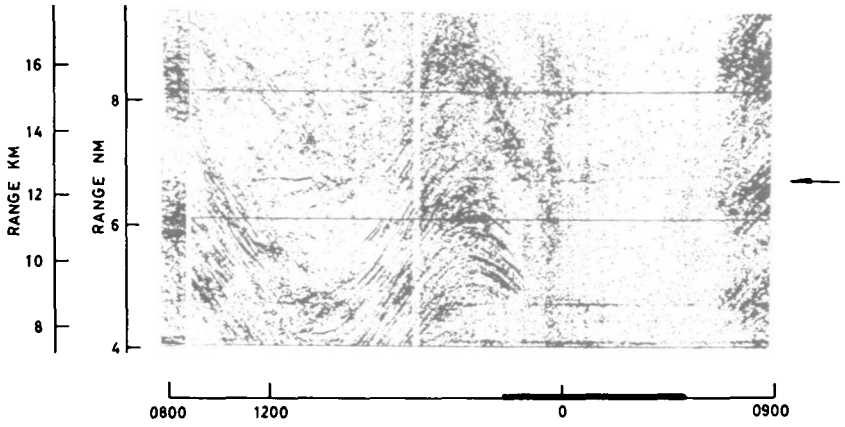


Figure 2. Display with echo due to anchoring, steered beam, 10–11 June 1964.

Equipment and records

The experimental echo-ranging facility has already been described briefly by Weston and Revie (1971). The mean working frequency was 1 kHz, and correlation sonar techniques gave a range resolution of 15 m. The correlator output was displayed on a large teledeltos drum recorder, high echo intensity corresponding to the degree of blackness of marking.

During the major part of these experiments one pulse was transmitted every 50 s but the drum was rotated once every 100 s. A number of receiver beams, each 4° wide, could be formed simultaneously. The returns for the natural or unsteered beam were displayed on the first half of the drum, and those for another beam (varying through the experiment) on the second half. Thus for each beam a delay time up to 50 s was displayed, corresponding to 20 nautical miles or 37 km.

From 1 to 24 June a total of 24 drum records were taken, the gap while changing paper being normally only a few minutes. The authors admit to being pleased by the performance of the equipment in allowing such a long and virtually continuous record to be taken. But the publishing of such a long record having so much detailed structure does present a problem. So the pull-out (Fig. 1) presents a photographic montage of the records for the natural beam only, with a linear reduction factor of about 10. Thus the pull-out shows as an intensity modulation all the reverberation returns for a beam 4° wide through the 23-day period.

Figure 1 (Pull-out). Continuous display for the unsteered beam, June 1964. Range in kilometres and nautical miles.

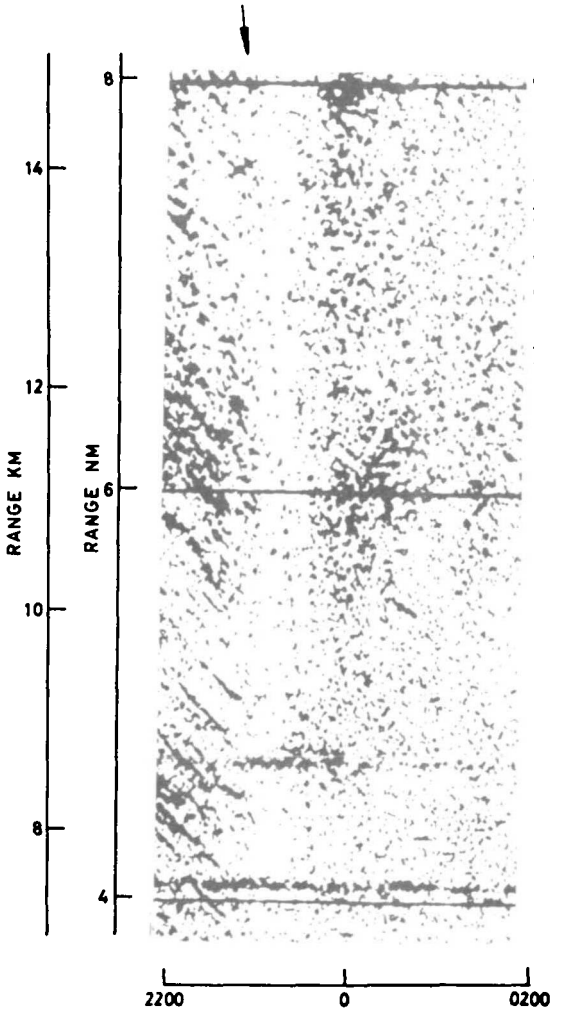
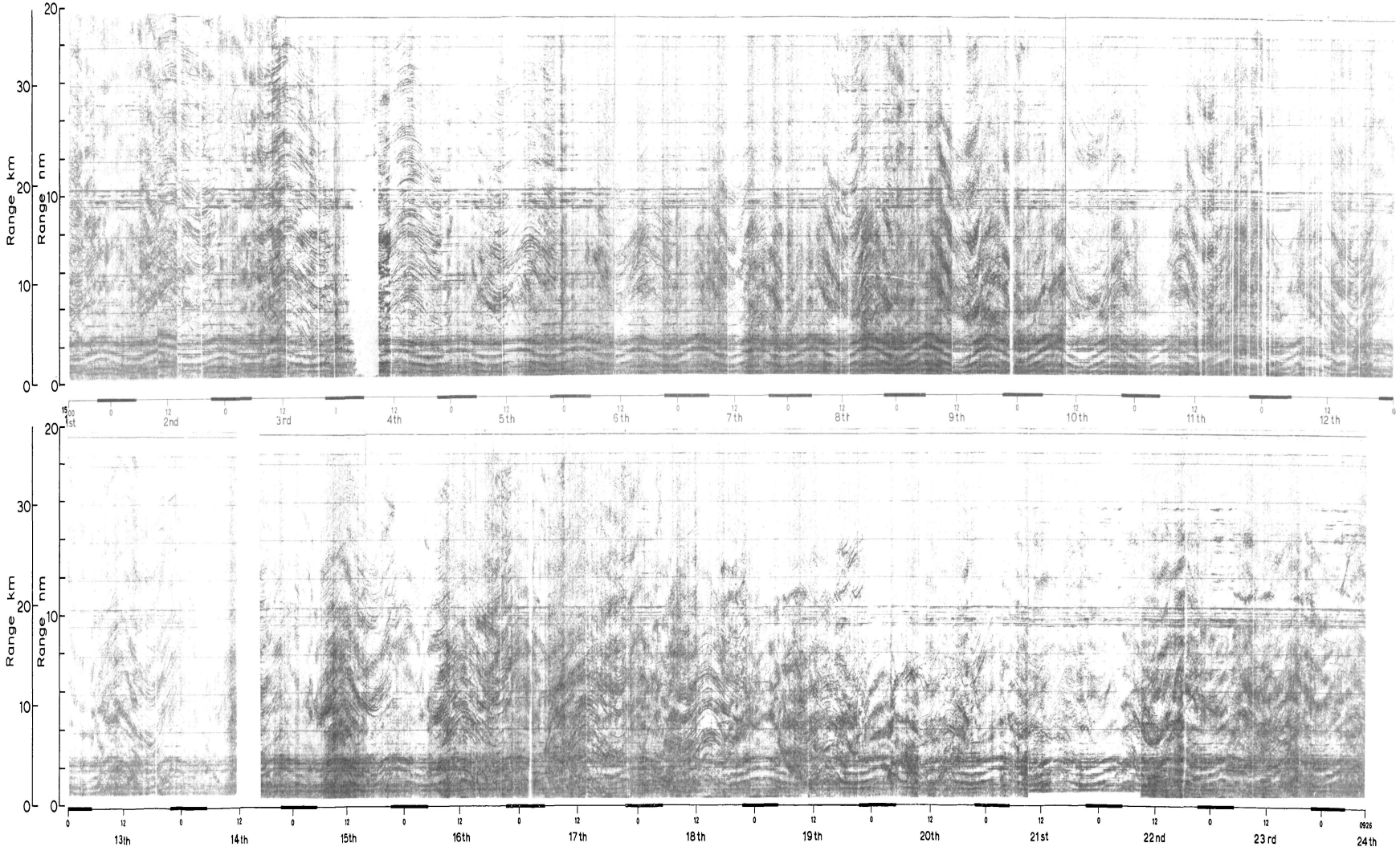


Figure 3. Sample display with trawl track, steered beam, 7 June 1964.



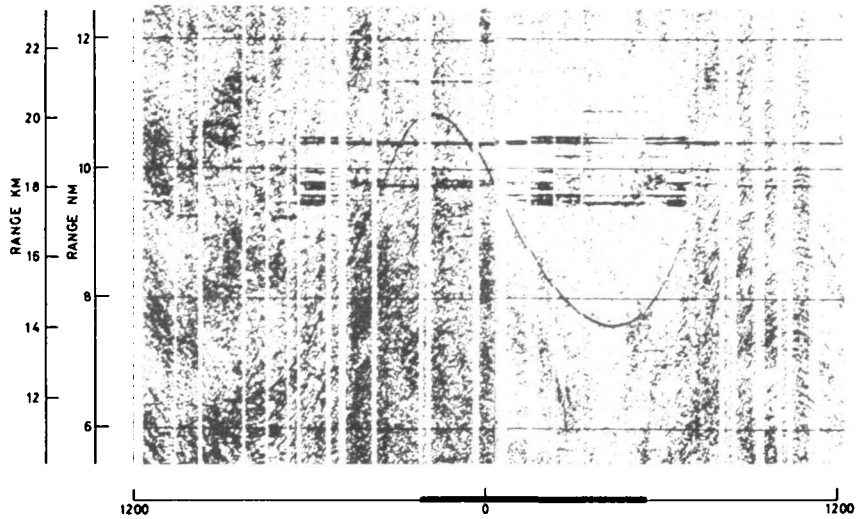


Figure 4. Sample display with artificial target, steered beams, 11–12 June 1964.

General features of the records

The general features are as in earlier records. First there are the discrete wriggling tracks due to pelagic fish shoals, assumed to be mostly pilchard. These show a sinusoidal range variation with the tidal streaming, sometimes with additional meandering. They usually disappear at night (times of sunset and sunrise are indicated on the time scale by thickness of line). Secondly, there are the fixed bottom echoes, at a constant range though not of constant intensity. Thirdly, note that the wriggler patterns, the bottom echoes (especially at close range) and the general diffuse background all show an intensity modulation owing to mode interference effects. This modulation has a typical spacing of 4 km, but its linear scale varies cyclically with the tidal changes in water depth.

A virtually continuous display for this length of time is unique, and allows the slow changes in the character of the display to be seen. For example the recording covered the period from neap tides on about 3 June, through springs on 11 June to neaps again on 18 June. The corresponding changes in the spatial amplitudes of both the wrigglers tracks and the modulation patterns can be very clearly seen.

It is possible to make up a brief diary of the character changes:

1– 5th Classical strong sinusoidal wriggler tracks, sometimes a little confused in the early daylight hours.

6– 7th Rough weather, due to the acoustic conditions there are few wrigglers to be seen beyond about 20 km.

8–13th The interference modulation of the wrigglers is very marked, note that this period is centred round springs. On the 13th wrigglers are present close inshore.

14th Rough weather, especially in the early daylight hours when there is a lack of definite wrigglers.

15–19th Wrigglers are still present at virtually all ranges. The records become steadily more confused. The sinusoidal patterns tend to give way to patches with criss-cross patterns of short tracks: – see for example 19th. Wriggler tracks at night become common.

20–24th The confusion grows. Wrigglers are no longer common close inshore, in fact the wriggler patterns generally are less definite and the concentration is patchy. There is a suggestion of very large numbers of parallel faint sinusoidal tracks (similar to tracks later associated with sprats), plus a few irregular strong tracks.

The taking of this long record proved extremely well worthwhile, but it needed much sustained effort. The next worthwhile advance would be a one-year record.

Special features of the records

(a) At about 1100 on 10 June RV "Clione" and PAS "Gossamer" anchored close together, at about 13 km range. At the same time a strong echo appeared

at the correct place in the correct beam (Fig. 2), looking rather like a fixed bottom echo though with slightly varying range. Fortunately the record was clear of wrigglers at that place and time. The echo faded later but then reappeared and was present throughout the night, only to vanish with the early morning arrival of wrigglers. The ships weighed anchor soon afterwards. The effect is thought to be most likely due to reflections from fish congregating round the anchors, the anchor chains, or beneath the ships. No other echoes associated with anchoring have been seen.

(b) RV "Clione"'s movements when towing the Engel midwater trawl were known, making it easier to locate afterwards her tracks on the long-range sonar records. Towing speed was about 2 m s^{-1} so that the lines lie almost parallel to the range axis, and even on the original records it is best to spy along the track. Visibility is best for haul No. 6 at about 2200 h on 7 June, reproduced in Figure 3. The track happens to come in the blank period on the record near sunset. Such a blank period with low reverberation happens occasionally due to a temporary increase in the fish attenuation. The relevant attenuation studies are reported by Ching and Weston (1971) and Weston et al (1969), and it is intended to describe the effects on the echo records more fully later.

Out of 16 hauls there were 10 with tracks detected. There were no tracks for haul 1 (very short), haul 7 (occurring 0425–0635h), nor hauls 13–16 (dated 12 June onwards). It may be noted that track visibility became steadily worse during the trial, perhaps connected with the changes in reverberation background. There was no obvious correlation between strength of track, depth of trawl, number of echo traces observed in the gape nor the number of fish caught. The echoes could be due to the headline floats, the fish in the cod-end, or the fish swimming near the gape which eventually escape. The headline floats theory is favoured.

(c) During the trial a new and simple type of artificial acoustic target known as "*Dentifrice*" was invented, the drifting of which could be monitored from the shore. The targets were made up of one or more vertical strings of about 30 floats with diameter 0·2 m which reflect coherently if they remain vertical. One or more "*Dentifrices*" were streamed on several occasions (see for example the strong sinusoidal track in Fig. 4). While there were "*Dentifrices*" in the water it was necessary to switch beams in order to track them, producing displays with a vertically broken-up appearance. The tracks of the fish shoals and of the floats may be compared for both movement and echo strength.

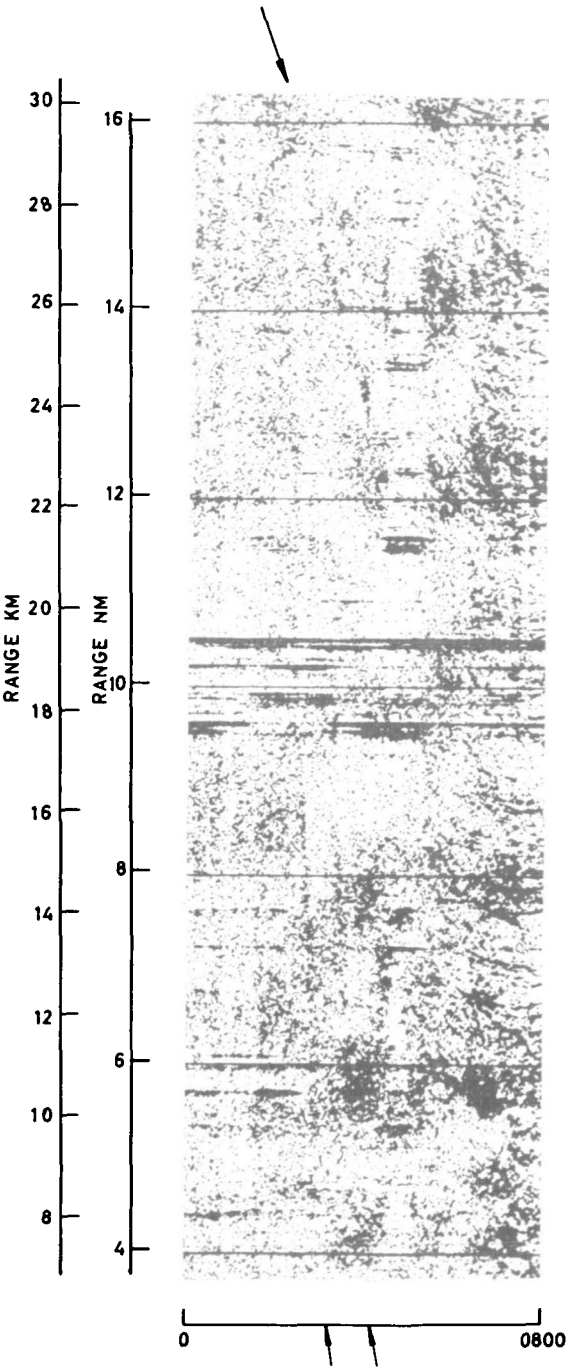


Figure 5. Display with broad tracks, unsteered beam, 3 June 1964.

(d) New features are being observed all the time on the sonar records, and it is not intended here to

make an exhaustive list of them. However, it is worth pointing out the broad tracks early in the morning of 3 June, the steepest of which corresponds to a closing speed of 4 m s^{-1} (Pull-out (Fig. 1), enlarged in Fig. 5).

Conclusion

One of the main objectives of the collaboration was to establish some correlation between the long-range sonar echoes, the various short-range echo observations and the catches made by RV "Clione". The general link was firmly established, and it is hoped to develop some of the points made in this paper when discussing fish populations later on. But a detailed link up could not be made, for none of the individual shoals found by the sector scanning sonar on PAS "Gossamer" could be positively identified on the long-range records. The difficulty comes from the high concentration of shoals, the different areas swept and the different spectra of shoal sizes which may be detected. It is not worth dwelling on this since detailed correlations have been achieved in later work which it is again intended to report separately.

The present paper has concentrated on the presentation of the unique long-range echo record, and demonstrated the advantage of continuity both generally and as a trials monitor.

Acknowledgements

Although this note is mainly concerned with the long-range echo display it is a convenient place to record our pleasure at the successful cooperation with the Lowestoft scientists, the Sector Scanner Team and the representatives from the National Institute of Oceanography (now Institute of Oceanographic Sciences).

Much of the credit is due to the Masters and Ships' Companies of RV "Clione", RV "Platessa" and PAS "Gossamer". The Hydrographer must be thanked for making HMS "Egeria" available, and Lt Cdr M. J. Stumbles and the Ship's Company for their willing help. The actual records are the culmination of the efforts of a large team, and the patient photographic work involved in reproducing them must also be acknowledged.

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