News and Short Contributions

The Destructive Potential of Earthworms on the Archaeobotanical Record

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*Earthworms are widely recognized as important agents in the formation, preservation, and alteration of archaeological sites. I conducted experiments that test the ability of earthworms (*Lumbricus rubellus*) to ingest and subsequently destroy carbonized seeds (*Papaver somniferum*) under controlled settings, designed to reflect field conditions during feeding or burrowing. Results suggest modest seed breakage rates at short time scales that may result in long-term selective removal of some small (< 2 mm) seeds from the archaeobotanical record.*

Introduction

Earthworms (Oligchaeta) are soil-inhabiting creatures with a widespread geographic distribution. Their behaviors have numerous effects upon the archaeological record, many of which have been recognized since Darwin's 1881 publication of *The Formation of Vegetable Mould, Through the Actions of Worms, with Observations on Their Habits*. He concludes:

> ...that all the vegetable mould over the whole country has passed many times through, and will pass again many times through, the intestinal canals of worms. Hence the term 'animal mould' would be in some respects more appropriate than that commonly used of 'vegetable mould' (Darwin 1881: 4).

Darwinian humor notwithstanding, earthworms are important agents of bioturbation, causing the burial and dispersal of artifacts, the obliteration or compression of cultural layers, and the blurring of natural strata due to soil mixing (e.g., Armour-Chelu and Andrews 1994; Canti 2003; Stein 1983). Darwin (1881: 115–116, 311) noted the vertical movement of seeds within the soil profile by earthworm activity, Keepax (1977) stressed the consequences of this as a source of modern contaminants during archaeobotanical studies, and Stein (1983) introduced the possibility that earthworm activity may actually remove or destroy carbonized plant remains during ingestion and decomposition. Contrasting opinions on the ability (Stein 1983: 281) or inability (Canti 2003: 139) of earthworms to destroy parts of the archaeobotanical record still suffer from a lack of direct investigation of the potential problem. I address this through controlled experiments that examine the destruction of carbonized seeds by earthworms during activity related to feeding or burrowing.

Feeding Habits of Earthworms

Earthworms are saprophagous animals whose diet is composed mainly of organic detritus in various stages of decay, with further nutrients derived from microorganisms present within the soil itself. Detritivorous species feed at or near the surface on plant litter and other organic debris, whereas geophagous species feed deeper beneath the surface, and ingest larger quantities of soil (Lee 1985). Soil or sediment ingested during feeding or burrowing is subsequently excreted as casts either above or below ground, depending on species and season. During such activity, seeds and other material smaller than the mouth of the earthworm will pass through the alimentary canal and the gizzard. The maximum dimension of the seed or other material that may be ingested, and that may pass unharmed through the gut, varies with earthworm species and size, but is typically considered to be less than 2 mm (Canti 2003). In laboratory studies, the percentage ingested varies by seed type, as does the proportion surviving digestion, which ranges between 30% and 100%, suggesting both deliberate selection by earthworms for specific seed varieties as well as the incidental breakage of seeds during pas-

Table 1. Summary of the results of the experiment over three time intervals. Sample number is earthworm specimen number. Seed count is of complete seeds only; the presence (+) or absence (-) of seed fragments is noted separately. Net seed loss is the number of seeds not recovered at the conclusion of the experiment at 120 hours.

		0 hr	*After 24 hrs**		*After 96 hrs†*		*After 120 hrs‡*		
Sample	*Worm wt. (g)*	*Seed count (n)*	*Seed count (n)*	*Seed frags?*	*Seed count (n)*	*Seed frags?*	*Seed count (n)*	*Seed frags?*	*Net seed loss*
1	0.9	10	10	-	0	-	0	-	0
2	1.1	10	5	-	5	-	0	-	0
3	1.0	10	9	-	1	-	0	-	0
4	0.9	10	9	-	1	-	0	-	0
5	1.0	10	8	-	0	-	1	+	1
6	1.0	10	10	-	0	-	0	-	0
7	1.0	10	9	-	1	-	0	-	0
8	1.2	10	6	-	0	-	3	-	1
9	1.1	10	6	-	1	-	1	+	2
10	1.0	10	6	-	1	-	0	+	3
11	1.3	10	6	-	0	-	1	-	3
12	1.2	10	0	-	0	+	0	+	10
13	0.9	10	10	-	0	-	0	-	0
14	1.3	10	8	-	1	-	0	-	1
15	1.4	10	9	-	1	-	0	-	0
16	1.0	10	10	-	0	-	0	-	0
17	1.5	10	4	-	0	-	0	+	6
18	1.1	10	4	-	0	-	0	-	6
19	1.0	10	5	-	1	+	2	-	2
20	1.2	10	4	-	0	+	2	+	4
Total		200	138		13		10		39

*Initial trial in dishes containing seeds.
†Trial after removal to dishes without seeds.
‡Trial 24 hours after subsequent feeding.

sage through the gut. Mineral grains and other unpalatable items are also ingested, either accidentally or as an aid in the grinding of material into small particles within the gizzard (McRill and Sagar 1973; Piearce, Roggero, and Tipping 1994; Willems and Huijsmans 1994). The applicability of these studies focusing on viable seeds for archaeological specimens remains uncertain.

Experimental Methods and Materials

A simple experiment was designed to test the hypothesis that as earthworms ingest soil or sediment during feeding and burrowing, they destroy carbonized seeds of the sort found at archaeological sites. The experiment examines whether some varieties of earthworm can and will ingest charred seeds, whether such seeds survive digestion, and what proportion of seeds are destroyed within a short time period under laboratory conditions. The experiment was designed to define a baseline for more complex applications to the archaeological record.

Poppy seeds (*Papaver somniferum*) were used in all experiments because of their commercial availability, diagnostic crescent shape and reticulate coat, and similarity in size (0.7–1.4 mm) to some other archaeologically recovered seeds (Wagner 1982). They are also sufficiently small for ingestion by earthworms. Several hundred poppy seeds were carbonized in an airtight foil packet heated to 500° F for two hours in a conventional oven. Following carbonization, seeds were inspected, sorted and counted using forceps, a small sable-hair brush, and a 10× binocular microscope to ensure selection of complete specimens.

Twenty earthworms were selected from samples obtained from a bait shop in Granby, Connecticut, identified as adult specimens of *Lumbricus rubellus* using the morphological criteria of Schwert (1990) and a binocular microscope at 10–30× magnification. *L. rubellus* is one of the most geographically widespread varieties of earthworm. It is a subsurface-casting, detritivorous, topsoil-dwelling species that normally occurs within the top 8 cm of soil but which may burrow ca. 20–30 cm below the surface (Edwards and Bohlen 1996; Lee 1985). The experiment was conducted in a darkened room at 14° C, near the optimal temperature for *L. rubellus* and most earthworms found in North America and Europe (Edwards and Bohlen 1996).

The experimental procedures, outlined below, followed those of McRill and Sagar (1973) and Piearce, Roggero, and Tipping (1994). Each earthworm was washed under running water, rough-dried on a paper towel, and weighed (TABLE 1). Twenty earthworms were each placed in individual Petri dishes (D. 9 cm, H. 1.5 cm) partially sealed with adhesive tape for 24 hours, in order for them to evacuate their gut contents that could otherwise obscure the presence of small seeds. Each earthworm was then placed in a second Petri dish with the base lined with tap water-moistened (pH 6.9–7.0) filter paper. Ten charred poppy seeds were placed in each in a circle roughly equidistant from each other, approximately 1 cm from the edge of the dish. The sample was thus 20 earthworms each with 10 seeds, for a total of 200 seeds. All earthworms were left for 24 hours, after which time they were removed from the dishes and the number of remaining seeds were tabulated (making sure to recover any seeds adhering to them). The worms were then placed in a third set of prepared Petri dishes that lacked seeds for an additional 72 hours (96 hours total). After 96 hours, all excreta (in the form of casts) were inspected at 10–30× magnification and the number of seeds and seed fragments were counted.

Experimental Results

The absence of 62 of the initial 200 seeds after 24 hours demonstrates that *Lumbricus rubellus* will ingest carbonized poppy seeds under laboratory conditions (TABLE 1). Subsequent recovery of only 13 excreted whole seeds after 96 hours suggests substantial seed loss and fragmentation (TABLE 1). More seeds were subsequently observed within the Petri dishes after the initial termination of the experiment at 96 hours, however. The worms had by this time been given additional food (bread crumbs), and after a further 24 hours (120 hr total), an additional 10 complete excreted seeds as well as fragments were recovered (TABLE 1). These data suggest that the earthworms reingested previously excreted seeds, as the gut transit time for all earthworms is less than 72 hours, and from 13 to 24 hours for *L. rubellus* (Martin 1982: 189). The data support the idea that multiple ingestions increase the likelihood of seed breakage, as numbers of seed fragments increased with time (TABLE 1). All seed fragments were recovered within excreted casts, and thus breakage cannot be attributed to crushing by earthworm movement within the dish.

As summarized in Table 1, 19.5% (n = 39) of the charred poppy seeds were absent after a 120 hour period, although it is possible that seeds still remained within the gut of some of the worms. Seed fragmentation was directly observed for 7 out of 20 worms (TABLE 1). These numbers should be regarded as minima, because many of the mineral grains that aid in the trituration of food, normally present within the gizzard, were excreted prior to the experiment. This is further supported by the observation that casts with seed fragments also contained mineral grains, apparently either retained in the gizzard from before the start of the experiment, or as calcium carbonate nodules subsequently secreted by the earthworms (see Canti 1998, 2003 for discussion of this phenomenon).

Discussion and Conclusions

Results from this experiment show that 39 of 200 (19.5%) carbonized poppy seeds were lost or apparently digested by 20 earthworms (*Lumbricus rubellus*) over a five-day period, with seed fragmentation a direct result of digestion observed for 7 of the 20 worms. These data indicate that the actions of earthworms during feeding and burrowing may lead to the selective destruction of part of the botanical record over the long time periods familiar to archaeologists. The effect is greatest upon our understanding of the frequency of the human use of a variety of plant resources, particularly those with small (< 2 mm) seeds or other diagnostic elements, such as *Chenopodium*. More specific research questions may be addressed by substituting plant taxa, varying particular attributes such as seed coat thickness, using different earthworm species, and introducing more realistic and complex elements such as a range of soil substrates in experiments. Earthworms are widely recognized as important agents in site burial and postdepostional artifact movement; to this we must now add their destructive potential for the archaeobotanical record.

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Armour-Chelu, Miranda, and Peter Andrews
1994 "Some Effects of Bioturbation by Earthworms (Oligochaeta) on Archaeological Sites," *Journal of Archaeological Science* 21: 433–443.

Canti, Matthew G.
1998 "Origin of Calcium Carbonate Granules Found in Buried Soils and Quaternary Deposits," *Boreas* 27: 275–288.
2003 "Earthworm Activity and Archaeological Stratigraphy: A Review of Products and Processes," *Journal of Archaeological Science* 30: 135–148.

Darwin, Charles
1881 *The Formation of Vegetable Mould, Through the Action of Worms, with Observations on Their Habits.* London: John Murray.

Edwards, C. A., and P. J. Bohlen
1996 *Biology and Ecology of Earthworms.* London: Chapman and Hall.

Keepax, Carole
1977 "Contamination of Archaeological Deposits by Seeds of Modern Origin with Particluar Reference to the Use of Flotation Machines," *Journal of Archaeological Science* 4: 221–229.

Lee, K. E.
1985 *Earthworms, Their Ecology and Relationships with Soils and Land Use.* Sydney: Academic Press.

Martin, N. A.
1982 "The Interaction Between Organic Matter in Soil and the Burrowing Activity of Three Species of Earthworms (Oligichaeta: Lumbricidae)," *Pedobiologica* 24: 185–190.

McRill, M., and G. R. Sagar
1973 "Earthworms and Seeds," *Nature* 243: 482.

Piearce, T. G., N. Roggero, and R. Tipping
1994 "Earthworms and Seeds," *Journal of Biological Education* 28: 195–202.

Schwert, Donald P.
1990 "Oligochaeta: Lumbricidae," in D.L. Dindal, ed., *Soil Biology Guide.* New York: John Wiley and Sons, 341–356.

Stein, Julie K.
1983 "Earthworm Activity: A Source of Potential Disturbance of Archaeological Sediments," *American Antiquity* 48: 277–289.

Wagner, G. E.
1982 "Testing Flotation Recovery Rates," *American Antiquity* 47: 127–132.

Willems, J. H., and K. G. A. Huijsmans
1994 "Vertical Seed Dispersal by Earthworms: A Quantitative Approach," *Ecography* 17: 124–130.