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Earthworms in England: distribution, abundance and habitats

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Foreword

Natural England commission a range of reports from external contractors to provide evidence and advice to assist us in delivering our duties. The views in this report are those of the authors and do not necessarily represent those of Natural England.

Background

Earthworms are of immense ecological and economic importance. However, more information is needed before we can understand the geographical distributions and habitat preferences of the UK's 27 native species.

In 2010 Natural England funded the Soil Biodiversity Group (SBG, Natural History Museum) to:

- sample earthworms in semi-natural habitats across England;
- compile a database of earthworm species records from all available Soil Biodiversity Group research projects; and
- assess the conservation status of the British fauna.

This report represents the findings of this study and is the first attempt at a structured national survey of earthworm diversity and abundance. It combines data from a commissioned survey with existing validated records to identify our commonest, less abundant and rarest earthworm species, as well as linking them to soil conditions and habitats.

The report is now being published as part of our work to make our evidence more accessible. It will be of interest to conservationists, biological recorders and anyone interested in earthworms. It will also enable people generating more data on earthworm populations to apply the same methods used in the report.

Natural England have used the findings to support a follow-up project to conduct further targeted surveys of our rarest earthworm species, and to collate additional distribution records from wider academic sources. We will use this data, alongside additional information, to identify and clarify the conservation status of our earthworm fauna, and to support any conservation action required to safeguard it.

We will also seek to ensure that future Natural England studies of earthworm abundance are compatible with, and improve upon, the data presented here.

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Further information
This report can be downloaded from the Natural England website: **www.naturalengland.org.uk**. For information on Natural England publications contact the Natural England Enquiry Service on 0845 600 3078 or e-mail **enquiries@naturalengland.org.uk**.

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EXECUTIVE SUMMARY

Earthworms are of immense ecological and economic importance. However, we lack detailed understanding of the geographical distributions and habitat preferences of the UK's 27 native species. Natural England funded the Soil Biodiversity Group (SBG, Natural History Museum) to (1) sample earthworms in semi-natural habitats across England, (2) compile a database of earthworm species records from all available SBG research projects, and (3) assess the conservation status of the British fauna.

With the assistance of a team of 16 trained volunteers from across the country, 56 sites were sampled using a standardised sampling protocol. All specimens were identified and these results were combined with the earthworm species records from nine previous SBG projects. The final dataset contains 7188 individual specimen records (including immatures) of which 6309 were identified to species. These specimens were from 1503 samples collected at 333 sites in 15 habitat types across England and Scotland. The dataset represents the largest and most comprehensive dataset of species records of British earthworms.

The most numerous species was *Allolobophora chlorotica* (34% of identified specimens in the dataset), followed by *Aporrectodea caliginosa* (19%) and *Lumbricus castaneus* (12%). The ten most abundant species represent 95% of all identified specimens. Twelve species each represent less than one percent of the dataset, while five species were not collected at all. Endogeic earthworms (species that live in the topsoil and feed on soil) tend to be most abundant in disturbed soils and sites with higher soil pH (arable land, field margins, pasture and amenity grasslands). In contrast, epigeic earthworms (species that live in leaf-litter or humus and feed on leaf-litter) are more closely associated with woodland habitats and sites with more acid soils.

Three criteria were used to assess the conservation status of each species: local population size, geographical range and habitat specificity. Nine species are classified as Common, twelve as Rare, and six (*Helodrilus oculatus*, *Lumbricus friendi*, *Allolobophora cupulifera*, *Dendrobaena pygmaea*, *Eisenia andrei* and *Aporrectodea limicola*) as Extremely Rare. Furthermore, an examination of published records and the NHM collections suggest that the Extremely Rare species have each been collected fewer than ten times in the British Isles, and may therefore warrant being classified as Vulnerable or Imperilled in conservation terms. However, the status of these six species must be treated with caution until further research is undertaken to determine whether they still persist at the sites where they were previously recorded, and whether other populations in similar habitats can be found.

INTRODUCTION

Earthworms are often described as “ecosystem engineers” because of their physical and chemical roles in pedogenesis, decomposition and nutrient recycling. They are generally acknowledged to be of enormous ecological and economic importance. Despite this, and the fact that earthworms are the dominant macro-invertebrate in many soils, we lack detailed understanding of the geographical distributions, habitat preferences and environmental tolerances of the UK’s 27 native species (all of which are members of the Lumbricidae family). While habitat preferences have been reported for some of the British fauna (Sims & Gerard, 1999; Doube & Brown, 1998; Lavelle & Spain, 2001), those findings were based on very limited data.

In March 2009, a new initiative called OPAL (Open Air Laboratories – a project involving the Natural History Museum and a consortium of universities) launched a national Soil and Earthworm Survey. It is aimed at members of the public, and especially secondary school children. The OPAL survey offered an opportunity to provide information on earthworm distributions in England. However, the vast majority of records generated by the OPAL survey were from domestic gardens, amenity grasslands and other easily accessible open spaces in urban and suburban areas. Moreover, these OPAL species records are not verified by a taxonomist, and must therefore be treated with some caution (DT Jones, unpublished data).

Given the continued lack of knowledge outlined above, Natural England funded the Soil Biodiversity Group (SBG) to investigate the distribution and conservation status of British earthworms. The aims of the project were:

1) to sample earthworms in a selection of semi-natural habitats across England with the aid of a team of trained volunteers. These sampling sites represent habitats that have been under-sampled for earthworms in the past.
2) to compile a database of earthworm species records from previous SBG research projects, and to incorporate within that database the new data collected by the project volunteers.

Natural England made an award of £29,379 to the NHM for the project. Of that amount, £17,689 was spent employing DTJ, and the remainder was spent on travel, accommodation, food and laboratory consumables. A full breakdown of the project budget is available upon request.

METHODS

Earthworm sampling by volunteers

A flyer advertising the project was sent to various interested groups, including wildlife trusts and the FSC’s network of AIDGAP beta testers. Of the 28 people who submitted an expression of interest and a CV, 16 were recruited as volunteers based on their previous experience and their willingness to do the fieldwork. Twelve of the volunteers attended an initial workshop at the NHM on 26 March 2009 run by DTJ, PE and Emma Sherlock (Zoology Dept., NHM). At the workshop the project was introduced, site selection was discussed and earthworm identification was taught. Subsequently, 15 of them attended one of four training days in the field at which the sampling protocol was taught. The sampling protocol used by the volunteers is outlined in Appendix 1.

During the Spring and Autumn/Winter of 2009 the volunteers, usually working in pairs, sampled earthworms at a total of 56 sites in their local region of the country. To encourage the volunteers to do as much fieldwork as possible, DTJ or ES accompanied a majority of them and assisted with the fieldwork. Some volunteers were very active and sampled at many sites, while others only sampled in a few (Appendix 2). Due to this varying level of commitment from the volunteers, sampling coverage across the country was unequal, with a majority of sampling sites being in southern or central England.

Eight of the volunteers identified the earthworms they collected. However, to ensure accuracy, all specimens were sent to the NHM and their identifications were determined by DTJ or ES.

Consolidation of existing data

Since 2001 the SBG has had numerous research projects in the UK that have included earthworms as one of the target groups. These discrete projects, including two PhD and two MSc studies plus several externally funded projects, varied in their aims, collecting methods and sampling intensity. However, the species locality records and other relevant data from nine of these previous projects (Appendix 3) were consolidated into a single dataset, and then incorporated into the results from the volunteers' sampling programme.

The final dataset has some limitations. First, the quantitative estimates of earthworm abundances are not strictly comparable among sites because they are scaled-up from different numbers and sizes of soil pits. Second, other microhabitats (for example: under dung, inside and under rotting logs, and piles of leaf-litter) were not searched in all projects. Third, the numbers of immature earthworms were not available from all projects. Four, measurements of soil pH, temperature and moisture were not recorded during all projects. Therefore, in this report only qualitative comparisons of abundance have been made, and earthworm responses to soil pH and moisture are based on a subset of the data.

We assigned each species to an ecological functional group, following the well-established classification given in Sims & Gerard (1999): anecic species (heavily pigmented, very large, deep-burrowing earthworms that build permanent vertical burrows), endogeic species (pale earthworms that live in the topsoil, making horizontal tunnels and feeding on soil), and epigeic species (red earthworms that usually live in leaf-litter or the surface humus layer and feed on leaf-litter). In addition, a forth functional group is recognised: compost species (red stripy earthworms that live almost exclusively in compost heaps and other similar accumulations of decaying vegetation).

RESULTS

The dataset contains 7188 earthworms, of which 6309 specimens were identified to species (Table 1). With more than 1500 samples from 333 sites across England and Scotland, this represents the largest and most comprehensive dataset of species records of British earthworms compiled to date.

Table 1. The number of sites, samples and specimens in the dataset

Total number of independent sites sampled	333
Total number of samples collected (mainly soil pits)	1503
Total number of earthworm specimens collected	7188
Number of specimens identified to species	6309
Number of immature earthworms	779
Number of damaged specimens not identified	100

The breakdown of specimens by species in the dataset is given in Table 2. The most numerous species sampled was *Allolobophora chlorotica* (34% of identified specimens), followed by *Aporrectodea caliginosa* (19%) and *Lumbricus castaneus* (12%). Twelve species each represent less than one percent of the dataset, while five species were not collected at all.

Table 2. The 27 native British species, the number of specimens in the dataset, their code names, and their ecological functional grouping.

Species	Code	Group	No.	%
Allolobophora chlorotica (Savigny)	Al.chl	Endogeic	2149	34.06
Allolobophora cupulifera Tétry	Al.cup	Endogeic	0	0.00
Allolobophoridella eiseni (Levinsen)[1]	Ad.esi	Endogeic	10	0.16
Aporrectodea caliginosa (Savigny)	Ap.cal	Endogeic	1218	19.30
Aporrectodea icterica (Savigny)	Ap.ict	Endogeic	40	0.63
Aporrectodea limicola (Michaelsen)	Ap.lim	Endogeic	0	0.00
Aporrectodea longa (Ude)	Ap.lon	Anecic	165	2.61
Aporrectodea rosea (Savigny)	Ap.ros	Endogeic	526	8.34
Dendrobaena attemsi (Michaelsen)	Db.att	Epigeic	34	0.54
Dendrobaena hortensis (Michaelsen)[2]	Db.hor	Epigeic	10	0.16
Dendrobaena octaedra (Savigny)	Db.oct	Epigeic	96	1.52
Dendrobaena pygmaea (Savigny)	Db.pyg	Epigeic	0	0.00
Dendrodrilus rubidus (Savigny)	Ds.rub	Epigeic	46	0.73
Eisenia andrei Bouché	E.and	Compost	0	0.00
Eisenia fetida (Savigny)	E.fet	Compost	41	0.65
Eisenia veneta (Rosa)	E.ven	Compost	7	0.11
Eiseniella tetraedra (Savigny)	El.tet	Endogeic	33	0.52
Helodrilus oculatus Hoffmeister	H.ocu	Endogeic	6	0.10
Lumbricus castaneus (Savigny)	L.cas	Epigeic	766	12.14
Lumbricus festivus (Savigny)	L.fes	Epigeic	7	0.11
Lumbricus friendi Cognetti	L.fri	Epigeic	0	0.00
Lumbricus rubellus Hoffmeister	L.rub	Epigeic	272	4.31
Lumbricus terrestris Linnaeus	L.ter	Anecic	78	1.24
Murchieona muldali (Omodeo)[3]	M.mul	Endogeic	631	10.00
Octolasion cyaneum (Savigny)	O.cya	Endogeic	35	0.55
Octolasion tyrtaeum (Savigny)	O.tyr	Endogeic	37	0.59
Satchellius mammalis (Savigny)	S.mam	Epigeic	102	1.62
Total			6309	

[1] Listed in Sims & Gerard (1999) as *Lumbricus eiseni* but transferred by Blakemore (2005).

[2] Listed in Sims & Gerard (1999) as *Eisenia hortensis* but transferred by Blakemore (2005).

[3] Blakemore (2005) showed that this species was misidentified as *M. minuscule* by Sims & Gerard (1999).

The ranked abundance of identified specimens in the dataset is shown in Figure 1. The first ten species (down to and including *Lumbricus terrestris*) represent 95% of all identified specimens in the dataset.

The 333 independent sampling sites were identified as one of 15 habitat types (listed in Table 3). Gardens and allotments were grouped together because of their similarity. However, samples from this single category are highly heterogeneous as they can include lawns, flower borders, vegetable patches, compost heaps and "wildlife" areas.

The ranked abundance (Fig. 1) is influenced by the sampling biases in the dataset. For example, 37% of all samples are from just six arable crop sites and five field margin sites. As a result, *Murchieona muldali* is over-represented in the dataset (making up 10% of specimens) even though it is rare or absent in all other habitats.

Table 3. The number of sites, samples and earthworms from different habitats

Habitat type	No. of sites	No. of samples	No. of earthworms
Grassland on acid soil	34	137	437
Grassland on base-rich or neutral soil	15	66	235
Set-aside grassland	4	25	91
Amenity grassland	28	110	220
Broadleaf woodland on acid soil	47	100	223
Broadleaf woodland on base-rich or neutral soil	10	45	250
Broadleaf woodland on wet/inundated soil	10	49	85
Pine woodland or pine plantation	5	30	117
Heathland	4	14	20
Mire	2	10	10
Riparian	5	15	76
Arable crop	6	179	616
Field margin	5	376	2862
Hedgerow	5	61	380
Garden or allotment	153	288	684
Total	333	1503	6309

The percentage of independent sampling sites at which each species was recorded is shown in Figure 2. This provides a more realistic representation of the distribution of species compared with Figure 1.

Correspondence Analysis was used to indicate the strength of association between species and habitats (Figure 3). The species that tend to be abundant in disturbed soils, and sites with higher pH (arable land, field margins, pasture and amenity grasslands), especially *Allolobophora chlorotica*, *Aporrectodea caliginosa*, *Murchieona muldali* and *Aporrectodea rosea*, are all endogeic earthworms. Many epigeic species, especially *Dendrodrilus rubidus*, *Lumbricus rubellus*, *Dendrobaena attemsi* and *Allolobophoridella eiseni* are more closely associated with woodland sites and sites with more acid soils.

Figure 1. Ranked abundance of earthworms (percentage of total, n = 6309 specimens) extracted from 1503 samples collected from 333 sites (all sampled habitats included)

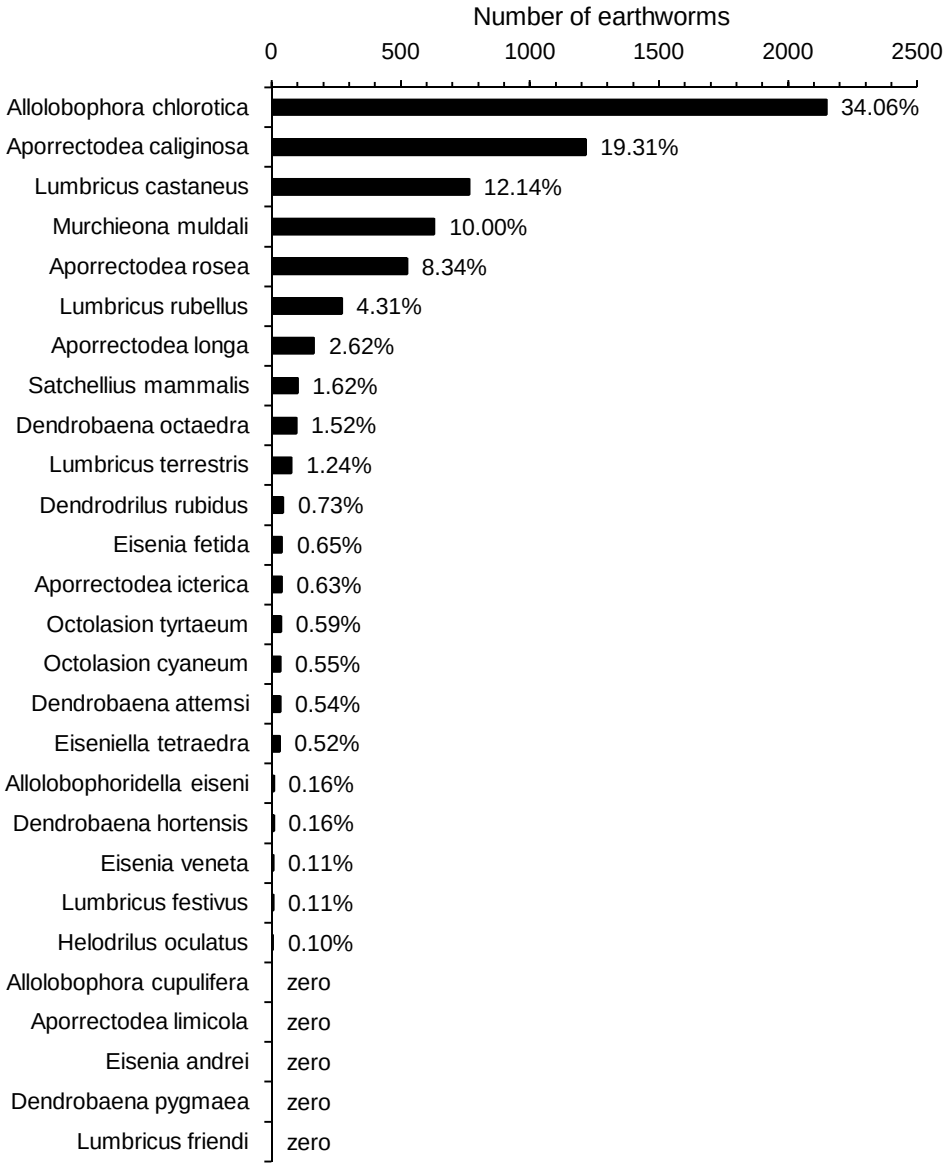


Figure 2. The percentage of sampling sites (n = 333) at which species were recorded. Species are listed on the vertical axis in the same order in which they appear in Figure 1

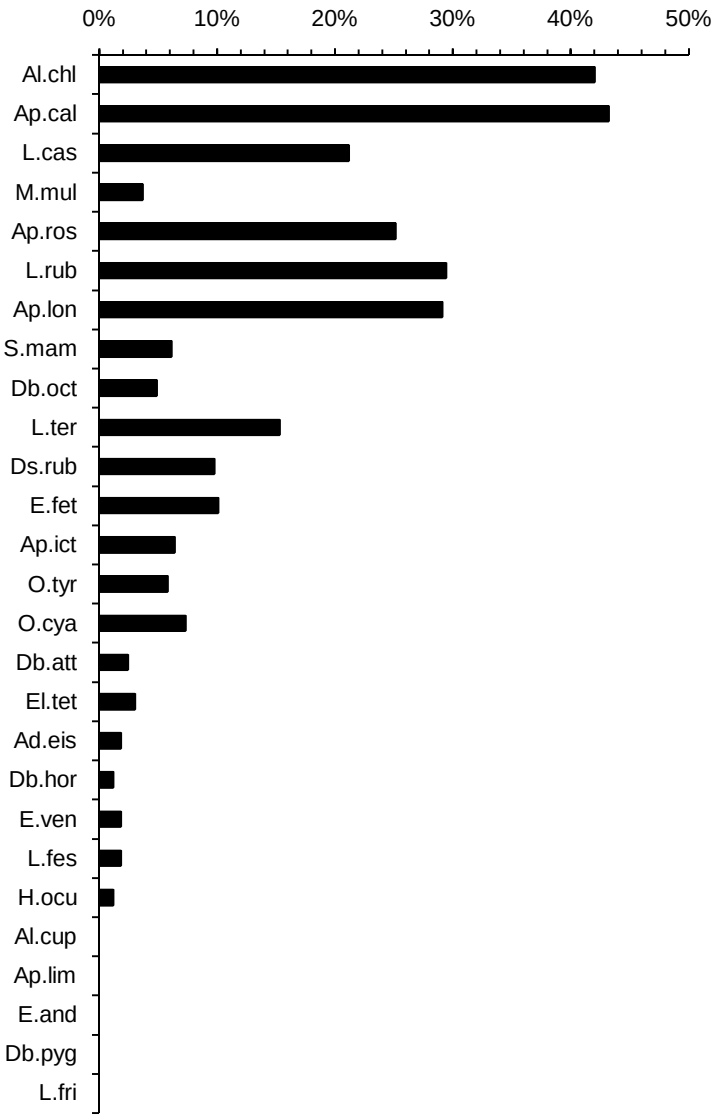
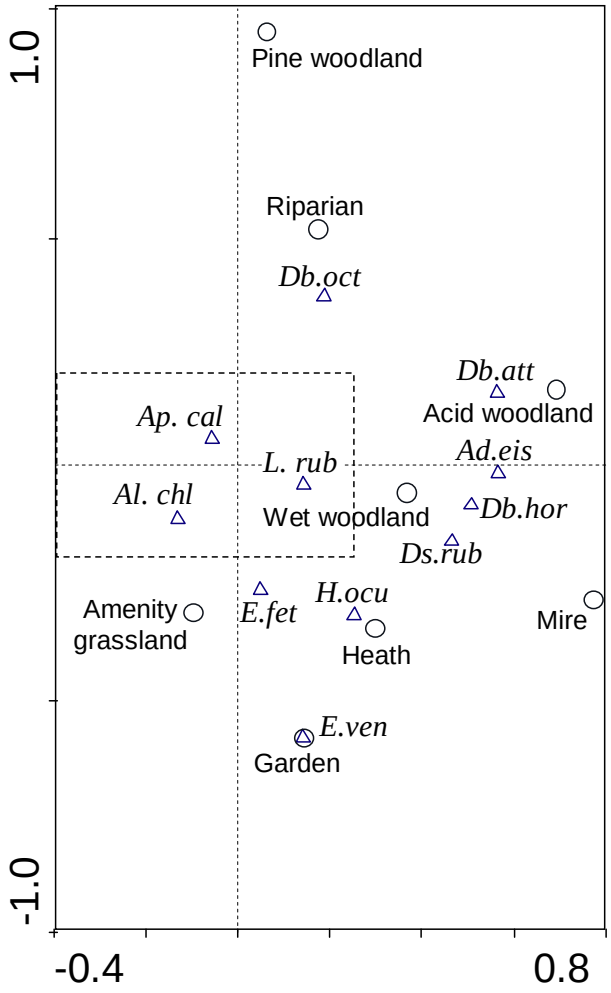
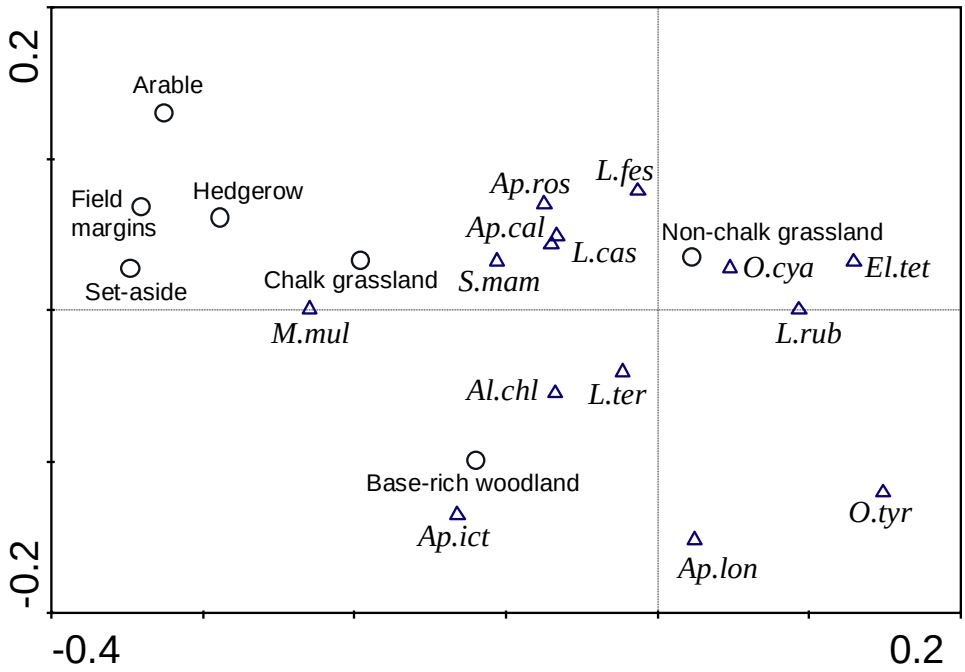


Figure 3a (right). Correspondence Analysis based on the number of identified specimens recorded from each of the fifteen habitats. This shows the relative associations of each species with different habitats. The more disturbed sites, and those with higher soil pH (arable, field margins, pasture and amenity grasslands) are on the left hand side of the plot. The species *Allolobophora chlorotica*, *Aporrectodea caliginosa* and *Murchieona muldali* are more strongly associated with these sites.

For clarity, the dashed rectangular box in the centre of the plot is enlarged in figure 3b (below).





The response of earthworm abundance to soil pH and soil moisture were modelled for those species with sufficient data. Many species show a unimodal response (giving a single optimum or peak in abundance), while others show an increasing or decreasing monotonic response across the sampled environmental range. Four epigeic species (*Dendrobaena octaedra*, *Dendrobaena attemsi*, *Lumbricus rubellus* and *Dendrodrilus rubidus*) have their optimum abundance in acid soils (Figure 4), while four endogeic species (*Allolobophora chlorotica*, *Aporrectodea caliginosa*, *A. rosea* and *Murchieona muldali*) and *Lumbricus castaneus* (epigeic) have their optima in base-rich soils. However, several species have relatively wide tolerances (i.e. a wide response curve), especially *Ap. caliginosa* and *L. rubellus*, indicating a greater resistance to variation in soil pH compared with species with a narrower response curve, such as *D. attemsi*.

Four species (*Al. chlorotica*, *Ap. caliginosa*, *M. muldali* and *L. castaneus*) clearly have their optima in drier soils (Figure 5), while four species (*Lumbricus rubellus*, *Octolasion tyrtaeum*, *Dendrodrilus rubidus* and *Eiseniella tetraedra*) have their optima in wetter soils. Again, *Ap. caliginosa* and *L. rubellus*, show relatively wide tolerances, indicating a greater resistance to variations in soil moisture compared with species that have narrower tolerances such as *M. muldali* and *D. attemsi*.

The conservation status of British earthworms

A preliminary assessment of the conservation status of each species has been made using the information available. Because the amount of data currently available for many species is still somewhat limited, the status of the rarer species must be treated with caution.

The assessment is based on three criteria, with each being divided into three classes.

1. **Local population size**: abundant, moderately abundant or sparse.

2. **Geographical range** within the British Isles. As well as the locality records in the dataset compiled for this project, additional records from Sims & Gerard (1999) and Sherlock *et al*. (unpublished data) were consulted to improve our understanding of species coverage across the British Isles.

- widespread – records dispersed widely across much of the British Isles
- moderately widespread – records dispersed less widely than above
- restricted – records restricted to one very limited region of the British Isles

3. **Habitat specificity**. This is based on the relative proportions of species occurrences (Figure 2) in the 15 different habitat types listed in Table 3. Many records from gardens are problematic because they do not specify if specimens were extracted from lawns, flower borders, vegetable patches, compost heaps or “wildlife” areas. Therefore, for most species the garden records have been ignored when considering habitat specificity.

- Low habitat specificity – abundant or moderately abundant in nine or more of the 14 habitats (ignoring gardens)
- Moderate habitat specificity – abundant or moderately abundant in less than nine of the 14 habitats
- High habitat specificity – only recorded from one or two habitat types

Figure 4. The response of earthworm abundance to soil pH. The response curves are constrained to a polynomial Poisson distribution (i.e. a Gaussian unimodal model that drops to zero at extreme values).

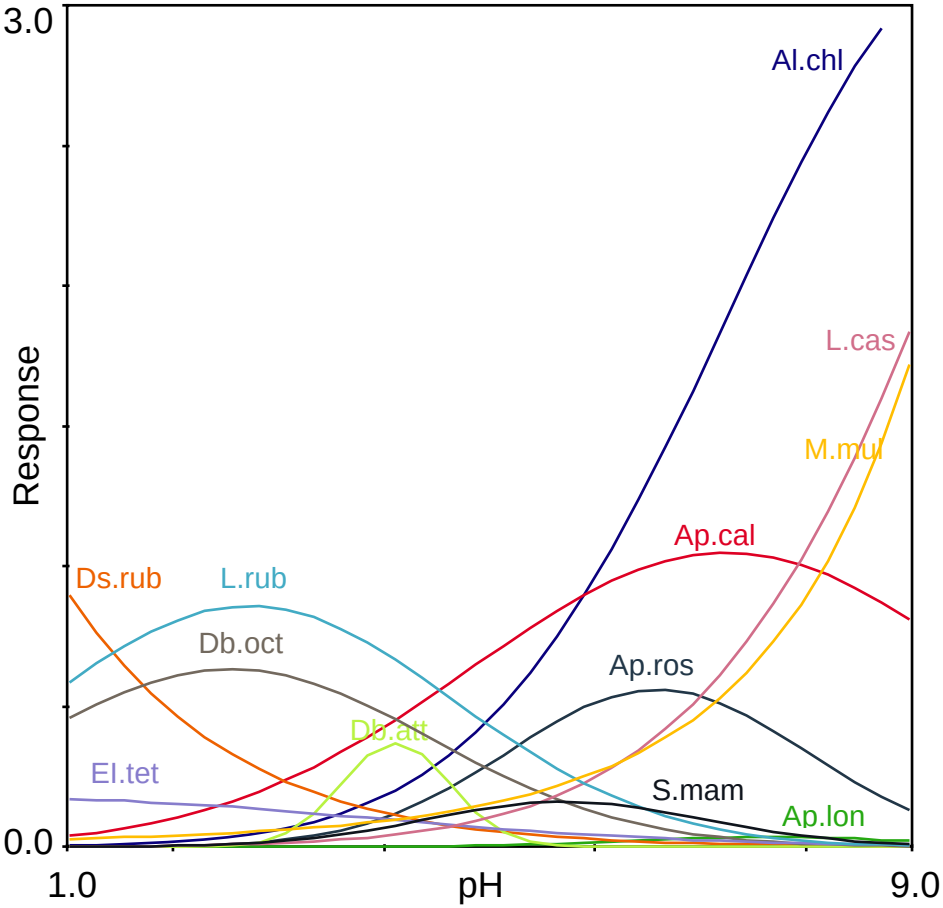
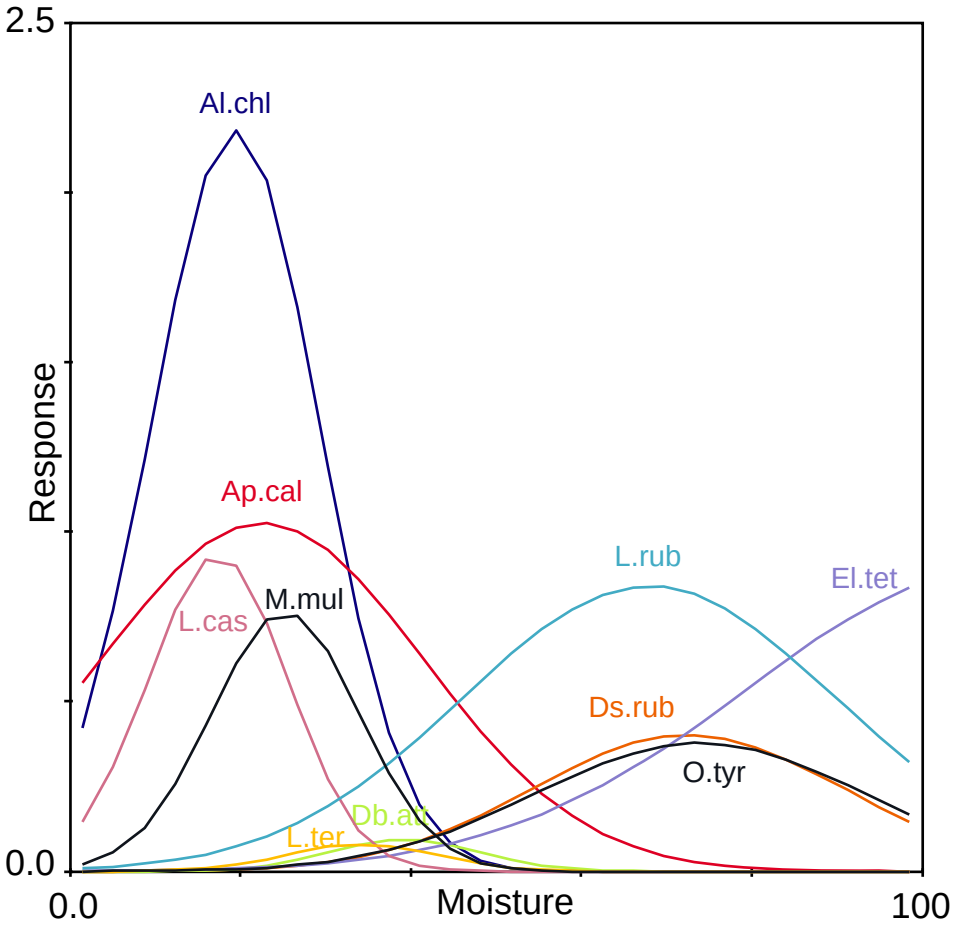


Figure 5. The response of earthworm abundance to soil moisture. The response curves are constrained as in Figure 4.



The status of each species is given in Table 4. Nine species are listed as Common and can be considered secure in conservation terms. A further twelve species are listed as Rare. Given our present knowledge, these rare species are probably not vulnerable to extinction in Britain as none of them are restricted to threatened habitats. Although *Eisenia veneta* has only been recorded about twenty times in the British Isles, it occurs in domestic compost heaps and is sold by some suppliers as a "composting worm". It is therefore probably more common than records currently suggest. One rare species, *Dendrobaena attemsi* is restricted to Southern England but requires further investigation as Eggleton *et al*. (2009) suggest that its range may be expanding due to drier summers and milder winters.

Six species are listed as Extremely Rare (*Allolobophora cupulifera*, *Aporrectodea limicola*, *Dendrobaena pygmaea*, *Eisenia andrei*, *Helodrilus oculatus* and *Lumbricus friendi*). As far as we can ascertain from published records and examining the NHM collections, these six species have each been recorded fewer than ten times in the British Isles. In conservation terms, given these very low numbers, all six species in this group may warrant being classified as Vulnerable or Imperilled. However, further research should be focused on this group to determine whether they still persist at the sites where they were previously recorded, and whether other populations in similar habitats can be found.

DISCUSSION

During the Pleistocene glacial advances, the entire earthworm fauna of the British Isles is thought to have been exterminated (Sims & Gerard, 1999). Today's native fauna, which is a subset of species belonging to the native Lumbricidae fauna of Western Palaearctic, is presumed to have recolonised from continental Europe. However, of Britain's 27 native species, Sims & Gerard (1999) suggest that *Aporrectodea icterica*, *Dendrobaena hortensis* and *Eisenia veneta* may have been introduced to the British Isles by humans after the last glaciation, while Muldowney & Schmidt (2002) speculate that *Allolobophora cupulifera* is a very recent importation. This deserves further research to decide whether they should be included on the list of native British species or classed as introductions.

Thirty-six non-Lumbricidae species have been recorded from Britain (Sherlock & Carpenter, 2009). All but three of these exotic species have been found only in temperature-controlled glasshouses (particularly at botanic gardens, especially Kew where 27 exotic have been recorded), probably due to the importation of soils and botanical specimens. Many of these species have not been recorded since they were initially collected, suggesting that subsequently they may have died out. Three exotics have been found as free-living species in the environment. *Mircoscolex phosphoreus* (Acanthodrilidae) has been recorded in the short-mown grass turf of at least ten golf greens and bowling greens scattered across Britain, and may be spreading (DTJ unpublished data). *Sparganophilus tamesis* (Sparganophilidae) is a limicolous species found in the benthic mud of rivers, streams, ponds and lakes. It was first recorded in the River Thames at Goring in 1892 and has since been found in another five localities in Britain. *Anisochaeta celmisiae* (Megascolecidae; listed as *Spenceriella minor* by Sims & Gerard (1999) but re-identified by Blakemore (2005)) was deliberately introduced to blanket peat bog in Strathclyde in 1975. A population

was found at the same site in 1982 but it was not recorded during surveys in 1995 (Sherlock & Carpenter, 2009).

There are some outstanding taxonomic problems that affect the list of British native species. Evidence from breeding experiments suggests that the green and pink colour morphs of *Allolobophora chlorotica* are two separate species (Lowe & Butt, 2008). Furthermore, mitochondrial DNA research on *Allolobophora chlorotica*, *Aporrectodea longa*, *Aporrectodea rosea* and *Lumbricus rubellus* suggests that these species may contain multiple cryptic species (King *et al*., 2008). However, more research is needed before these possible new species could be formally described. According to Blakemore (2005) *Esenia andrei* may be a junior synonym of *E. fetida*, since it has only been recorded from commercial cultures of *E. fetida*, and is very difficult to separate morphologically from this species.

To increase our confidence in the assessment of the conservation status of the Rare and Extremely Rare species, future research should focus on the following activities:
(1) sampling in marshes, peat bogs, stream beds and lake margins to search for those species that may favour semi-aquatic environments such as *Aporrectodea limicola*, *Eiseniella tetraedra* or *Helodrilus oculatus*.
(2) sampling in highly threatened habitat types in England, to see if any species are associated with these habitats.
(3) visit the localities where the Extremely Rare species were originally recorded to see if their populations still persist.

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Table 4. The conservation status, population size, range and habitat preferences of the 27 native species of British earthworms.

Species	Conservation Status	Population size	Geographical range	Habitat specificity	Comments
Allolobophora chlorotica (Savigny)	Common	Often locally abundant	Widespread	Low specificity	Recorded from all habitats except pine woodland and mires. Often the numerically dominant earthworm species, especially in neutral to base-rich grasslands and arable soils
Aporrectodea caliginosa (Savigny)	Common	Can be locally abundant	Widespread	Low specificity	Recorded from all habitats except heathland and mires. Often abundant in neutral to base-rich grasslands, woodlands arable soils and amenity grasslands
Lumbricus rubellus Hoffmeister	Common	Can be locally moderately abundant	Widespread	Low specificity	This species shows the lowest specificity, having been recorded from all habitats. However, shows a preference for acid grassland and woodland where it can be moderately abundant, and for wetter soils. Often found under dung
Aporrectodea rosea (Savigny)	Common	Can be locally abundant	Widespread	Low specificity	Recorded from all habitats except heath and mires. Often locally abundant, and shows a preference for grassland and woodland on neutral and base-rich soils
Lumbricus castaneus (Savigny)	Common	Can be moderately abundant	Widespread	Low specificity	Recorded from all habitats except heath and mires. Shows a preference for base-rich and neutral grassland, woodland and hedgerows where it can be moderately abundant
Aporrectodea longa (Ude)	Common	Can be moderately abundant	Widespread	Moderate specificity	Shows preference for grasslands and garden lawns where it can be moderately abundant in undisturbed sites. Usually sparse when it occurs in woodland and arable soil
Lumbricus terrestris Linnaeus	Common	Can be moderately abundant	Widespread	High specificity	Shows preference for grasslands and garden lawns where it can be moderately abundant in undisturbed sites. Rarely found in woodland and arable soils where it is always sparse
Satchellius mammalis (Savigny)	Common	Sparse but occasionally moderately abundant	Widespread	Moderate specificity	Occurs at low densities in woodland and grassland but can be moderately abundant in broadleaf woodland on base-rich and neutral soils
Eisenia fetida (Savigny)	Common (in domestic gardens)	Abundant in compost heaps	Widespread	High specificity	Abundant in garden compost heaps. Can also be found in grassland improved with farmyard manure, and sewage filter beds. Sparse in decaying matter in woodlands
Murchieona muldali (Omodeo)	Rare	Can be moderately abundant	Moderately widespread	High specificity	Widespread across England but very few records from rest of British Isles. Very sparse in grasslands and arable soils but can be moderately abundant in field margins
Dendrobaena octaedra (Savigny)	Rare	Sparse but occasionally moderately abundant	Widespread	Moderate specificity	Sparse in woodland and grassland. However, shows preference for broadleaf woodland on acid soils and pine woodlands, where it can sometimes be moderately abundant

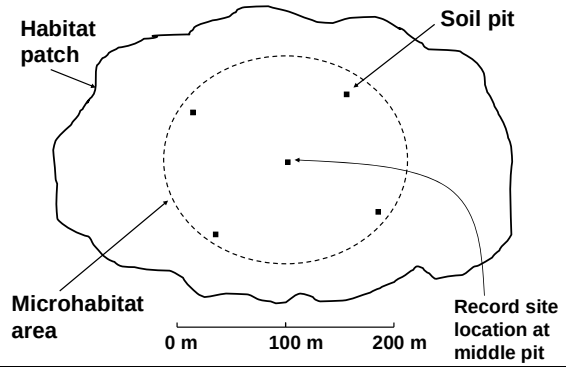
Dendrodrilus rubidus (Savigny)	Rare	Sparse to moderately abundant	Widespread	Moderate specificity	Sparse in woodland, grassland, heathland and mires. However, shows preference for broadleaf woodland on acid soils, where sometimes it can be moderately abundant
Octolasion cyaneum (Savigny)	Rare	Sparse	Widespread	Moderate specificity	Occurs in woodland and grassland. Possible preference for wetter soils
Octolasion tyrtaeum (Savigny)	Rare	Sparse but occasionally moderately abundant	Moderately widespread	Moderate specificity	Widespread across England but very few records from rest of British Isles. Sparse in woodland and grassland but can be moderately abundant in wetter soils and in broadleaf woodlands on base-rich and neutral soils
Aporrectodea icterica (Savigny)	Rare	Sparse but occasionally moderately abundant	Widespread	High specificity	Restricted to grasslands. Usually sparse but occasionally may be moderately abundant in amenity grasslands
Eiseniella tetraedra (Savigny)	Rare	Sparse to abundant	Widespread	High specificity	Recorded from wet soils in woodlands and grasslands. Often sparse but can be locally abundant in waterlogged soils
Allolobophoridella eiseni (Levinsen)	Rare	Sparse	Moderately widespread	High specificity	Widespread across Britain but few records from Ireland. Restricted to acid soils, particularly broadleaf woodlands
Dendrobaena attemsi (Michaelsen)	Rare	Sparse to moderately abundant	Restricted	High specificity	Only recorded from a few broadleaf woodlands on acid soils in southern England (plus a single old record from Cumbria)
Dendrobaena hortensis (Michaelsen)	Rare	Sparse to moderately abundant	Moderately widespread	High specificity	Widespread across southern England and Wales, with one record from Ireland and none from Scotland. Restricted to broadleaf woodland on acid soils
Lumbricus festivus (Savigny)	Rare	Sparse	Widespread	Moderate specificity	Restricted mainly to grassland and arable soils
Eisenia veneta (Rosa)	Rare	Sparse	Moderately widespread	High specificity	Only recorded in England and Wales (and one record from Ireland). Restricted to garden compost and sewage beds
Helodrilus oculatus Hoffmeister	Extremely rare	Sparse	Restricted	High specificity	Only recorded from a few wet broadleaf woodlands in southern England (plus two records from Ireland)
Aporrectodea limicola (Michaelsen)	Extremely rare	Sparse	Moderately widespread	High specificity	Only six know records from British Isles. Thought to be restricted to waterlogged soils
Dendrobaena pygmaea (Savigny)	Extremely rare	Sparse	Moderately widespread	High specificity	Less than ten records from the British Isles. Restricted to broadleaf woodlands
Lumbricus friendi Cognetti	Extremely rare	Sparse	Moderately widespread	Moderate specificity?	Only four known records from the British Isles. Reported from woodland, grassland and wet soils.
Eisenia andrei Bouché	Extremely rare	Sparse	Moderately widespread	High specificity?	Only two records from British Isles, found in commercial cultures of *Eisenia fetida*
Allolobophora cupulifera Tétry	Extremely rare	Sparse	Restricted	High specificity?	Only three records from the British Isles, all from grassland sites in Ireland

Appendices

Appendix 1. Volunteer sampling protocol

1.

Sampling site within a habitat patch



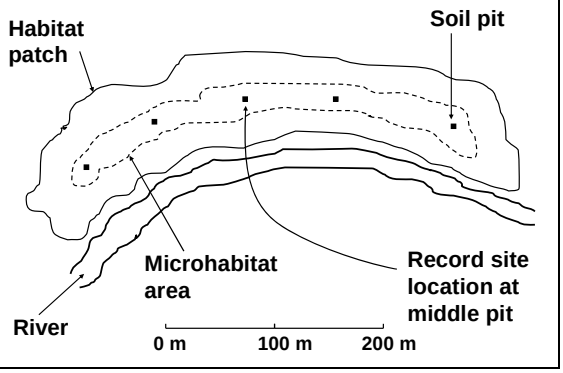
2.

Sampling site location

- Choose a representative area of habitat within a large patch of habitat
- All 5 soil pits must be at least 50 m from the nearest edge of the habitat patch
- All 5 pits must be at least 100 m from each other
- Microhabitat search area must be at least 50 m from the habitat edge, and enclose all 5 soil pits
- If possible, the minimum diameter of any habitat patch should be 300 m
- In extreme cases, the position of the soil pits and the microhabitat sampling area can be more linear to fit a narrower habitat patch

3.

Sampling linear habitat patches



4.

Sampling protocol consists of:

- Digging 5 soil pits
- Each soil pit = 25 cm x 25 cm x 10 cm depth
- Dig out pit as quickly as possible
- Pour in mustard solution (25 ml volume of mustard powder in 0.75 litre tap water) and keep checking for earthworms for 10 minutes
- Sort the top 10 cm layer of soil, plus any leaf litter on the surface. Collect all earthworms. Check in the root mat. Maximum sorting time for 2 people = 10 minutes
- Collect environmental variables (see next slide)
- 2 people search microhabitats for 10 minutes each (i.e. 20 minutes in total) – microhabitats include under dead wood, piles of leaf litter, under dung
- One site should take 2 people 90 minutes to complete

5.

Sampling environmental variables

Three environmental variables should be collected from the top 10 cm layer at every soil pit:

- Soil pH. Half fill a small zip-lock bag with topsoil. Open zip-lock bags at home and allow to air dry for a few days, then close bags. Send to DTJ
- Soil moisture. Fill a 20 ml plastic Sterilin tube with topsoil and screw on the cap tightly so the soil does not dry out. Send Sterilin tubes to DTJ. The soils will be weighed before and after drying at 104ºC to measure moisture content.
- Soil temperature. Insert the soil thermometer probe next to the pit to a depth of 10 cm. Record temperature to nearest degree. The thermometer has a brightly coloured ribbon attached so you don't lose it in the field!

6.

Recording and labelling of data

- Fill in all the data on the recording form:
  - Date of sampling
  - Name of site and location (6 figure grid ref. or GPS)
  - Altitude (from GPS or estimated from OS map)
  - Habitat type
- Label earthworm samples as follows:

  Site name, habitat type, pit number (P), from topsoil (T) or mustard (M), or name of microhabitat, e.g.
  - Shipley pasture P3T
  - Shipley woodland P5M
  - Shipley woodland under cow dung
- Label soil samples (both pH and moisture samples) with pit number
  - e.g. Shipley pasture P4

Appendix 2. Table of sites sampled by volunteers

Volunteers	Assisted by	Sites sampled	Location
VG, EF, TW & NI	DTJ	2	Kent (training day)
AR, AB, HB, DB & JM	DTJ & ES	1	Nottinghamshire (training day)
MS, KS, EP & JG	DTJ & ES	1	Nottinghamshire (training day)
JH, ND & JD	DTJ	1	Devon (training day)
ND & JD	DTJ	8	Devon & Cornwall
ND		2	Devon
MS	ES	2	Hampshire & Berkshire
MS	DTJ	10	Dorset
MS	DTJ	4	Wiltshire
TW & NI	DTJ	2	Surrey
TW & NI		2	Middlesex
VG		2	Kent & Berkshire
VG	ES	4	Kent
VG	DTJ	1	Kent
AB & HB		8	Lancashire
KS		1	Lancashire
DB & JM	DTJ	5	Derbyshire

Total = 56

Appendix 3. Sources of earthworm data used to compile the final database of species records.

Project	No. sites	No. samples	Sampling method (cm)
London parks (range of habitats)	21	141	Soil pit: 15 x 15 x 10 depth
Felixstowe gardens	19	94	Soil pit: 15 x 15 x 10 depth
Cambridgeshire agricultural landscapes (range of habitats)	12	565	Soil pit: 25 x 25 x 10 depth
Burnham Beeches (range of habitats)	9	17	Soil pit: 25 x 25 x 10 depth
Lowland Scotland	14	82	Soil pit: 25 x 25 x 10 depth, then formalin added
Study of natural woodlands (across southern and central England)	16	82	A sample consists of 4 pits (each 15 x 15 x 10 depth)
2007 testing of earthworm field guide (beta testers across England)	86	98	Soil pit: 25 x 25 x 10 depth, then mustard water added. Searching of microhabitats
2008 testing of OPAL field guide (beta testers across England)	61	87	Soil pit: 20 x 20 x 10 depth, then mustard water added. Searching of microhabitats
2009 verification of OPAL national survey results (sites across England)	39	57	Soil pit: 20 x 20 x 10 depth, then mustard water added. Searching of microhabitats
Volunteer sampling programme (this project) (for sites see Appendix 2)	56	280	Soil pit: 25 x 25 x 10 depth, then mustard water added. Searching of microhabitats
Total	333	1503	