Południowo-Wschodni Oddział Polskiego Towarzystwa Inżynierii Ekologicznej z siedzibą w Rzeszowie, Polskie Towarzystwo Gleboznawcze, Oddział w Rzeszowie
Zeszyty Naukowe

Zeszyt 17 rok 2014

KEVIN R. BUTT[1], CHRISTOPHER N. LOWE[1], PAM DUNCANSON[2]

[1]Earthworm Research Group, University of Central Lancashire, Preston, PR1 2HE, UK
[2]Preston City Council, Preston Cemetery, New Hall Lane, Preston, PR1 4SY, UK
e-mail: *krbutt@uclan.ac.uk*

EARTHWORMS OF AN URBAN CEMETERY IN PRESTON: GENERAL SURVEY AND BURROWING ACTIVITY OF *LUMBRICUS TERRESTRIS*

Cemeteries in the UK are predominantly represented by grassland areas which have a variety of origins. Each can act as a haven for wildlife and numerous studies have looked at the flora and fauna present and in particular lichens associated with gravestones which offer chronological assessment. However, very few studies have looked at invertebrates in such settings and surprisingly, few if any have investigated earthworms - given the folklore associating these animals with the decomposition of human remains in the soil. This investigation set out to identify which species of earthworm were present in an urban cemetery in Preston and to discover how deep the animals were burrowing and indeed, if they were capable of burrowing to a depth of 2 metres – the depth at which bodies are usually buried. Nine species of earthworm were found, representing all three ecological categories, epigeic, endogeic and anecic. Burrow configurations were measured through casting with polyurethane resin. Vertical burrows of clitellate Lumbricus terrestris penetrated to a mean depth of 0.49 m (maximum 0.59 m), a function of soil type and water table. Where previous land use had created a relatively impervious layer below the soil surface, complex branched burrows of L. terrestris were found. These were significantly ($p<0.001$) shorter (mean depth 0.21 m) but confirmed the behavioural flexibility that this species of earthworm is known to exhibit. The presence of a healthy earthworm community in the grassland of the cemetery may well assist ecosystem services, but assistance with decomposition of human remains is unlikely.

Keywords: graveyard, *Lumbricus terrestris*, burrow, behavioural flexibility, polyurethane resin

I. INTRODUCTION

Within urban settings there are often surprisingly large areas of green space. These may be represented by obvious locations such as parks and gardens, but other spaces may be overlooked or not seriously considered when assessing their ecological value. Cemeteries are one such area. Traditionally, burials took place in churchyards, but more recently as populations have grown and urbanisation has occurred, specifically designated cemeteries, often managed by Local Authorities have been utilised for internments. There are thought

to be in excess of 20,000 burial grounds in England alone, ranging from less than 1 ha up to 5 ha in area [6]. Cemeteries often provide relatively large grass-covered spaces within urban settings and the ecological value of cemeteries has not gone totally unnoticed. A review by Dennis [6] highlighted botanical surveys of such areas, particularly more ancient churchyards, and also focussed on bird species and mammals such as bats.

More recently, Krupa and Czerniakowaki [12] looked at the interrelationships of natural and human history in cemeteries. Many Local Authorities in the UK e.g. [15] now provide heritage and ecology trails around some of the older cemeteries, which may have received no pesticide or fertiliser treatments for over 150 years. Because of the large number of gravestones in cemeteries and the variety of stone used, colonisation by lichens is something that has been studied for decades. In unpolluted areas this can reveal much, due to the known date of headstone erection, with the British Lichen Society [3] representing a source of valuable information on the ecology and conservation of this group.

Despite the research so far described, little is known of the soil fauna associated with cemeteries. Earthworms are one important group of soil organisms, renowned for their ecosystem service provision e.g. [1]. The work here described, therefore set out to obtain data on the earthworm community associated with a cemetery close to the centre of the city of Preston (53º 46' 03" N, 2 º 39' 40" W) in NW England. This cemetery, which opened in July 1855, is owned and managed by Preston City Council [14].

Objectives were (a) to qualitatively unearth which species were present and in what numbers/biomasses; and (b) more directly to ascertain the status of the largest earthworm in Britain, the deep burrowing (anecic *sensu* Bouché [2]) *Lumbricus terrestris*. This species is of interest as it is reputed to be able to burrow to depths of 2- 3 metres [7]. Therefore in the given context, the relationship of such burrows with burial plots was something considered worthy of exploration, as it has been the subject of folklore for centuries. This is exemplified as shown below in an excerpt from a traditional English Folk song (Ilkla' Moor baht'at) – which describes the fate of a young man who is buried and eaten by worms after catching "his death of cold" after going out on to a moor without his hat.

"…Then t'wurms'll come an' ate thee up, ate thee up
On Ilkla' Moor baht'at
Then t'wurms'll come and ate thee up
Then t'wurms'll come and ate thee up..."

II. MATERIALS AND METHODS

Undisturbed areas were required to give a clear indication of the earthworm species present. General sampling employed a number of methods, including digging and hand-sorting of soil plus mustard vermifuge extraction [4]. Two parts of the cemetery, the Victorian (from the nineteen century) and the New (brought into use in the 1950s), were both examined. For legal and moral reasons no sampling took place upon or immediately beside any point of human burial. The New part of the cemetery had previously been used for growth of vegetables, sand extraction and had been used as a dump site for disposal of construction waste.

In the Victorian section of the cemetery, qualitative sampling for earthworms initially involved searching through earth which had recently been excavated to create graves. This was followed by more systematic applications of a vermifuge (mustard suspension equivalent to 50 g in 10 litres of water) over quadrats of 0.25 m^2. Each area sampled had an application of 20 litres of vermifuge per quadrat over a period of 30 minutes. Specimens were preserved in formalydehyde, taken to the laboratory, examined and identified to

species level, using the nomenclature of Sims and Gerard [16]. Earthworm masses were also recorded and each individual was allocated to an age category; simplified as adult (fully clitellate) or juvenile. Similar sampling was also undertaken in the New section of the cemetery and results were combined.

In both the Victorian and the New parts of the cemetery, *L. terrestris* burrows were examined following the method of Shipitalo and Butt [17]. Within demarcated areas of 2 m^2, all *L. terrestris* middens were located at the soil surface by feeling manually and exploring with blunt knives [13]. These middens were then removed to expose the burrows below. Each burrow had a vermifuge (mustard suspension as previously described) applied from a syringe, and the emerging earthworm was collected, preserved and referenced to the burrow from which it emanated, permitting burrow and burrow occupant to be cross-referenced. Additional vermifuge was added if the animal did not initially surface. Each burrow was then marked with a small plastic peg and left overnight for excess liquid to drain away. Thereafter polyurethane resin and hardner was mixed as directed by the manufacturer (Scott-Bader, Stockport) with the addition of yellow acrylic paint for visual clarity of casting. This was poured directly into each burrow until excess resin collected at the burrow opening. The resin was then left for 24 hours to harden. To assist the *in situ* exposure of resin casts, a small soil excavator, normally used to prepare graves, dug a trench beside the area where burrow-casting had taken place (fig. 1). This then enabled burrows to be exposed by standing in the trench and digging laterally into the soil profile (fig. 2). Lengths of burrows and masses attributable to mature (clitellate) animals were measured and compared between the Victorian and New sections of the cemetery using students' t-tests.

Fig. 1. Excavation of trench in Preston Cemetery beside area where *Lumbricus terrestris* burrows have been located and cast with coloured polyurethane resin

Fig. 2. Excavation of soil from within a trench to expose the marked, polyurethane-filled burrows of *Lumbricus terrestris* in Preston Cemetery

III. RESULTS

Within Preston Cemetery, nine earthworm species were located, representing all 3 ecological groups. The surface dwelling species *Lumbricus castaneus* (Savigny), *Lumbricus festivus* (Savigny) and *Lumbricus rubellus* (Hoffmeister); shallow working species (green morph of) *Allolobophora chlorotica* (Savigny), *Aporrectodea caliginosa* (Savigny), *Aporrectodea rosea* (Savigny) and *Octolasion cyaneum* (Savigny); and also two deep burrowing species *Aporrectodea longa* (Ude) and *L. terrestris* (Linnaeus).

A. chlorotica and *O. cyaneum* were not located during systematic sampling but were recorded during hand sorting of soil and extraction of *L. terrestris* burrows. Of the other seven species extracted with a mustard vermifuge, their relative contribution to the community is shown in figure 3. From this, *L. terrestris* could be considered dominant, four species abundant, with *L. castaneus* and *L. festivus* as occasional. Mean density recorded in this manner was 41 ± 5.9 earthworms m^{-1} with a mean biomass of 42.95 g m^{-1}. The largest clitellate *A. longa* and *L. terrestris* recorded from this sampling were 1.77 g and 4.73 g respectively.

In the Victorian cemetery, *L. terrestris* burrows were found to a depth of 0.51 m in a heavy clay soil, water-logged at depth. The shape of these burrows was of the type normally associated with this species, i.e. near vertical with little or no branching. When filled with resin and excavated, it was found that the burrows tended to terminate at the level of the water table (around 0.53 - 0.57 m). In the New cemetery *L. terrestris* burrows were very different in form from those previously described, see examples in figures 4 and 5. Greatest burrow depth was 0.3 m and these were often branched, with a mean of 1.2 divisions (max. = 8) below a depth of 0.1 m.

Clitellate animals taken from the Victorian and New sites had mean masses of 3.18 ± 0.16 g and 3.06 ± 0.35 g respectively which did not differ significantly ($p>0.05$). However, burrow length of clitellate *L. terrestris* from Victorian and New sites was significantly different ($p>0.001$) with means of 0.49 ± 0.02 m and 0.21 ± 0.02 m respectively.

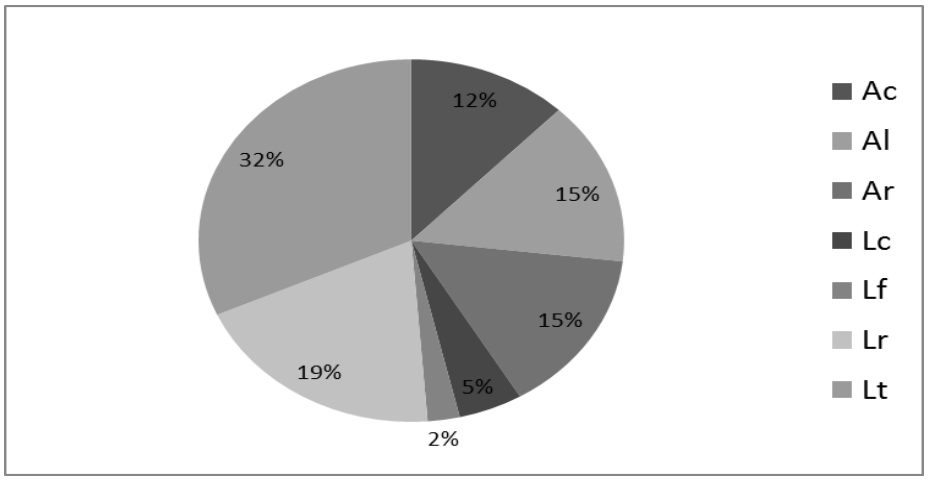

Fig. 3. Proportion of earthworm species located from mustard vermifuge sampling in Preston Cemetery (Ac - *Aporrectodea caliginosa*, Al - *Aporrectodea longa* , Ar - *Aporrectodea rosea* , Lc - *Lumbricus castaneus*, Lf - *Lumbricus festivus*, Lr - *Lumbricus rubellus*, Lt - *Lumbricus terrestris*)
Rys. 3. Udział gatunków dżdżownic wypłoszonych roztworem proszku musztardowego na cmentarzu w Preston (Ac - *Aporrectodea caliginosa*, Al - *Aporrectodea longa*, Ar - *Aporrectodea rosea*, Lc - *Lumbricus castaneus*, Lf - *Lumbricus festivus*, Lr - *Lumbricus rubellus*, Lt - *Lumbricus terrestris*)

Fig. 4. *In situ* yellow-coloured, polyurethane-cast of a *Lumbricus terrestris* burrow to show its shape, curling around a number of bricks and other impenetrable objects in Preston Cemetery

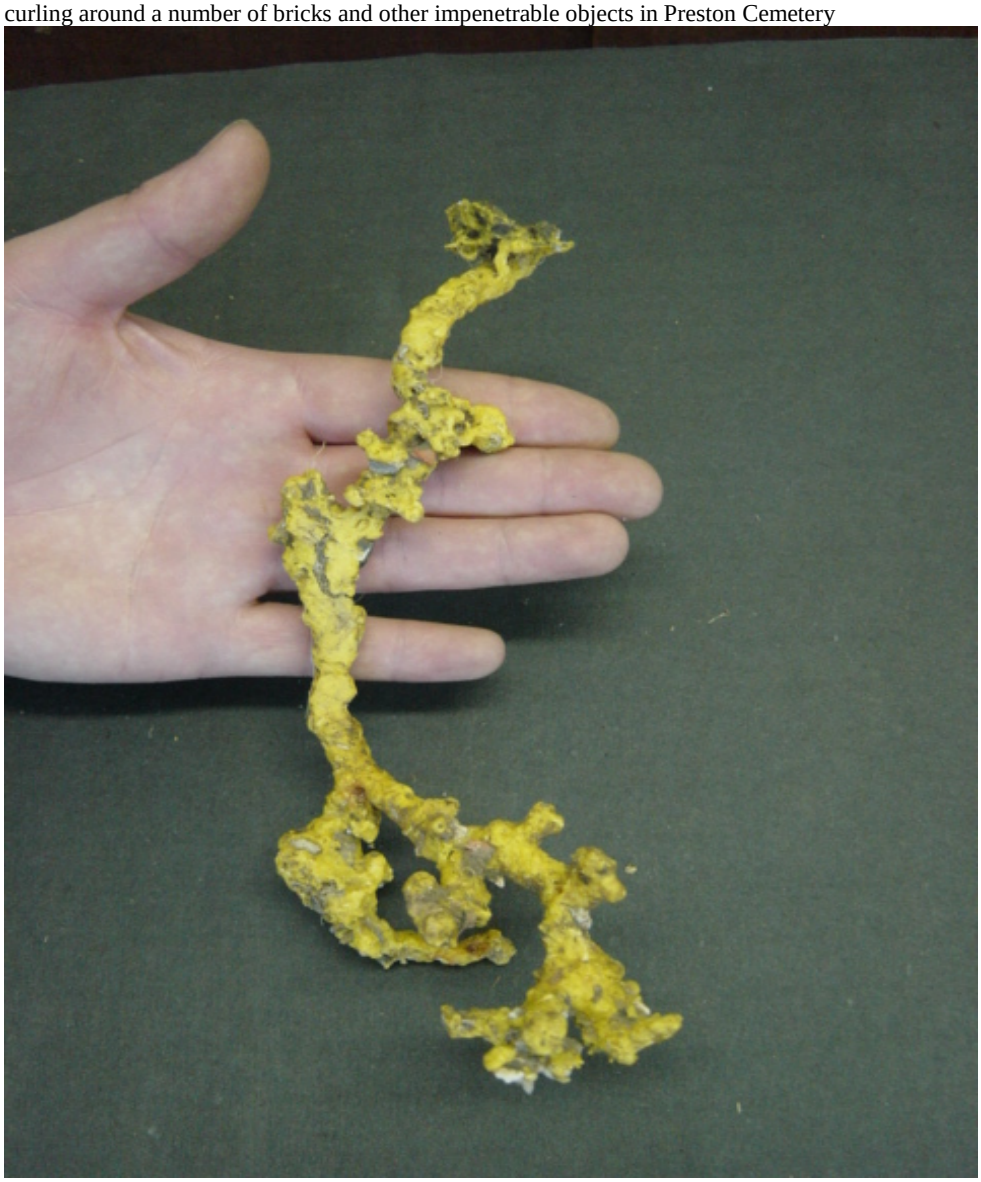

Fig. 5. Example of an extracted polyurethane cast of a *Lumbricus terrestris* burrow from Preston Cemetery, showing multiple branches (total depth = 0.2 m)

In the Victorian section of the cemetery, there was evidence of burrows which extended to 0.48 m that were occupied by small (immature) *L. terrestris*. These had a mean mass of only 2.23 g (n = 3). The burrow dimensions were not dissimilar to those occupied by mature animals in this location. In addition, one individual (mass 1.9 g) had a burrow whose resin impression came to an end after 0.20 m, but below some earthworm soil casting, the burrow continued with a larger diameter to a greater depth.

IV. DISCUSSION

The community in the cemetery, comprising of all ecological groups of earthworms, is what might be expected for any grassland. The collection of nine species is a relatively high number for grassland as Guild [10] working in Scotland, showed that no more than 7-10 species occurred in any one pasture habitat – with little relationship between pasture age and species number.

The (vermifuge) extraction method used in this work does not favour collection of endogeic species such as e.g. *A. chlorotica* which might be considered as recalcitrant. For this reason, no attempt was made to draw comparison with documented densities and biomasses from other UK grasslands, [7] as hand-sorting of soil was normally employed. *O. cyaneum*, a larger species, only found when digging, is more suited to vermifuge expulsion but is parthenogenetic and where found, is described as locally common but never abundant [16]. This may help to explain its perceived scarcity in the cemetery.

Burrow dimensions of *L. terrestris* have been studied extensively in the field, particularly in agricultural settings using the technique employed here e.g. [13, 17]. However, the depth of burrowing in agricultural settings has been found to extend to 1 m and as here, depth is a function of soil type and water table level. The masses of mature *L. terrestris* found in the cemetery were not dissimilar to those from other UK grassland sites e.g. [4] with no differences present between the two sections of the cemetery. However, there were significant differences between the "Victorian" burrows and the "New" burrows with the branching nature of the latter caused by a limited soil layer, where sand had been extracted historically and the void created filled with refuse and rubble. The building rubble and bricks in the soil made creation of a vertical burrow almost impossible. However *L. terrestris* was able to colonise and survive in this inhospitable area. This demonstrates a remarkable flexibility in burrowing behaviour, as also shown by Butt and Nuutinen [5] for this species at an effectively shallow soil above a waste site in the UK. Such field observations are supported experimentally. For example, in an applied setting, Hawkins et al. [11] have shown that a sand layer can be used to prevent burrows of *L. terrestris* from penetrating the surface of soil-wastewater treatment system trenches.

The discovery of immature *L. terrestris* in larger burrows suggests that some form of burrow inheritance may well be occurring. This supports experimental observations reported in 2D terraria [9] and from field plots [8].

That the burrows of *L. terrestris*, at their very deepest, extended to a depth of much less than 1 m in the cemetery is worthy of note. What it means in this context, is that folklore must be dismissed with respect to interactions between earthworms and buried human remains. The reality is surely that "wurms'll *not* come and ate thee up"!

V. REFERENCES

1. Blouin M., Hodson M. E., Aranda Delgado E., Baker G., Brussaard, L., Butt K.R., Dai J., Dendooven L., Pérès G., Tondoh J., Cluzeau J., Brun J-J: A review of earthworm impact on soil function and ecosystem services. European Journal of Soil Science. 64. s. 161-182. 2013.

2. Bouché M. B.: Stratégies lombriciennes. In: U. Lohm & T. Persson (eds.) Soil Organisms as components of Ecosystems. Biological Bulletin (Stockholm). 25. s. 122-132. 1977.

3. British Lichen Society. Churchyard Lichens: A fact Sheet – your questions answered. [electronic document; *http://www.thebls.org.uk/activities/churchyard-survey/churchyard-lichens.* Accessed January 2014].

4. Butt K. R., Grigoropoulou N.: Basic Research Tools for Earthworm Ecology. Applied and Environmental Soil Science. vol. 2010, Article ID 562816. doi:10.1155/2010/562816. http://www.hindawi.com/journals/aess/2010/562816.html 2010.
5. Butt K. R., Nuutinen V.: Behavioural flexibility in the deep burrowing earthworm *Lumbricus terrestris* under adverse subsoil conditions. Poster presentation at XVI International Colloquium on Soil Zoology, Coimbra Portugal. 2012.
6. Dennis E.: The Living Churchyard.- Sanctuaries for Wildlife. British Wildlife. 4 (4). s 230-241. 1993.
7. Edwards C. A., Bohlen P. J.: Biology and ecology of earthworms (3rd edition). Chapman and Hall. London. 1996.
8. Grigoropoulou N., Butt K. R.: Assessment of burrow re-use by *Lumbricus terrestris* L. through field experimentation. Zeszyty Naukowe. 15. s 43-51. 2012.
9. Grigoropoulou N., Butt K. R., Lowe C. N.: Interactions of juvenile *Lumbricus terrestris* with adults and their burrow systems in a two-dimensional microcosm. Pesquisa Agropecuaria Brasileira. 44. s 964-968. 2009.
10. Guild W. J. Mc. L.: The distribution and population density of earthworms (Lumbricidae) in Scottish pasture fields. Journal of Animal Ecology. 20. s 88-97. 1951.
11. Hawkins C. L., Rutledge E. M., Savin M. C., Shipitalo M. J., Brye K. R.: A sand layer deters burrowing by *Lumbricus terrestris* L. Soil Science. 173 (3). s 186-194. 2008.
12. Krupa B., Czerniakowaki Z. W.: Historical and Natural aspects of Pobitno Municiple Cemetery in Rzeszow. In: Practical Applications of Environmental Research (Eds. Kostecka, J., Kaniuczak, J.), s 413-423. University of Rzeszow, Rzeszow. 2012.
13. Nuutinen V., Butt K. R.: Interaction of *Lumbricus terrestris* L. burrows with field subdrains. Pedobiologia. 47. s 578-581. 2003.
14. Preston Cemetery. [electronic document; http://www.cemsearch.co.uk/preston/preston.html. Accessed February 2014].
15. Salford Weaste Cemetery Heritage & Ecology Trail. [electronic document; http://www.salford.gov.uk/cemeteries.htm Accessed January 2014].
16. Sims R. W. Gerard B. M.: Earthworms. Synopses of the British Fauna No. 31 (revised). Published for The Linnean Society and the Brackish-Water Sciences Association by Field Studies Council. Shrewsbury. 1999.
17. Shipitalo M. J., Butt K. R.: Occupancy and geometrical properties of *Lumbricus terrestris* L. burrows affecting infiltration. Pedobiologia 43. s 782-794. 1999.

Acknowledgements

Preston City Council for access to Preston Cemetery and assistance with digging of trenches. Mustard powder was supplied by Colman's of Norwich.

DŻDŻOWNICE MIEJSKIEGO CMENTARZA W PRESTON: PRZEGLĄD OGÓLNY I AKTYWNOŚĆ LUMBRICUS TERRESTRIS W DRĄŻENIU KORYTARZY

Streszczenie

Cmentarze w Wielkiej Brytanii mają różne pochodzenie a każdy może stanowić siedlisko życia dla wielu przedstawicieli dzikiej przyrody. Na cmentarzu prowadzono liczne badania flory i fauny, w szczególności porostów na nagrobkach, co umożliwia ocenę chronologiczną. Niewiele badań poświęcono tu jednak bezkręgowcom a zaskakująco niewiele dżdżownicom - ludowo kojarzonych z rozkładem szczątków ludzkich w glebie. Prowadzone badania określiły które gatunki dżdżownic były obecne w miejskim cmentarzu w Preston i jak głębokie ryły korytarze a dodatkowo, czy były w stanie schodzić do głębokości 2 metrów - na której szczątki ludzkie są zazwyczaj pochowane.

Stwierdzono tu dziewięć gatunków dżdżownic reprezentujących wszystkie trzy kategorie ekomorfologiczne; epigeiczne, endogeic i anecic. Konfiguracje korytarzy mierzono poprzez odlew z żywicy poliuretanowej. Pionowe korytarze dojrzałych Lumbricus terrestris dochodziły średnio do głębokości 0,49 m (maksymalnie 0,59 m), w zależności od rodzaju gleby i wód gruntowych.

Tam gdzie poprzednie użytkowanie gruntów powodowało stosunkowo nieprzepuszczalną warstwę pod powierzchnią gleby, znaleziono złożone i rozgałęzione nory L. terrestris. Wśród nich były istotnie (p < 0,001) krótsze (średnia głębokość 0,21 m), co potwierdza elastyczność behawioralną tego gatunku dżdżownicy. Obecność zdrowych populacji dżdżownic w użytkach zielonych cmentarza może również pomóc funkcji ekosystemu , ale udział w rozkładzie szczątków ludzkich jest mało prawdopodobny.

Słowa kluczowe: cmentarz, *Lumbricus terrestris*, korytarz, elastyczność behawioralna, żywica poliuretanowa