THE DEEP SCATTERING LAYER

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1. — INTRODUCTION

At depths of, generally, between 20 and 250 fathoms in the oceans, sonic and ultrasonic transmissions are frequently scattered by a layer which can be detected on the echo sounding trace, sometimes so strongly as to suggest a sea-bed echo. The cause of this layer, of which the depth has been observed to rise at sunset and sink at sunrise, is not precisely known, thought it is generally thought to be biological. Investigations into the deep scattering layer (DSL), as it is called, are being conducted in many countries, principally in the United States, France and Great Britain and a recent paper by Tchernia (1) has set out the present state of knowledge on the subject.

During H.M.S. *Challenger's* voyage in the Pacific in 1950 and 1951, when the ship was engaged in continuous echo sounding, (2) a record was kept of all observations of the DSL and investigations into it were conducted as circumstances permitted. Il seems worth while discussing some of these observations, which are of oceanographical interest and have some relevance to navigation.

The positions in which the DSL was recorded are shown in Fig. 1; only in Positions 1, 2 and 3 did the layer endure long enough for useful observations to be made and it is these observations which will be discussed in this paper.

2. — THE OBSERVATIONS

The positions in which the DSL was recorded are shown in Fig. 1 ; only in Positions 1, 2 and 3. Details of the investigations carried out are given under the heading of each position.

Position No. 1. — At 0600 (Z.T.) on 20 October 1950 when proceeding northwards in position N. 21°00', W. 111°30', about 130 miles north of Socorro Island, in a depth of 1900 fathoms, a thick scattering layer appeared on the echo sounding trace. When first noticed the layer was at 20 fathoms, increasing its depth. An alteration of course of 180° to run back on to the 'shoal' failed to arrest its deepening progress and it was finally lost at 105 fathoms. For the next five days calm, clear weather prevailed and this layer was regularly seen in the echo sounder at dawn and dusk until position N. 31°00', W. 117°25' was reached. Only occasionally was it seen during the night in its shallow position and by day at depths of 100 fathoms or more.

Fig. 2 shows the diurnal vertical migrations of the layer seen on the echo sounder morning and evening from 20—25 October; the times of sunset and sunrise are shown on the diagram. Records were taken of the diurnal migration measured against light as recorded by the depth at which a Secchi disc could be sighted, this being a white disc of 1 foot diameter, and also with reference to sunset and sunrise. As the weather conditions were very clear the two records were similar. Fig. 3 shows the layer depth against time relative to sunrise and sunset. All observations over the five days have been included in this diagram. The rate of change of depth for descent over the five days averaged about 14 feet per minute, but speeds of ascent varied from 9 to 3 feet per minute. No apparent difference in light conditions could be seen to explain the observations for 20 October being below the remainder.

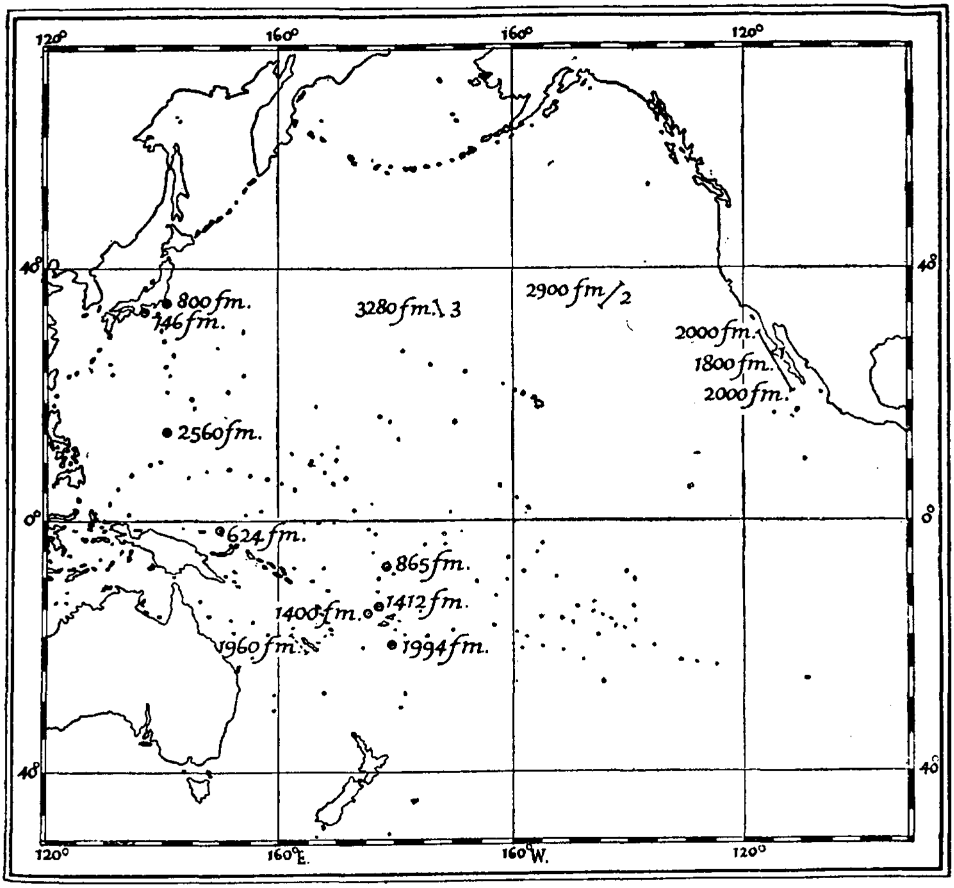


Fig. 1. — Positions of DSL recordings by H.M.S. *Challenger.*

A number of plankton hauls were made with an open plankton net both within and outside the layer during the five days' observations. Nine hauls were made in the layer and four hauls above the layer in positions shown in Fig. 2. The hauls contained *copepods, sagittae, medusae, euphausiids, siphonophores, pteropods, salps, Tomopteris* and *ctenophores,* but no *euphausiids, salps* or *ctenophores* were caught in the hauls taken above the layer. The catches from within the layer were considerably greater in quantity than those taken outside the layer.

Thirteen bathythermograph records were made during the course of the observations as show on Fig. 2, a somewhat similar temperature/depth pattern being obtained on each occasion. This pattern showed a marked discontinuity at about 90 feet, with an almost isothermal gradient down to this depth. Fig. 4 shows the bathythermograph trace taken just after sunrise on 24 October, which gave a pattern typical of all the traces obtained in this series of observations.

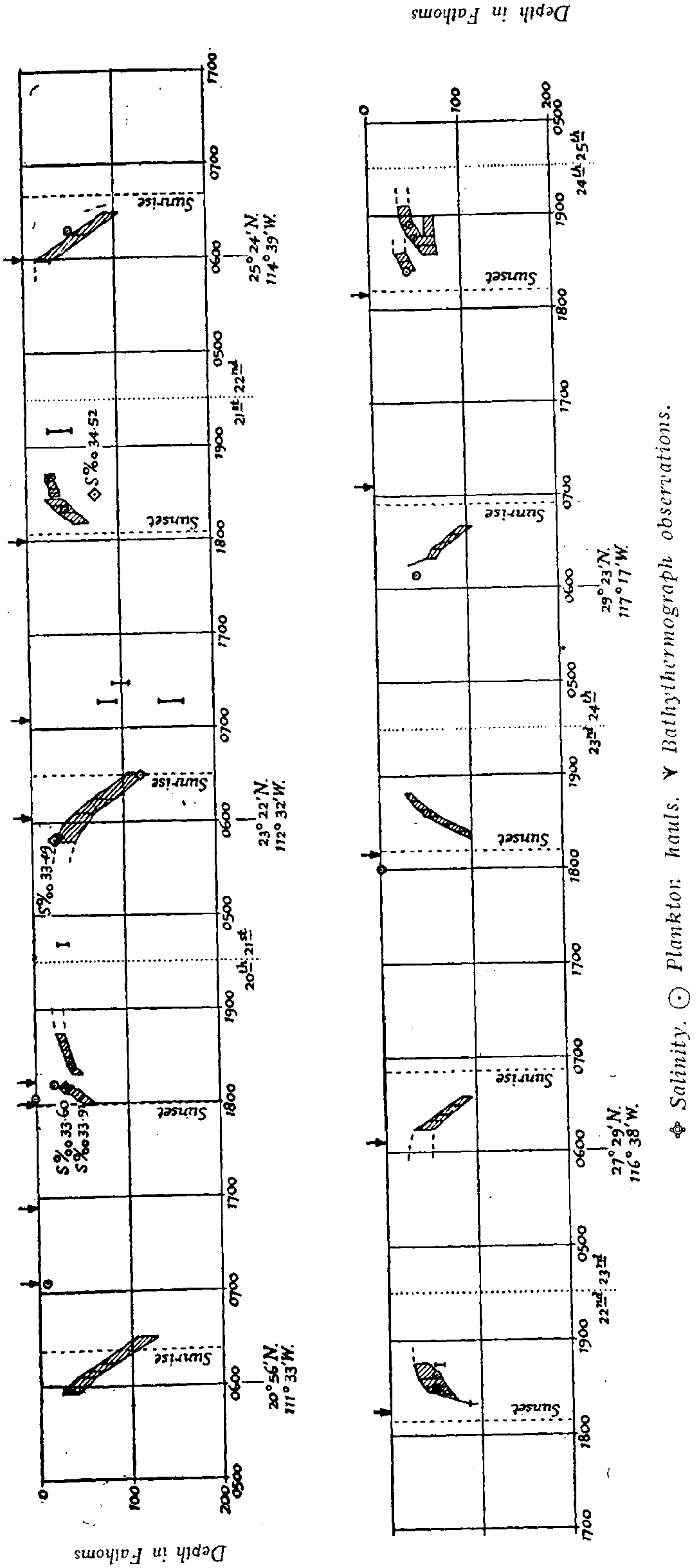
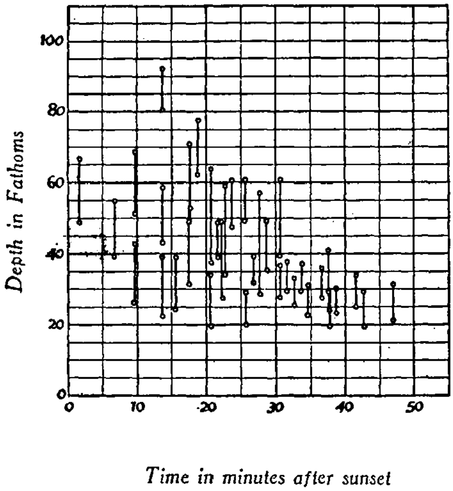


Fig. 2. — Recordings of DSL, 20-25 October 1950.

Some water samples were taken in and below the layer and the salinities of these samples are shown on Fig. 2.



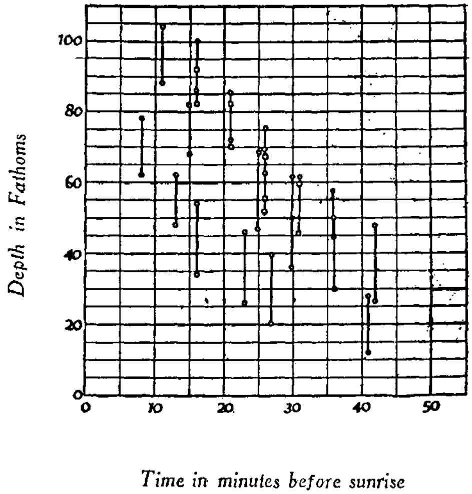


Fig. 3. — Combined DSL observations for 20-25 October.

Position No. 2. — At about 0745 (Z.T.) on the morning of 19 February 1951 in position N. 37°27'3, W. 140°57'7, in a depth of 2900 fathoms, a layer was seen on the echo sounding trace descending steeply. The layer continued to appear on the echo trace throughout the day, during which time the vertical movements and also the thickness of the layer were very erratic (see Fig. 5). The

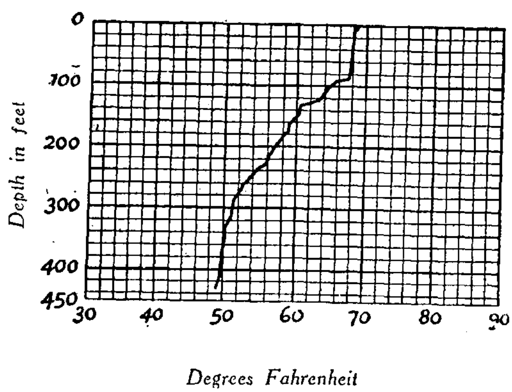


Fig. 4. — Bathythermograph reading on 24 October.

layer became very thin and weak as it came towards the surface at sunset and was lost soon after the end of twilight. Between 22h00m and 24h00m four different layers were seen moving upwards, and later they combined to form one very thick layer, the shallowest depth of 34 fathoms being reached at 01h.40m. Descent then began, but was interrupted by an upward movement, which turned into a steep descent again at dawn, the layer being lost at 125 fathoms.

Nothing was seen on the echo sounder during the remainder of the day of 20 February, but shortly after twilight two distinct layers were visible which

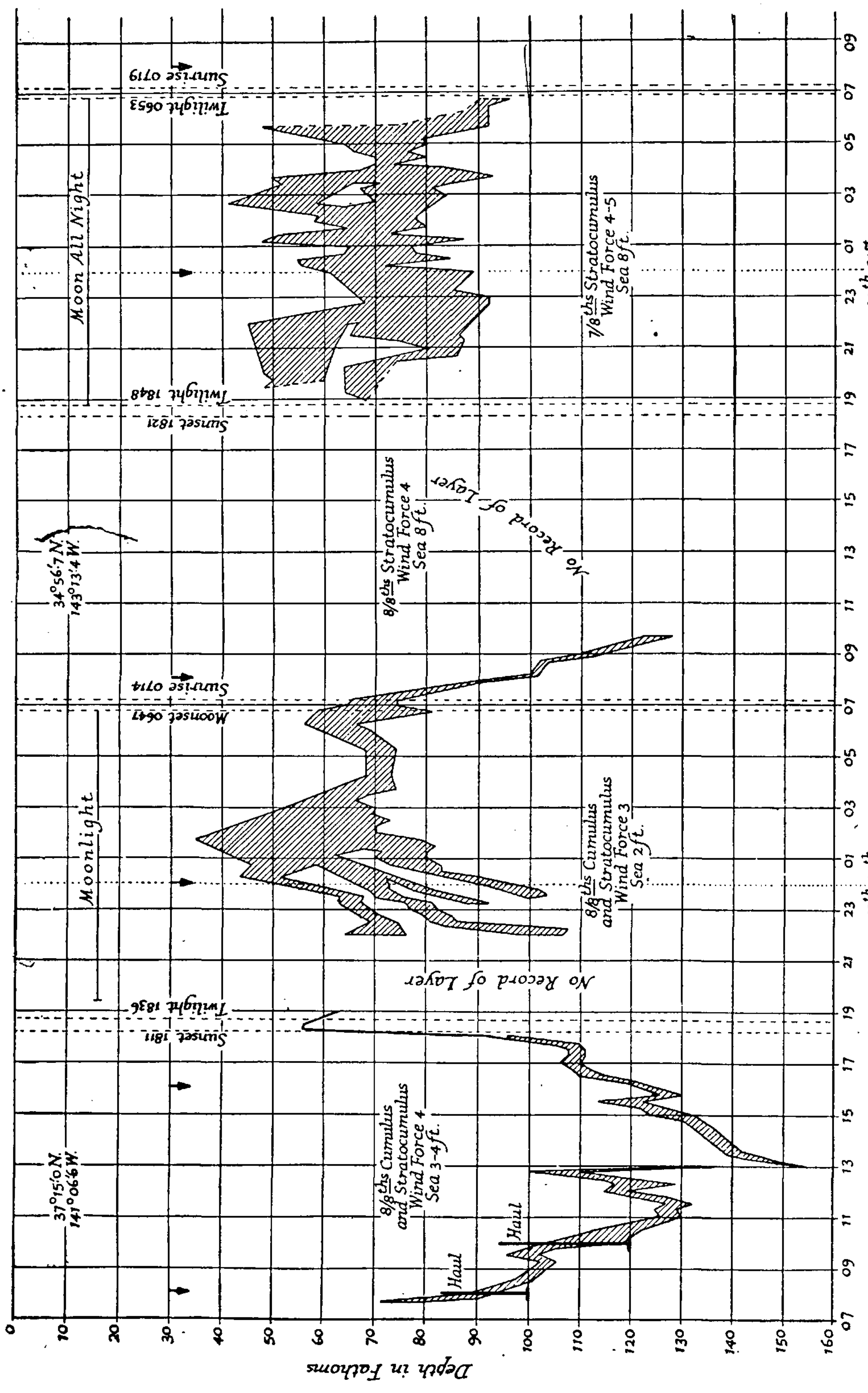


Fig. 5. — DSL observations for 19-21 February 1951. The times of bathythermograph readings are marked by arrows.

had apparently completed the ascent without being seen on the echo sounding trace. These two soon formed into one solid layer, which varied in thickness until descent began about an hour before twilight on the morning of 21st. Speeds of ascent and descent were considerably slower than those for Position No. 1, and as far as they can be deduced from this complicated picture would appear to be much the same at about 2 feet per minute.

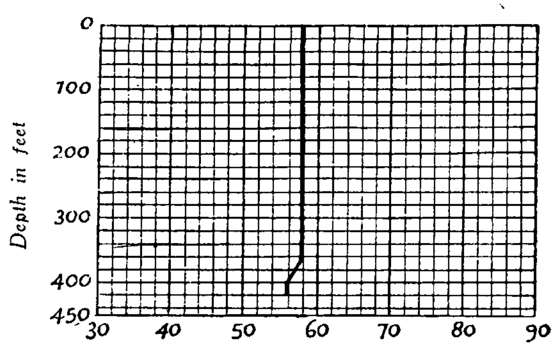


Fig. 6. — A typical baththermograph reading in February.

The weather conditions were overcast throughout this period of observations and sea conditions got steadily worse, permitting plankton hauls only on the morning of the 19th when two hauls were made through the layer at depths

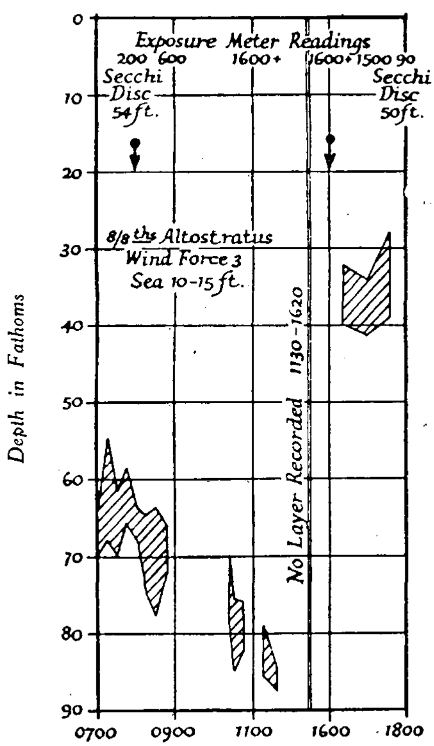


Fig. 7. — DSL observations showing Secchi disc and exposure meter readings.

of 100 and 120 fathoms (Fig. 5). These catches were composed of large *pteropods, copepods,* large *sagittae* and *medusae.*

Six bathythermograph records obtained during these observations (Fig. 5.) gave similar temperature/depth patterns. These showed isothermal water to an average depth of 385 feet. The bathythermograph record shown in Fig. 6 is typical of the other five slides obtained during these observations.

Position No. 3. — At 0700 (Z.T.) 18 March in position N. 34°28'.7, W. 171°39'2 in a depth of water of 3280 fathoms the layer was seen descending but was lost from time to time as may be seen in Fig. 7. The layer was lost at 85 fathoms shortly before noon when the daylight had reached its maximum intensity, but was picked up again at 32 fathoms at about 1620 having apparently made the ascent although the light was still at its maximum intensity for the day. The layer was finally lost as it was moving towards the surface at sunset. Bathythermograph records taken in this position showed isothermal water to a depth of 450 feet.

Conditions for observing the layer were not good on this occasion; 8/8ths altostratus giving an overcast sky and a heavy sea and swell made the hauling of plankton nets impossible.

The light intensity on this occasion was measured with an exposure meter pointed vertically at the sky; the values in foot-candles of these observations are shown on Fig. 7, together with two Secchi disc depth measurements taken simultaneously with the exposure meter readings.

3. — DISCUSSION

Tchernia has pointed out that all observations which have an incontestable bearing on the DSL have been effected with special ultrasonic appliances transmitting continuous waves with a long duration of transmission, and that ordinary navigation sounding appliance are most frequently appliances with damped transmissions and short durations of transmission. *Challenger's* set, Admiralty Type 767, was similar in these respects to a navigation sounding equipment, transmitting damped transmissions of 150—200 μsec. duration. This set is normally fitted in British surveying ships and has a superior transmitting power to many navigational sets. The deepest sea-bed soundings taken with this particular set during *Challenger's* voyage were 4100 fathoms with the ship stopped and 3629 fathoms with the ship under way, both taken in the Japan trench under ideal conditions.

The sighting of fish shoals on navigational echo sounding sets in coastal waters is already common enough, and in fact is regularly used as a method of locating fish, particularly herring. It now seems likely that as modern echo sounding performance improves the DSL will be seen by those using their echo sounding machines in deeper waters, perhaps when searching for the 100-fathom of the sea-bed, and if both are on the same phase of the echo sounding machine the depth of both may be read off. If these two appear on different phases there is a possibility of mistaking the DSL for the sea-bed echo.

The bathythermograph records do not show any correlation with the movements of the layer and at first sight it would certainly seem that light is the main factor which governs the diurnal migrations of the layer.

Challenger was on a sounding and seismic cruise and carried no biologists or adequate gear for collecting plankton from the layer; an obvious criticism of our methods is that open plankton nets were used, which having been towed through the layer may have caught specimens from above no matter how quickly they were hauled to the surface. We are indebted to Surgeon Lieutenant D. O. Haines, the ship's Medical Officer, for taking the plankton samples and preserving them. They are now in the British Museum (Natural History). It is interesting to record that a new species of *siphonophore, Lensia challengeri,* has been reported by Mr. A. K. Totton of the British Museum (Natural History), (3) being found in eight of the samples taken from the layer in Position No. 1.

As already stated a number of workers have studied the causes of the deep scattering layer and in the United States a considerable amount of effort has been expended in towing nets of various types through the layer. (4) Among these workers is Tucker of the U.S. Electronics Laboratory, San Diego. Plankton and fish have been caught, and from such catches it seems possible that the *euphausiids* may be one of the scatterers of sound. The *euphausiid* is a shrimp-like animal having a hard shell; like many other forms of plankton it has a diurnal vertical migration. There are 85 known species, some attaining a length of as much as 2 inches.

Perhaps fish, feeding upon the migrating plankton, may be the cause of the scattering layer, and this would be more likely with types of fish having an air bladder, as in the *Myctophidae*, the Lantern Fishes, which have been collected in considerable numbers by Tucker in nets towed through the layer, and he attributes an essential role to such fish. There are about 150 species of *Myctophidae* varying in length from about 1 to 6 inches. Marshall, of the British Museum (Natural History), has examined a considerable number of bathypelagic fish for swim bladders and has found that the commonest fishes in deep oceanic waters (between 100 and 1000 metres) have such bladders, which might be expected to scatter sound. (5)

It might be thought that no fish could be so numerous that they could cause this solid layer. However, Tucker points out that *Myctophidae* are among the commonest fish in the sea, and on the results of an oblique net haul through the scattering layer from 1240 to 860 feet he estimates the number of fish in the sound cone within the layer to be 55,000, or 0.001 fish per cubic foot; it must be borne in mind that fish may easily avoid such a net, so that the population could be considerably denser.

Whether the deep scattering layer is caused by plankton or fish feeding upon the plankton or a combination of these two and further unknown factors, it is a most interesting phenomena, and one which will explain many of the 'false echoes' which appear on the echo sounding trace in oceanic areas.

4. — ACKNOWLEDGEMENTS

The assistance of Mr. N. B. Marshall of the British Museum (Natural History) in identifying the plankton specimens is gratefully acknowledged. Acknowledgement is also made to the Admiralty for permission to publish this paper.

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