Burrows and Oscillative Behavior Therein of *Lumbricus terrestris*

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Introduction

Our paper is presented as a contribution to the knowledge of the annelid worm *Lumbricus terrestris* Linnaeus, 1758 (part) Müller 1774 (part). This large peregrine earthworm was an accessory to the importation of plants from Europe by our colonists and has become widely established (3, 6, 7, 8, 9). There has been no complete study of the life history, ecology and behavior of *L. terrestris* though Darwin (1) and others (4) have made significant contributions.

While it is not the purpose of this paper to detail any behavior but oscillative activity in the burrow, it is pertinent to this report that *L. terrestris* performs certain basic burrowing, feeding and reproductive activities which differ from those of other Lumbricidae found in association with them. The latter seldom leave the earth and are inclined to feed on the organic fraction of the soil. Incidentally, many species of worms, including *L. terrestris*, willingly forsake the soil to take up residence in suitable concentrations of organic waste such as leaves or compost, but since such concentrations are atypical the phenomena will be noted only in passing.

The burrows of *L. terrestris* open directly to the surface of the soil and at night the worm extends its body from it in search of food which, if found, is grasped in the mouth and drawn back to the burrow opening where it remains until consumed. In some cases such a large amount of food is accumulated around a burrow opening that the name "earthworm midden" has been applied to it.

The relation of the reproductive activity of *L. terrestris* to this report is found in the manner in which copulation is frequently, if not always, carried out on the soil surface. It seems to us that if *L. terrestris* constructed a network of interconnecting burrows it would copulate there, as do other Lumbricidae, rather than at the surface where they are more vulnerable to predators. In other words above-ground copulation tends to indicate that no extensive interconnecting burrow systems are constructed by *L. terrestris*.

Burrows of *Lumbricus terrestris*

The surface of the soil occupied by *L. terrestris* will usually be mammilated with mounds of castings at the burrow openings. The castings are, of course, the excreta which results from the consumption of soil by the worm during burrowing. The quantity of soil which accumulates on the surface indicates that *L. terrestris* must actively ingest soil and bring it to the surface for deposit, thus excavating a burrow. While it cannot be stated with certainty that *L. terrestris* does not cast underground, the practice of surface casting, to the degree observed, contrasts with the

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subsurface casting into burrows, root tunnels and chambers by *Allolobophora caliginosa, Allolobophora chlorotica* and various *Diplocardia* sp.

The apparent extensive burrowing activity of *L. terrestris*, as indicated by the accumulation of castings and the observation of distinct burrows beyond 12 inches, led us to a more thorough investigation of the burrows. Attempts to trace the extent and pattern of these met with limited success until we turned to the use of natural rubber latex. The feasibility of using this material was reported some years ago by Garner (2).

Methods and Materials

Investigation of the burrows of *L. terrestris* was undertaken on bluegrass sod away from the roots of trees. The sod which would interfere with the flow of latex was removed by scalping the surface with a spade. The burrow (or burrows) located before scalping was cleared of soil particles to allow drainage of the latex. A circular container open at both ends was placed over the burrow to act as a reservoir for the latex while drainage into the burrow was completed. Latex was added to the reservoir until all drainage ceased and a thin cap of rubber was allowed to form on top of the soil.

Natural rubber latex coagulates to elastic rubber upon water loss and change in pH. Soil absorbs both the moisture and the ammonia used to maintain the liquid state of the latex. Our experience suggests that latex casting in moist soils will not be successful and we recommend that initial attempts at casting be made in dry soils.

After a minimum of 24 hours the arduous task of digging the cast was undertaken. It was necessary to make a deep excavation adjacent to the area containing the cast to facilitate its removal. In the laboratory the cast was washed to remove clinging soil particles and then photographed. (The casts tend to become sticky in time and cannot be stored indefinitely.)

Discussion

The flexible, three dimensional casts obtained by the above method disclosed that the burrows of *L. terrestris* are distinctly separate vertical tunnels. The terminal depth of burrows in this study was three feet but it is probable that burrow depth would vary with soil and moisture conditions. Guild (4) reports that Darwin and Müller both noted that *L. terrestris* burrows to a depth of ten feet under certain soil conditions in Great Britain.

The cast illustrated (Fig. 1) is included to show that the earthworm burrow did not come out as a simple cast as other spaces filled by latex complicate the picture. Two other recognizable types of soil space were filled by the latex. These were: (1) the soil cracks common to dry soil, and (2) long branching tunnels formerly occupied by roots. The latter structures were recorded in fine detail.

Oscillative Behavior

The behavior of *L. terrestris* at the surface coupled with the new knowledge gained from latex casts that a single worm occupies a nonbranching vertical burrow led us to an investigation of the behavior of the worm in the burrow and in particular its vertical movement. We desired answers to such questions as how far, how often, in what direction,

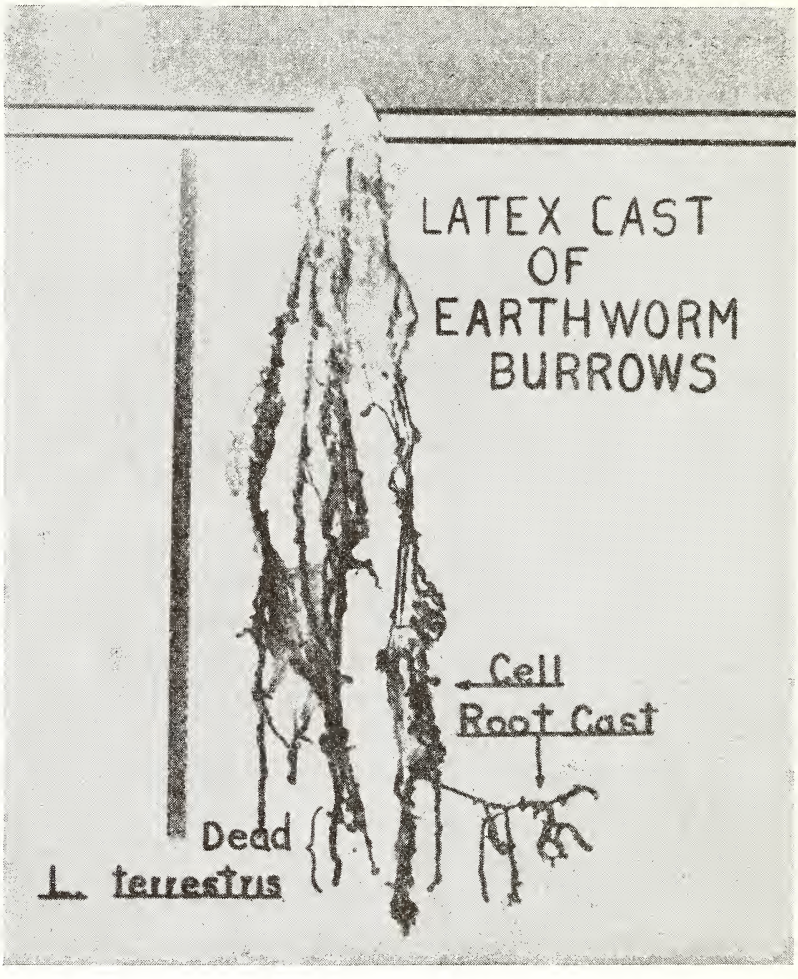

Figure 1. Latex cast of the burrows of *Lumbricus terrestris*.

when and with what regularity did it display what we have termed oscillative behavior.

Since visual observations of such worm movements under field conditions were impossible we turned to radioactive isotope tagging; a technique which had already found application in tracing the movements of many kinds of animals.

Methods and Materials

For the purposes of our investigation, earthworms were gathered at night when they came to the surface. After careful removal by hand they were placed in numbered containers. The burrows were marked with a corresponding number and plugged so that the worm could be returned to its own burrow following its being tagged with a radioactive isotope.

In the laboratory each of the worms was etherized, confined in a sheet of plastic between the jaws of a paper clamp, and then injected intracoelomically with approximately 12 lambdas of Aurcoloid, a commercial preparation of radioactive gold (Au-198), diluted in 12 lambdas of double strength invertebrate Ringer's solution. After injection the worms were held in petri dishes in a cool room for at least a day to be sure that the injection caused no ill effects.

The choice of Au-198 was based on its being a high gamma source and its having a short half-life of 2.7 days. The high gamma source was required because it was known that a probable barrier of from four to six inches of soil interposed between the injected worm and the window of a G-M tube would preclude the use of an isotope which emitted the lower energy alpha and beta particles.

On the site where the worms were captured, a two inch auger shaft was sunk to 36 inches approximately four inches away from each of the several numbered burrows. If a small quantity of water poured in the burrow opening appeared in the auger shaft it was taken as an indication that the burrow had been intersected by the auger shaft and such a burrow was not used.

After the above preparations had been made, the injected worms were released into their own burrows and the process of tracing their movements was begun. The tracing was accomplished by lowering a Geiger-Müller tube attached to a graduated stick into the auger shaft. The point of highest radiation as monitored visually on a Nuclear-Measurements field survey meter was recorded to the nearest two inch interval. The depth location of the worms was monitored and recorded in this manner every two hours during the periods that the studies were carried out.

Results

The first field study of earthworm movement was conducted for seven consecutive days from July 20 through July 26. During this period weather conditions were warm and humid. Rain showers were noted on each day of the study period.

Data were gathered on the position of each of eight worms at two hour intervals for the entire period. Taken as individuals, vertical movement of the worms varied a great deal. The oscillation in the burrow by one worm was limited to the 3 inch to 15 inch zone. In contrast, two worms oscillated between the surface and 30 inches. The greatest depth attained by any worm was 34 inches. Certain worms were never detected at the surface. The mean depth maintained by all worms for the entire period was 16 inches.

When the mean depth of the eight worms at each two hour interval was plotted on a graph against time, a daily oscillative movement was disclosed. The upward trend of the oscillation began about 6:00 p.m. and peaked during the period following midnight. The downward trend, begun in the early morning hours, terminated during a period following noon. Figure 2 and Figure 3 display curves similar to those obtained in the first study.

The mean data used in the graph hides the fact that certain worms were erratic in their movement. We refer, in particular, to sudden drops

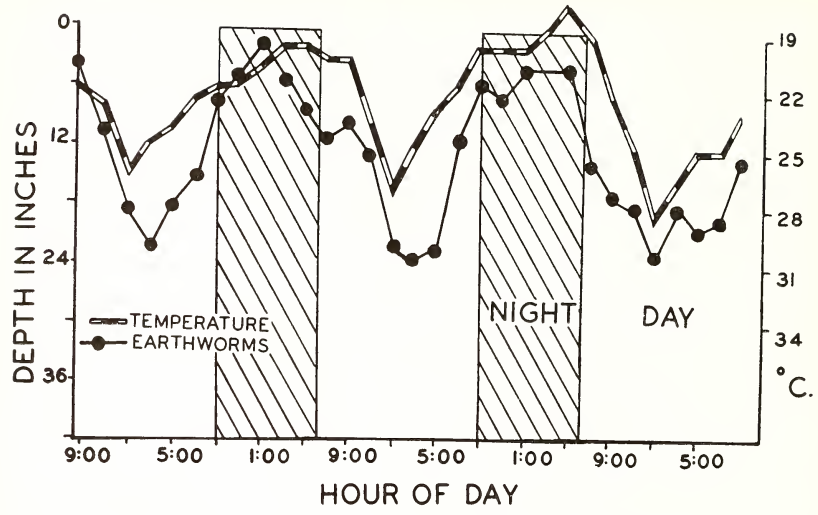

Figure 2. Mean bihourly depth of four earthworms for three days with bihourly temperature readings superimposed. (Centigrade scale inverted.)

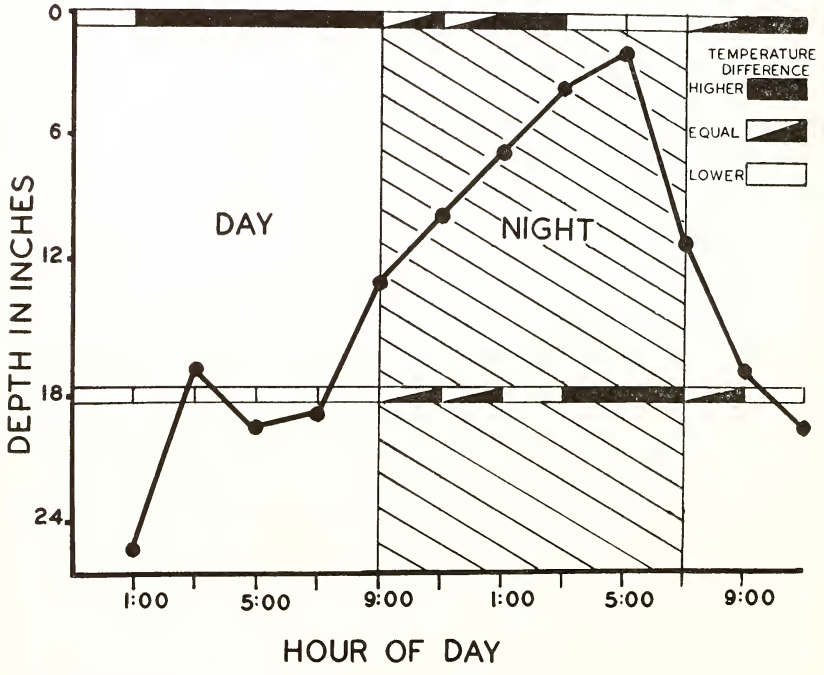

Figure 3. Mean bihourly depth of four worms for one day as related to differences in soil temperatures at two fixed points.

in position during the night followed by a return to the same or higher position. Two examples of this behavior were as follows:

(1)	Night	Depth	(2)	Night	Depth
	10:00	7 inches		10:00	10 inches
	12:00	34 inches		12:00	30 inches
	2:00	13 inches		2:00	0 inches

In the second field study, carried out August 5 through August 9, similar procedures were followed except that four worms were studied for five days and data on several environmental factors were recorded simultaneously with the depth location of the worms at two hour intervals. Temperature readings were obtained from air, soil surface, and soil at 18 inches. Soil moisture, expressed as percent of dry weight, was obtained by collecting, weighing, drying and reweighing soil samples from the surface near the burrows. Relative humidity of air data were obtained with a Serdex hygrometer.

The data obtained on worm movement during the second study were similar to the first study both in the mean depth maintained of 16 inches and in the general nature of the daily oscillative movement (Fig. 2).

In seeking relationships between movement and environmental factors we have plotted bihourly air temperature readings (scale inverted) on the graph of daily oscillative movement (Fig. 2). As the temperature rose the worms went deeper and as the temperature fell the worms came nearer to the surface.

Temperature difference between surface soil and soil at 18 inches (Fig. 3) when positioned with earthworm movement at a given time showed that the worms were located in the region of cooler temperature or were moving while the temperatures were equal.

Discussion

An obvious daily oscillative movement existed during the period of our study. Soil moisture, air temperature and other environmental factors were not at such levels that they limited activity.

Air temperature variations and soil temperature differences both showed a direct relation to earthworm movement but we do not, at this point, believe that this is an absolute relationship since it is obvious that temperature changes, during the period under study, were a function of heating during the day and cooling during the night and perhaps only coincidentally varied with the earthworm's movement.

Summary

The general pattern of burrowing of *Lumbricus terrestris* (L.) was established by liquid latex casting and disclosed that the worms constructed vertical burrows to a depth, in this instance, of 36 inches.

Investigation of the worm's movement in the burrow was accomplished by means of intracoelomic tagging with radioactive gold (Au-198). The course of their movements, following release, was checked bihourly by lowering the Geiger-Müller tube of a survey meter into an auger shaft adjacent to the vertical burrow.

Bihourly mean depth data for periods of seven and five days were plotted against time. A daily oscillative trend in movement was disclosed. The worms reached a mean point near the surface of the soil after mid-

night and then began a descent which reached its lowest mean point after noon. Some 800 depth position figures were obtained; the mean of these was 16 inches.

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