

and not their activity. The statement that the farm worms contribute significantly to flood relief in the Netherlands is open to question, for it is well known that earthworms have a low tolerance to carbon dioxide and will perish in most water-logged soils. The Darwin estimates of yearly soil turnover by worms at 400 lb/acre would more properly read from 7 to 18 tons per acre, per yr.

In general it can be said that worms are abundant in well-aerated soils of high organic content, but it is doubtful whether they actually improve poor soil conditions because their action is most likely effective only in the maintenance of good soil properties already present. The organic gardener should look with some skepticism on the claims for the benefits derived from the introduction of worms into soil and at least should be certain that worms supplied by the earthworm farmers are of a species known to inhabit the type of soil into which they are to be introduced.

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A Scattering Layer Observation

The deep-scattering layer has been shown to be present over most of the oceans with the possible exception of the polar areas. It is generally believed to consist of marine organisms, and one of its remarkable features is the constancy with which it shows on an echo sounding record as a ship moves along. This constancy is surprising in view of the relative patchiness of plankton indicated by the towing of continuous plankton samplers (1).

At the depth of the scattering layer an echo sounder indicates only the presence or absence of a scatterer within a large area. In an effort to obtain better resolution in recording the layer a transducer was lowered to various depths. With the echo sounder set on its shortest range, only a small volume of sea was returning echoes at any one time. The drifting of the ship moved the transducer through the water and resulted in scanning. Figure 1 shows the type of record obtained under these conditions. Two conclusions can immediately be drawn. First, the scattering is patchy as though it was caused by individuals or small schools. Second, the size of the "individuals" is small relative to 25 ft. This is indicated by the concave underside of the patches on the record even at ranges as short as 50 ft. As the scatterer passes through the beam its distance from the transducer varies. It is initially further away, reaches a point of closest approach directly beneath the transducer and then again recedes as it passes out of the conic sound beam. If the scatterer were longer than the beam width it would return sound from a greater range when part of it was at a minimum range. Since this is not the case even at a range of 50 ft, where the sound beam is 25 ft wide, the second conclusion seems justified.

The velocity of the scatterers relative to the transducer can be computed from the curvature of the upper sides of the patches. Nearly the same value is obtained for all patches; therefore it would seem that the scatterers are not affected by the sound and are not moving about randomly. For this reason it is straightforward to count the number of patches in a known volume of water scanned and calculate their density.

So far it has been possible to do this only outside the scattering layer. The scatterers occur on the average of one for every 3×10^5 ft³ of sea. This is in agreement with the frequency of large individual echoes found by Raitt (2) outside the scattering layer in the Pacific Ocean. It is also in substantial agreement with the numbers of fish caught by a mid-water trawl of efficient design described in some unpublished work of Backus. Backus' investigation was made in the same area of the Atlantic as ours.

The scattering layer in the North Atlantic is usually best developed during the day at a depth of about 250 fathoms. Consider that some transducers are sensitive over an angle of about 30 deg. Then from the surface the sound beam is sampling a circular section of the layer 750 ft in diameter. Echoes are returned from a thickness of half a pulse length, which for the records here is 20 ft. The volume of sea returning sound at any instant is then about 10^7 ft³.

Unfortunately the only figures here are for outside the main region of scattering. Even in this sparsely populated area there are 30 individuals in the sound beam at one time. Backus (personal communication) reports a density of fish in the layer that would place at least 500 in the beam at one time. Marshall (1) has presented plausible evidence that bathypelagic fish are widespread and nonschooling in behavior. It is not surprising then that the scattering layer record appears continuous. Such a large average number would only rarely be expected to fluctuate to a low value and thus give no echo.

Work will be done to narrow the cone angle and

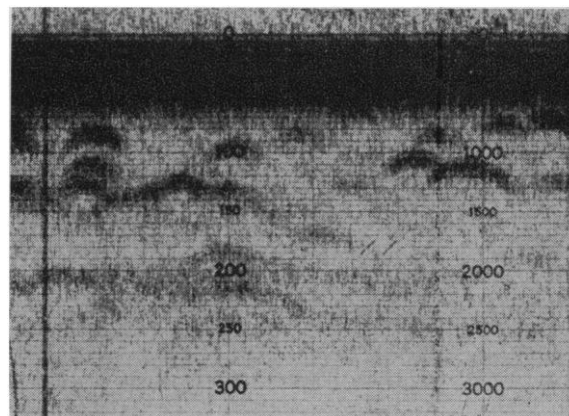


Fig. 1. Section of recording tape with the transducer at a depth of 200 m. The vertical scale is 0 to 500 ft. This represents depths below the transducer. The frequency of the sound was 12 key/sec.

shorten the pulse length. This will permit the counting of scatterers in more densely populated regions. In addition, a measurement of the echo intensity will help to establish the size range of the scatterers. The possibility exists of using a surface-controlled camera in conjunction with the transducer. This should constitute marked improvement over the random picture-taking technique now in use.

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References

1. N. B. Marshall, "Bathypelagic fishes as sound scatterers in the ocean," *J. Marine Research* **10**, 1 (1951).
2. R. W. Raitt, "Sound scatterers in the sea," *ibid.* **7**, 393 (1948).

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Pure Cultures of Fungi Produced by Ants

Experiments and observations elucidating the mechanisms by which pure cultures of fungi are cultivated and maintained in the nests of attine, or fungus-growing, ants have been conducted in Panama and Florida in 1954, and at Swarthmore College in 1953-54, with similar results. The ants' habit of stripping the leaves of economic plants causes the larger attine species to be ranked as major agricultural pests throughout much of Latin America. Heretofore, an explanation for the ability of the ants to create pure cultures of fungi despite the constant bringing in of alien bacteria and fungi has been lacking.

The attine ants are found exclusively in the New World and primarily in the tropical regions. The fungi that the ants cultivate have not been recognized outside of ant nests, and the ants are dependent on the fungus for their food supply. In most of the species, a nest, consisting of one or more chambers in which a fungus garden is developed, is formed in the soil. The fungus garden is usually formed on a vegetal substrate, such as triturated leaves. Removal of the ants from a fungus garden causes it to be soon overwhelmed by alien fungi and bacteria. The fungi are clearly unable to maintain themselves and do not grow except under the care of the ants.

The northernmost of the fungus-growers, *Trachymyrmex septentrionalis* McCook from New Jersey, has been kept under observation since September 1953, at Swarthmore. Two types of fungi appear regularly in the artificial cultures and have been cultured on potato dextrose and Sabouraud's agar. A few workers are able to maintain a fragment of fungus garden in its normal condition on an agar plate, despite flourishing alien fungi of *Penicillium*, *Aspergillus*, and *Mucor* types and bacterial colonies that are close to the garden. The ants walk over these regularly as they forage for substrate.

In Panama, fungus gardens and parts of colonies of *Cyphomyrmex costatus* Mann and species of *Atta*,

Trachymyrmex, and *Apterostigma* were kept under observation at the Gorgas Memorial Laboratory, and their fungi were cultivated on Sabouraud's agar. Several types of fungi were produced. *Atta* and *Trachymyrmex* strains produced bromatia, a concentrated form of gongylidia that is eaten by the ants, and which grew in these artificial cultures much as in ant nests. These were fed back to the ants after culturing for 2 mo or more. The ants accepted them as food and used them as a nucleus for a fungus garden. As at Swarthmore, it was found that the ants of these genera could maintain fragments of fungus gardens in the pure condition on agar plates despite a forest of surrounding alien fungi.

At the Archbold Biological Station in Florida, *Trachymyrmex septentrionalis seminole* Wheeler and *Cyphomyrmex rimosus minutus* Mayr were kept under observation in the same manner. Ants of *T. septentrionalis seminole* from Florida adopted and cultivated fungus gardens of the New Jersey form at Swarthmore.

This Florida *Cyphomyrmex* fungus developed, on Sabouraud's agar, two strains quite different from that of the Panama *Cyphomyrmex costatus* or from that of any of the other attines. One strain developed a morel-like or vermiculate form that has been recorded in the literature [*Rev. de Ent.* **16**, plate 1, Fig. 2 (1945)], and which the author developed in 1935 from the same ant in Trinidad. After the fungus had been reared in artificial culture for more than a month, it was fed back to the ants, which used it as food and cared for it as though it were their normal fungus.

On the basis of these and other data to be published more extensively elsewhere, it is postulated that the salivary and anal secretions of the ants may play a primary role in creating conditions for pure cultures of ant fungi. Identifications of these fungi are desired, and cultures will be submitted to mycologists upon request.

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Modern Cosmology and the Fixed Stars

Herbert Dingle's article, "Science and modern cosmology" [*Science* **120**, 513 (1 Oct. 1954)] is a most provocative and explicit statement of the uneasiness and dissatisfaction that any thoughtful student of modern cosmology must feel. It might be remarked, however, that this unhappy situation cannot wholly be blamed on the "newer" cosmologies; it reflects as well a growing realization that general relativity itself is inadequate to the claims that are often made in its behalf.

Dingle, of course, makes no such rash claims, and rightly stresses the *relativity* of the theory, the emancipation of physical reality from coordinate systems. This, with the allowance for curved metrics and consequently the incorporation of gravitational "forces" as inertial effects, is the great advance—and it is truly