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Darwin's earthworms revisited

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ABSTRACT

Down House was Charles Darwin's home from 1842 until his death in 1882 and where he wrote ''The Formation of Vegetable Mould through the Action of Worms''. The work described here is based upon passages from this book and from further observations on earthworms in this area. General observations were made in addition to systematic sampling in areas selected either from signs of earthworm activity, habitat type or in direct relation to Darwin's documented work.

Greatest species richness ($n = 9$) was found in Middle Field. Greatest earthworm density was present in Darwin's Kitchen Garden (715 m^{-2}) with the largest associated biomass (261 $g\,m^{-2}$). *Aporrectodea longa* was the most abundant species. *Lumbricus terrestris*, described by Darwin in terms of its behaviour, but not directly named, was located in relatively low numbers, but its diagnostic middens and associated burrows were easily detected. Earthworms associated with Darwin's cinder and chalk application experiments were also examined. In total, 19 of Britain's 28 earthworm species were located within the nominated World Heritage Site.

1. Introduction

The rationale for this work stemmed from the publication of ''The Formation of Vegetable Mould through the Action of Worms'' (FVM) by Charles Darwin [4]. Many authors have discussed these writings [8], but as previously noted [1], most of Darwin's references to earthworms do not define which species were under scrutiny (even though behavioural descriptions make some species recognisable). It was therefore determined that with the permission of English Heritage, the grounds of Down House (Darwin's home from 1842 to 1882 and the location of many of Darwin's observations recorded in FVM) would be surveyed for earthworms, where possible with direct reference to passages drawn from FVM. From what is known about the management of the land through the 125 years since Darwin's time, there appears to have been little change in its suitability for different kinds of earthworm, and Darwin's records can therefore be linked with some confidence to likely species.

During sampling (2004–2006) a decision was taken by groups including English Heritage, The Charles Darwin Trust and the London Borough of Bromley to propose Down House, and the surrounding areas of 996 ha, for nomination by the British Government as a World Heritage Site (WHS), ''Darwin at Downe'', because of the extent to which Darwin's historic observations there can be repeated today. Information on

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the work of Darwin, and equally importantly how it relates to current science, was therefore of great interest in the preparation of the nomination document. To this end further investigation of Darwin's work on earthworms was seen as relevant.

In addition to the Down House survey, investigations also took place at an adjacent estate, High Elms Country Park, owned by John Lubbock in Darwin's time, and on common land which Darwin frequented in the surrounding chalk-dominated and heath landscape (all within the nominated WHS). Close scrutiny was also given to some of the experimental fieldwork which Darwin organised on his own estate, i.e. the spreading of chalk and cinders on fields and examination of their position in the soil, by Darwin himself [4] and subsequent researchers [9].

The aims of the work described were: to establish which species of earthworm were present in and around the grounds of Down House (probably the descendents of those studied by Darwin) and quantify their density and biomasses in selected habitats, to revisit bioturbation experiments begun by Darwin on movement of objects from the soil surface and through the soil profile, and to possibly determine the number of earthworm species Darwin may have been familiar with when he wrote FVM, and provide evidence to support the identification of some whose behaviour he described.

2. Materials and methods

Sampling took place during the period 2004–2006 with most work undertaken during visits in March of each year. Wherever possible, a standard sampling regime was employed. This comprised digging and hand-sorting replicated samples of 0.1 m^2 (dug to 0.2 m) followed by application of a suspension of mustard powder (5 $g\,l^{-1}$) [2]. Animals collected were preserved in 4% formaldehyde for identification, following the nomenclature of Sims and Gerard [10].

At Down House, sampling was undertaken in woodland beside Darwin's Sandwalk, his Kitchen Garden and Great Pucklands Meadow. The latter was an area last ploughed in 1841 and was called by his sons ''The Stony field'', as ''when they ran down the slope the stones clattered together'' (when Darwin first moved to Down House), but as he further remarked in FVM, ''the smaller stones disappeared before many years had elapsed, as did every one of the larger ones after a time; so that after thirty years (1871) a horse could gallop over the compact turf from one end of the field to the other, and not strike a single stone with his shoes''[4].

Identical sampling was undertaken at further locations within the nominated WHS. These included the High Elms Estate (3 km NE of Down House) where chalk grassland and woodland were investigated. The latter was of interest as different stands of trees had been established on similar, adjacent soils. At Keston Common (approx. 4 km NW of Down House) a variety of habitat types were sampled, many mentioned specifically by Darwin in his writings [5]. These included: *Calluna*-dominated heath, *Ulex*-dominated heath, Keston Bog and associated woodland, and Ravensbourne Meadows.

On more sensitive areas open to the public (mainly grassland close to Down House) only a mustard vermifuge (5 $g\,l^{-1}$) was applied to replicated 0.2 m^2 quadrats. Here areas below specific tree species, as mentioned by Darwin, were investigated. Earthworms were also obtained from use of an electrical apparatus [11] and from general turning of stones/other objects on the soil surface [7]. Other areas, including different tree stands, were also investigated, as was rotten wood. In addition, earthworms were sought from beneath observed middens on the soil surface, by direct injection of a mustard vermifuge (5 $g\,l^{-1}$) into the burrow below. An estimation of earthworm activity (formation of vegetable mould) was also obtained by photographing the amount of earthworm surface casts present on 10×0.1 m^2 areas of lawn close to Down House. These digital photographs were then manipulated to produce a measure of percentage cast coverage.

Sampling for chalk and cinder artifacts and further earthworm sampling was permitted at two locations in the Great Meadow. The first of these ($n = 10 \times 0.1$ m^2 quadrats) was where cinders were spread by Darwin in 1842/1843 and the second, close to the Sandwalk Woodland, where chalk was spread in 1842. All sampling points were recorded using a geographical positioning system (GPS) total station. Artifacts were also investigated from within larger ''trenches'' of 0.5 m × 0.5 m excavated in the same areas where chalk and cinders were spread. Although these locations were not all recorded directly by Darwin, they were relocated by Keith [9].

Darwin's famous ''wormstone'', a stone quorn used by his son Horace to measure the effect on heavy stone objects in the soil of earthworm activity in the earth below, was located close to Down House. Sampling [11] was undertaken close by, but no attempts were made to use this stone for casting estimates. This was because it is known that the wormstone has been moved at least once since Darwin's time.

3. Results

From systematic sampling of grasslands using vermifuge alone, earthworm densities in the range of 25–158 m^{-2} with an associated biomass range of 37–120 $g\,m^{-2}$ were recorded (Table 1). *Aporrectodea longa* was mostly the dominant species detected in this manner. Use of this method plus soil excavation gave densities of 85–422 m^{-2} and biomasses of 26–144 $g\,m^{-2}$ for grassland. Woodland figures were 3–310 m^{-2} and less than 1–149 $g\,m^{-2}$ for density and biomass, respectively. Highest figures for density and biomass resulted from Darwin's Kitchen Garden (Table 1), recorded from only four species. Thirteen species were located from these standard sampling techniques (Table 2).

On Keston Common, no earthworms were found below heather (*Calluna*) in organic-rich soils and also in skeletal soils above a gravel layer supporting patchy grass. Only very small numbers of *Lumbricus rubellus* (10 m^{-2}) were present below gorse (*Ulex*)-dominated habitat. In and around a compost heap in the ''1/4 acre field'' *Dendrodrilus rubidus*, *Eisenia fetida* and *Lumbricus festivus* were located. Results from Keston bog and from a rotten tree trunk nearby, also added *Dendrobaena attemsi*, *Eisenia andrei* and *Lumbricus eiseni* (Table 2). No additional species were located by sampling electrically or from searching below objects on the soil surface. A total of 19 earthworm species, including both colour morphs of *Allolobophora*