The OPAL Soil and Earthworm Survey Report[1]

"It is not about *'Citizen Science'* but good science: *Community Science*"

Prepared by the OPAL Soil Centre

December 2009

LOTTERY FUNDED

[1] based on the first 3134 survey responses

The main contributors for this report include; Michael Archer (ERM), Declan Barraclough (EA), James Bone (IC), Paul Eggleton (NHM), Martin Head (IC), David Jones (NHM/IC), Nick Voulvoulis (IC).

TABLE OF CONTENTS

1 BACKGROUND

The OPAL Soil and Earthworm Survey was launched in spring 2009, as the first of the five National Surveys under OPAL. The survey was completed by the general public using a field guide prepared by the Imperial College OPAL Soil Centre in collaboration with staff from the Natural History Museum (NHM), the Environment Agency (EA), the Field Studies Council (FSC), the University of Central Lancashire (UCLAN) and the British Geological Society (BGS). The survey data included information on the importance the respondent placed on environmental science, identification of the surveyed location, descriptions of environmental conditions encountered, basic soil property assessment, earthworm species identification and counts of earthworms and other macro-organisms.

The survey aimed to achieve both scientific and social beneficial outcomes. Many aspects of the survey were aimed at stimulating involvement of the general public in environmental science for educational purposes through providing an introduction to the process of observing, measuring and interpreting environmental variables.

The main objective was to develop a method to identify areas of soil degradation through data on soil conditions and earthworms collected by people of all ages and ability.

2 AIM AND OBJECTIVES

As the first OPAL National Survey to go live, the overall aim was to produce a comprehensive and engaging survey and provide support to the survey during its live period.

The survey needed to be interesting (enable the use of as many senses as possible), integrated (selected soil properties and their influence on earthworms), easy-to-perform to a wide range of people and abilities, as well as provide a means by which useful data could be collected and submitted for scientific analysis.

It was facilitated by a newly developed website and database for the benefit of all surveys and tools for analysing and interpreting the data collected.

In summary, the Soil and Earthworm National Survey provides an exciting and innovative tool for people of all ages and abilities to collect 'data' about the natural environment, contributing this way to a much greater understanding of its state. At the same time, the Survey offers a purpose to participants to spend time outdoors observing and recording, an opportunity for anyone to become an 'environmentalist' and a platform for strong and useful partnerships between the community, voluntary and statutory sectors.

In addition, our work aimed not just to generate interest and awareness in the subject but to demonstrate how data collected through public participation can produce useful and valid science.

3 SURVEY APPROACH

Through the following tasks, the survey was developed, tested, delivered and validated to assess its potential, while at the same time delivering the aims above.

- Develop survey guide and data submission form planning for data processing and analysis of findings
- Testing of the guide with target groups (schools, general public) to be as easy to use as possible and accurate enough to record good quality data
- Deliver a training programme for group leaders and community support scientists to further improve quality of data submissions
- Participate in a series of launch events and support the survey live during March to May 2009 to boost participation numbers (39,732 packs distributed)

A survey field-pack was developed to collect information about soils and earthworms in the environment. Through a series of observations and simple tasks, data on soil conditions and earthworm species were recorded, with the overall objective of identifying areas of soil degradation. The guide was designed to allow useful data to be collected by people of all ages and abilities. The toolkit includes a laminated field guide and a workbook, as shown in Figure 3.1 (and included in Appendix 1), as well as pH strips, a magnifying glass, mustard and vinegar.

Figure 3.1 *Front pages of the field guide and workbook for the OPAL Soil and Earthworm Survey.*

As the survey materials developed, consultation and feedback from diverse target groups allowed materials to be as easy to use as possible and accurate enough to record good quality data. Examples of testing and development events are presented in Table 3.1.

Table 3.1 *Testing and development events organised by the Soil Centre*

Date	Location	Audience
2nd July 2008	Hounslow Heath London	School, General Public
14th July 2008	St Peter's Primary School	School (Year 3 – 6)
4th August 2008	Imperial College Garden	General Public, Specialists
26th September 2008	Hyde Park London	Specialists

A training programme was rolled out, placing particular emphasis on the completion of the survey and data quality. This was done to support our intention to not remove any records from the dataset, thus facilitating a more thorough analysis to identify and select records that meet the required level of quality, based on its intended use.

The launch of the Soil and Earthworm Survey was of key importance for the Soils National Centre in order to raise public awareness and attract people to participate. It included a number of launch events including;

- Public Launch (OPAL) in Kensington Gardens – 7th December 2008
- Media launch and photocall in Hyde Park – 23rd March 2009
- Launch to partners at Imperial College – 27th March 2009

as well as a number of regional launches in the OPAL regions.

Media events around the launch date included

- The One Show (filmed at Silwood Park – 12th March 2009) and
- Breakfast Radio Interviews at the BBC for stations across the country (see Table 3.2).

Table 3.2 *Media coverage associated with the Survey Launch:*

Coverage	Date
The One Show	March 2009
The One Show Blog	23rd March 2009
BBC Radio Oxford	23rd March 2009
BBC Radio York	23rd March 2009
BBC Radio Cumbria	23rd March 2009
BBC Radio 3 Counties - Luton	23rd March 2009
BBC Radio Coventry and Warwickshire	23rd March 2009
BBC Radio Northampton	23rd March 2009
BBC Radio Somerset	23rd March 2009
BBC Radio Scotland	23rd March 2009
BBC Radio Derby	23rd March 2009
BBC Radio Lincolnshire	23rd March 2009
BBC Radio Lancashire	23rd March 2009
BBC Radio Three Counties – Milton Keynes	23rd March 2009
BBC Radio Kent	23rd March 2009
Which? Gardening magazine	March 2009 edition
The Garden	March 2009 edition
Folio (Bristol and Bath)	March 2009 edition
Surry Advertiser	20 March 2009
Citizen (Bury St Edmonds)	18 March 2009
News and Star	16 March 2009
Bury Free Press	13 March 2009
The Journal (Newcastle)	7 March 2009
The Stour and Avon Magazine	27 February
Teacher Science Network News	Winter edition

As respondents completed the survey the results were uploaded to an online database which was linked to a real-time map of the data as it was received. An inclusive approach was adopted so that all participants could see the contribution from their entries. All records were included demonstrating that everyone's data is of use and is helping to build a better overall picture for the state of the environment. When interpreting the data, our methodology assumed that the accuracy of individual records was likely to be variable and therefore used a tool that utilised values from records in the vicinity to 'correct' and estimate – produce interpolated values.

In order to identify reliable data that met the objectives outlined earlier in this report, an appropriate investigative method was developed and validated through comparison with other existing datasets. In summary this methodology included the following actions:

- Exclude points where the same information has been entered a number of times exactly and points where there is evidence for incorrect “geo-referencing”.
- Compile histogram plots for each of the attributes that are to be investigated and identify if there are any points that don’t seem to fit the overall data distribution (outliers).
- Use a Geographical Information System (GIS) to plot results for each of the attributes at each location. Using interpolation these point values are then used to create a predicted continuous surface across England. Appropriate colours and classes are used to represent the data.
- Immediately evident trends are identified in the interpolated surface.
- Hotspots/ coldspots on the interpolated surface are identified using the colour differences. The number of points that appear to be driving the hotspot/cold spot is investigated to check the confidence in the result.

As spatial variability in soil properties are often described through use of interpolation and used frequently in agricultural and environmental applications, we reviewed appropriate tools to achieve this effectively. There are a number of well established interpolation methods that have developed over the last 30 years. Regionalized variable theory[1] has been used extensively and consists of a semi-variogram and the kriging interpolation method[2]. Other well used methods for analysis of spatial variability of soil properties include inverse distance weighting[3] and splines[4]. Of the classical interpolation methods kriging is thought to be the best method to describe soil properties[5]. and therefore was used for our survey. Findings were then investigated by comparison of the interpolated data to other available datasets appropriate to the attribute and area being investigated.

4 RESULTS TO DATE

The data presented in this report has been based on records received as of the 6th October 2009 when a total of 3,134 survey records had been submitted by respondents. The survey records provided spatial coverage of much of England; however a greater density of respondents were located in urban centres, primarily around London and Birmingham.

In addition to submitted records, it is clear from feedback from community scientists, and from first hand observations at events, that there are a number of cases where participants have gained and learnt a great deal from the survey but for various reasons have not then uploaded their data to the OPAL website.

---

1 Matheron, G., 1963, Principles of geostatistics: Economic Geol., v. 58, p. 1246-1266.

2 Krige, D. G., 1951, A statistical approach to some basic mine valuation problems on the Witwatersrand:
J. Chem. Metal. Min. Soc. South Africa, v. 52, p. 119-139.

3 Shepard, Donald .1968. "A two-dimensional interpolation function for irregularly-spaced data". Proceedings of the 1968 ACM National Conference. pp. 517–524.

4 Erh, K.T. 1972. Application of spline function to soil science. Soil Sci. 114:333–338.

5 Shi, W. Liu, J. Du, Z. Yinjun, S. Chem C. Y Tianxiang. 2009. Surface Modelling of Soil pH. Geoderma. 150 pp 113 – 119.

4.1 RECORDS RECEIVED PER AREA

As OPAL operates over nine regions, the number of records received in each of these regions up until 6th October is illustrated in Table 4.1 and Figure 4.1. The only data that have been filtered out and excluded from our survey and therefore its quality assessment and further analysis are from records where we have sufficient evidence that the location information had been incorrectly provided (explained later - Section 3).

Table 4.1 *Number of Records received by OPAL region up to 9th October 2009.*

OPAL Region	Number of Records	Percentage of Total
South West	229	9%
South East	222	9%
London	300	12%
East of England	273	11%
West Midlands	532	22%
East Midlands	327	13%
North West	255	10%
Yorkshire and The Humber	206	8%
North East	109	4%

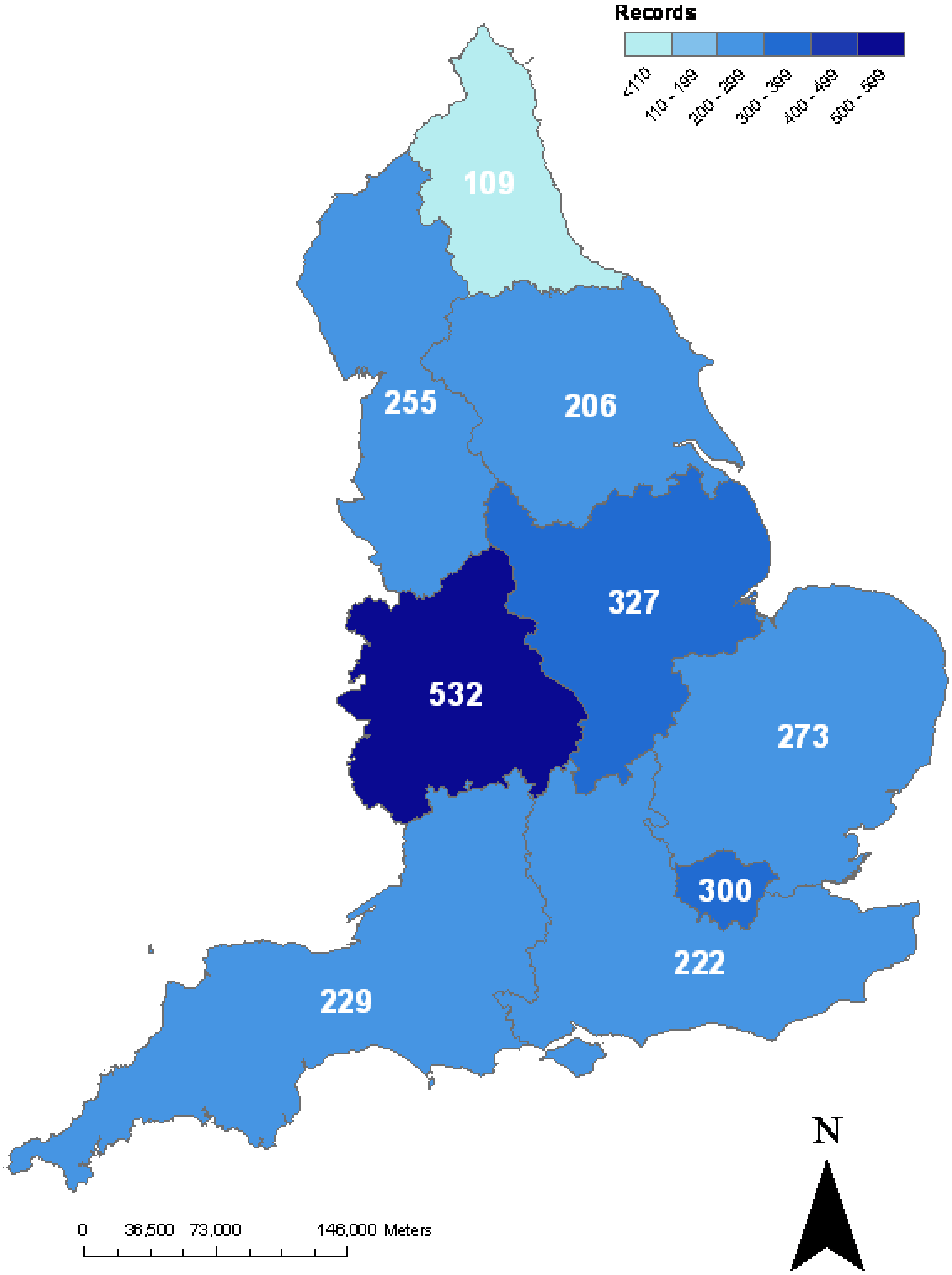


Figure 4.1 *Choropleth map illustrating responses received within each of the OPAL regions up to 6th October 2009.*

4.2 RECORDS RECEIVED FROM DEPRIVED AREAS

One of the aims of the OPAL project is to target deprived and hard to reach communities. Of the records that make up this report 14.14% of records are in the 20% most deprived areas of England according to the Index of Multiple Deprivation 2007[1].

4.3 CHANGES OVER TIME

The number of survey responses collected in the field and submitted online increased as the packs reached participants, wider media coverage was achieved and community scientists supported participation, this can be seen in Figures 4.2 and 4.3 below. A peak in submissions was observed approximately halfway through the "live" phase of the survey.

[1] Department of Communities and Local Government, Indices of Deprivation 2007

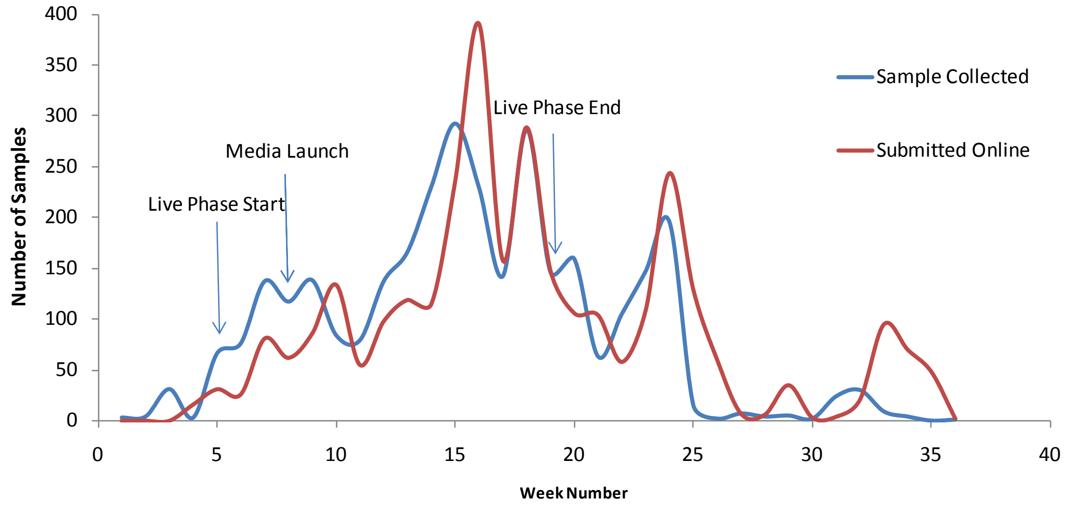


Figure 4.2 *Weekly submissions for OPAL Soil and Earthworm Survey to the OPAL Portal Website*

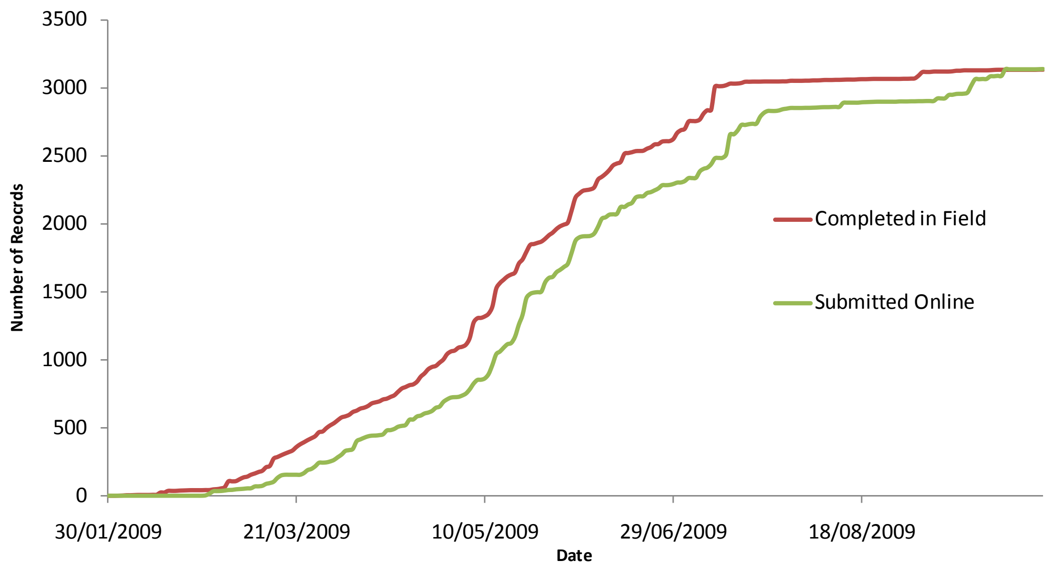


Figure 4.3 *Cumulative submissions of OPAL Soil and Earthworm Surveys to the OPAL Portal Website.*

4.4 TYPE OF PARTICIPATION

Based on data provided by the participants, 15% of responses came from individuals working as part of voluntary groups, 56% through schools and 28% from individuals working on their own (Figure 4.4).

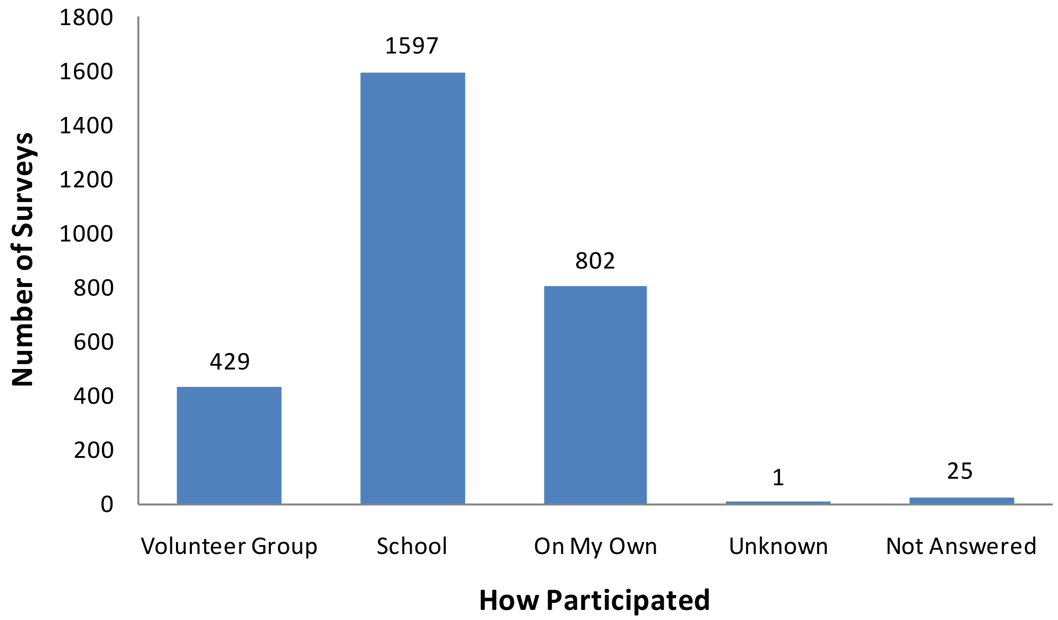


Figure 4.4 *Participation recorded by OPAL Soil and Earthworm participants*

4.5 DATA COVERAGE AND DENSITY

The distribution of samples across England is not even and is clustered around urban areas, especially those where an OPAL community scientist is based (Figure 4.5). This is considered to be of value as a greater sample density has been achieved in urban areas where we would expect greater heterogeneity in the soil environment. Analysis of areas where there is a low density of samples, however, has a higher level of uncertainty associated with it.

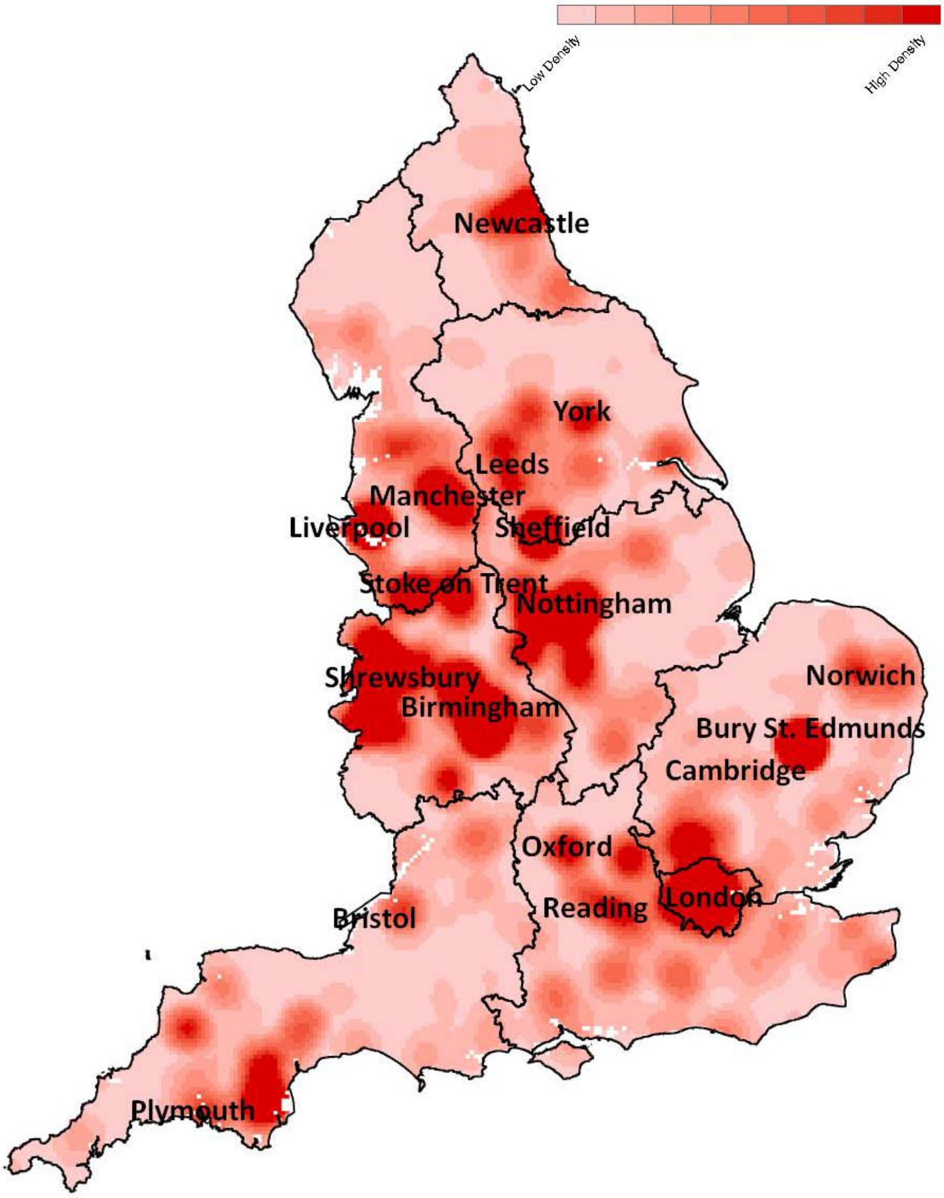


Figure 4.5 *Density plot of received records to the OPAL Soil and Earthworm survey.*

4.6 QUALITY ASSESSMENT

An extensive investigation of the quality of the data received from the OPAL Soil and Earthworm Survey was also undertaken and presented in a separate technical report (Appendix 2). This report assessed the quality of the data received through practical exercises and comparison to existing data sets. It was concluded that the accuracy of the data was acceptable for use as a whole to assess the state of the environment, considering the limitations of the methodologies used and the typical level of experience of the survey respondents.

The data quality assessment did not indicate that any records should be selectively removed from the dataset but instead that further analysis should be allowed to select the records that meet the level of quality required. There were only two exceptions to this that again were not associated with the type of participants:

1. records for which there was evidence that the wrong spatial information was recorded and
2. records where identical information was submitted for exactly the same location (duplicate records).

4.7 MAIN FINDINGS

The following sections provide an overview of the records submitted through the OPAL Soil and Earthworm Survey. The results summarise responses for the soil attributes and earthworm numbers and identification. For key soil attributes, total earthworm numbers and ecological group plots of interpolated values are included to give indications of trends and distributions across the country.

Participants of the OPAL Soil and Earthworm Survey were asked to record various properties about the site where they carried out their sampling. The setting of the site, (Figure 4.6), shows that the number of urban and suburban samples recorded outweighs the rural samples. This is likely to be due to the community scientists based at regional universities in larger conurbations and the large number of schools taking part in the survey. Urban soils are not regularly sampled compared to rural soils and therefore it is positive to have a good coverage of these urban areas.

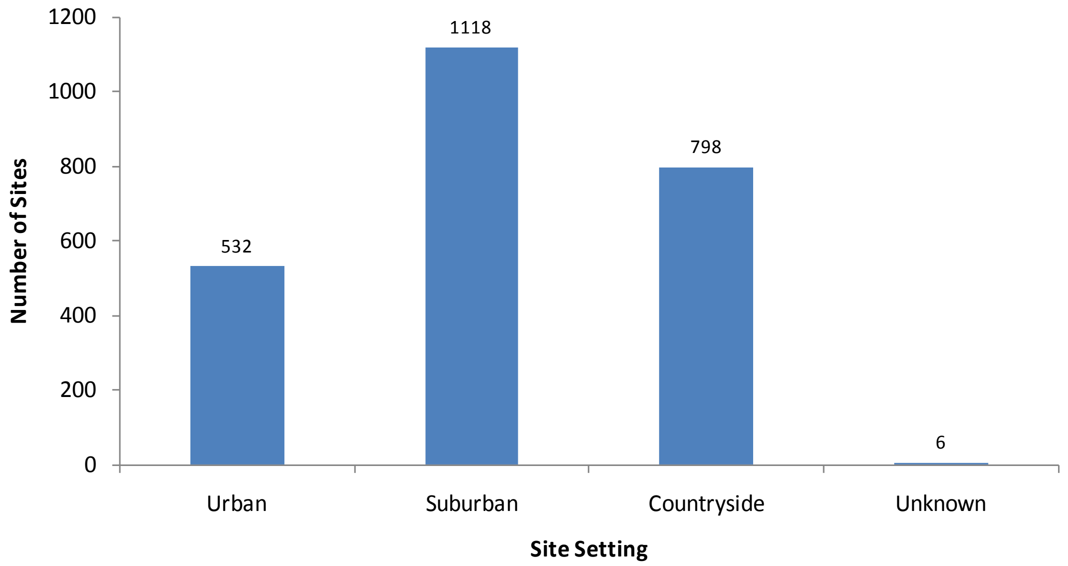


Figure 4.6 *Site setting of responses to the Survey.*

The land use of the submitted surveys again shows the large contribution made by schools, those in urban and suburban settings and the relatively small occurrence of some hard to access sites such as industrial sites and ploughed fields (Figure 4.7).

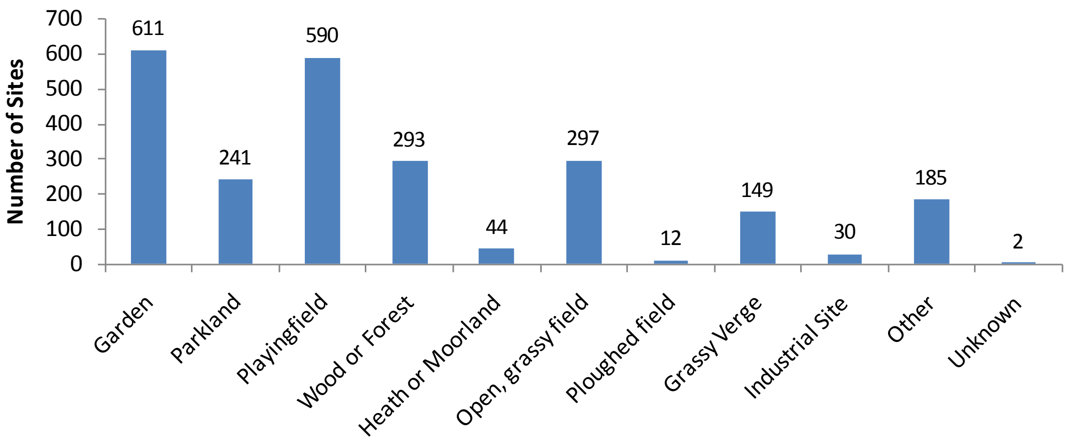


Figure 4.7 *Land use of survey site.*

The dominance of urban and suburban settings and access requirements is shown in the distance to the nearest road, showing that by far most samples were taken less than 100m from a road, Figure 4.8.

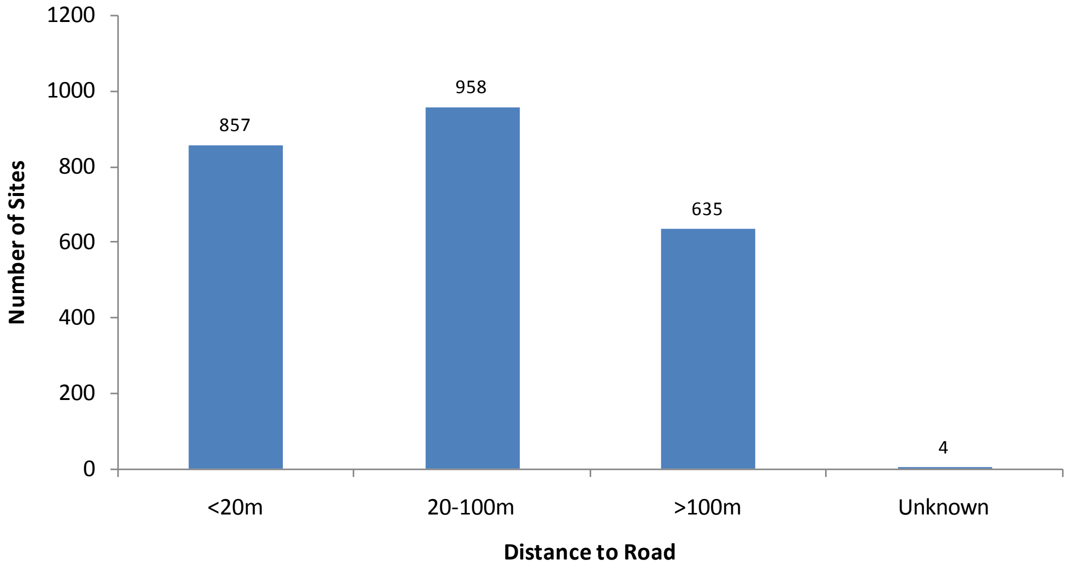


Figure 4.8 *Distance to nearest road of survey sample sites.*

Despite a predominance of urban/suburban site settings, the majority of participants recorded no signs of pollution in close proximity to the sampling sites (Figure 4.9).

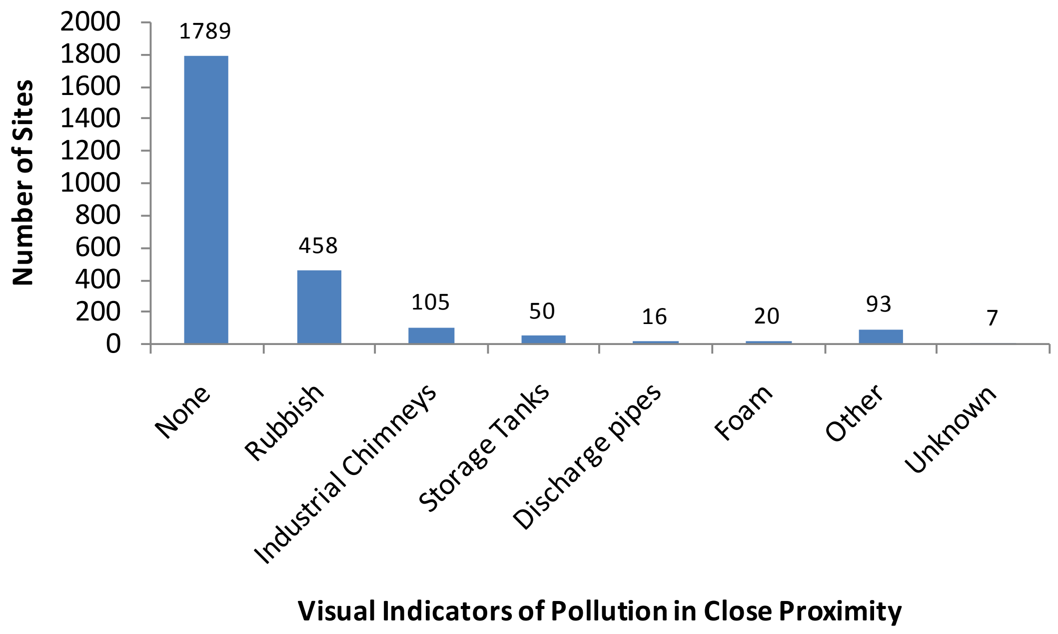


Figure 4.9 *Signs of pollution reported in close proximity to the sampling site.*

The level of plant cover on the ground where surveying took place was recorded by participants (Figure 4.10). The high level of plant cover is likely to reflect the high number of gardens and playing fields sampled.

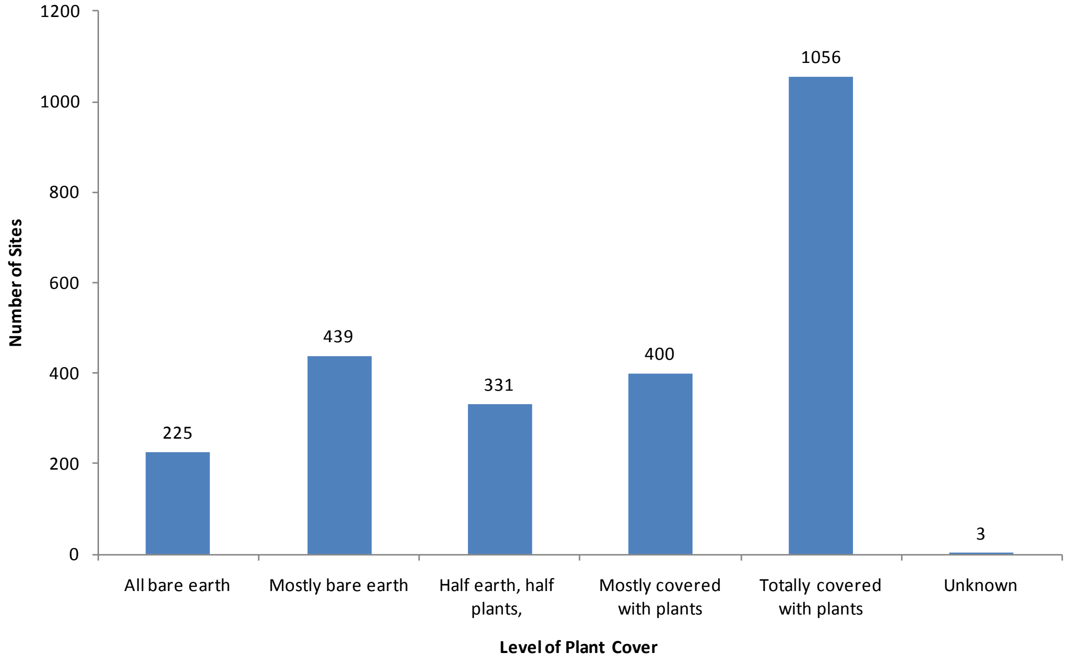


Figure 4.10 *Levels of plant cover on the ground where survey was carried out.*

4.7.1 SOIL PROPERTIES

Participants were asked to record a number of properties of the soil where they were carrying out the survey. A large range of soil textures were found across the country (Figure 4.11). Soil texture types that were expected to occur relatively less frequently, such as sand and clay, are reflected in the results from the survey. Despite this being one of the more difficult aspects of the survey the number of unknown responses is small.

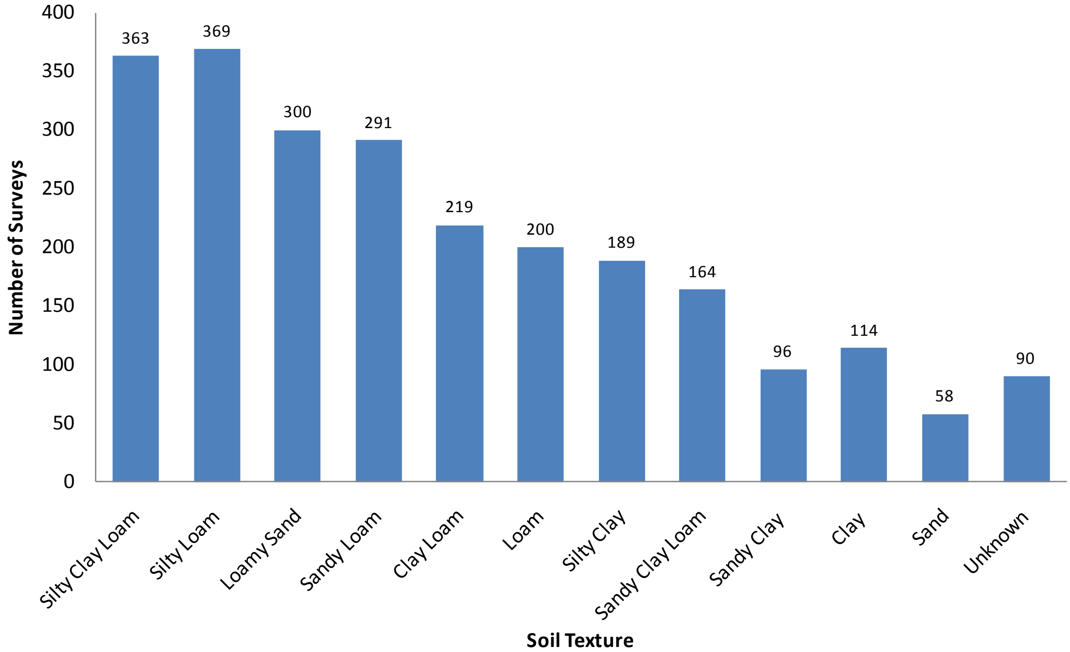


Figure 4.11 *Survey soil texture frequency distribution.*

The topsoil pH was recorded by participants using a pH strip (Figure 4.12). The frequency distribution of responses shows a roughly normal distribution with a skew toward slightly acidic conditions, as would be expected of soils in England. The roughly normal distribution is thought to be due to limitations on the measurement strip and use of tap water to measure the soil pH.

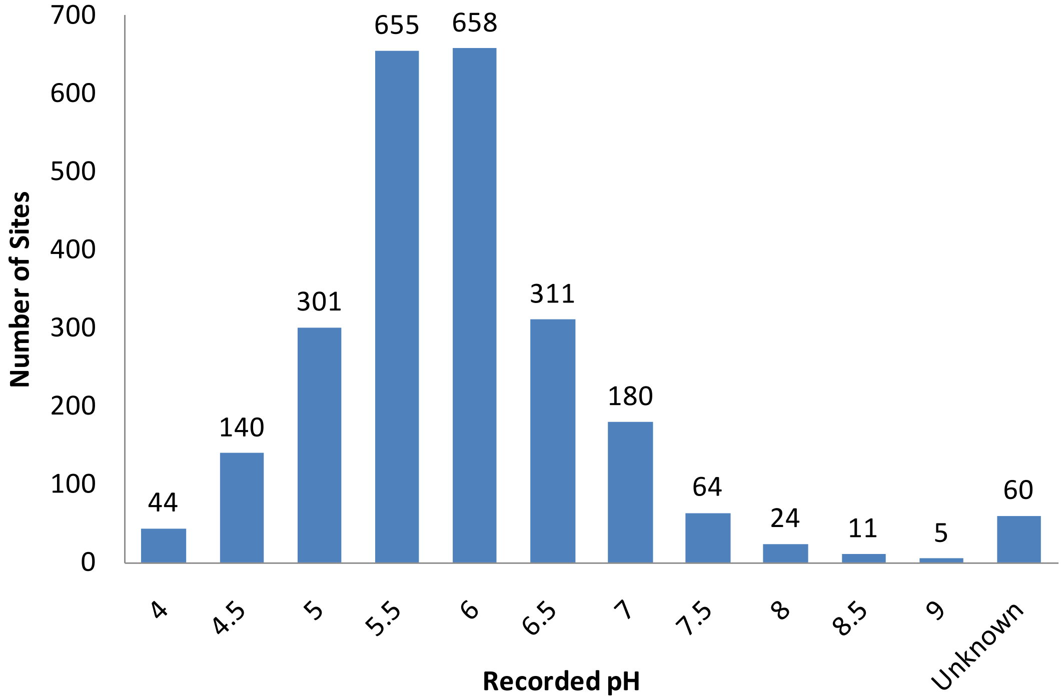


Figure 4.12 *Frequency distribution of topsoil pH values.*

Soil moisture was reported by respondents to the survey and most of the responses found moist soils (Figure 4.13). Few soils were very dry or wet, which may be significant when jointly considering other indicators such as infiltration rates, levels of compaction and soil particle sizes.

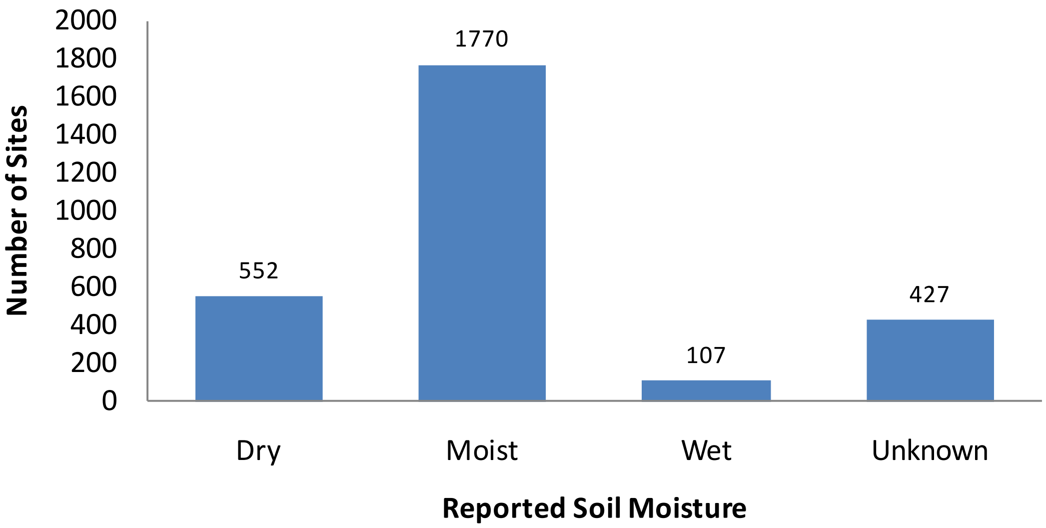


Figure 4.13 *Soil moisture distribution of sample sites.*

The soil colours found across the country show a large number of soils being reported in the light to dark brown categories (Figure 4.14). There were a number of responses that had more unusual colours and these can be used when investigating sites in more detail.

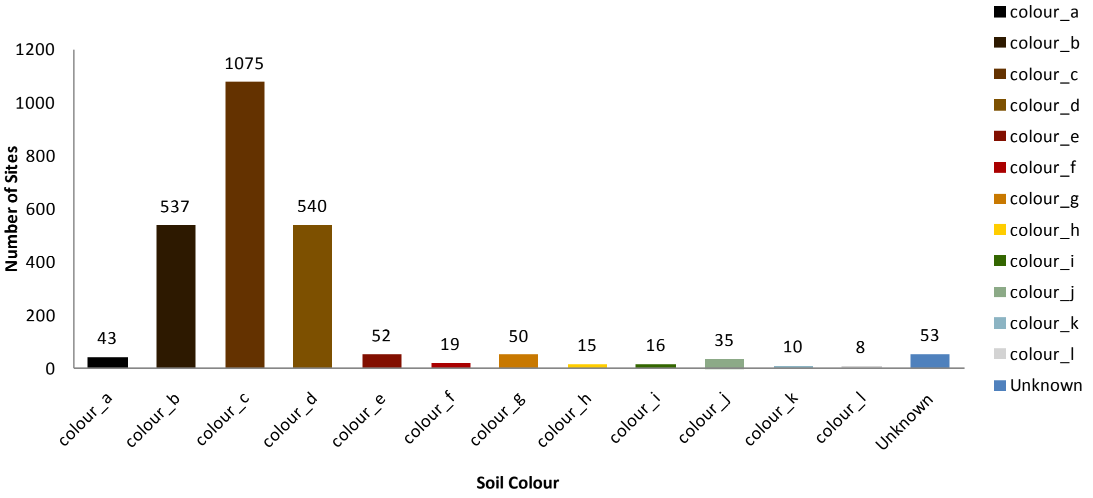


Figure 4.14 *Colour distribution of sample site soils.*

Soil compaction was evaluated by participants using a pen, pencil or similar as a penetrometer (Figure 4.15). The results show almost equal numbers of respondents reporting that it was easy or difficult to push the implement into the soil surface; whereas a lower number of respondents reported penetration of the soil to be very difficult, indicating a possible high level of soil compaction at those sites.

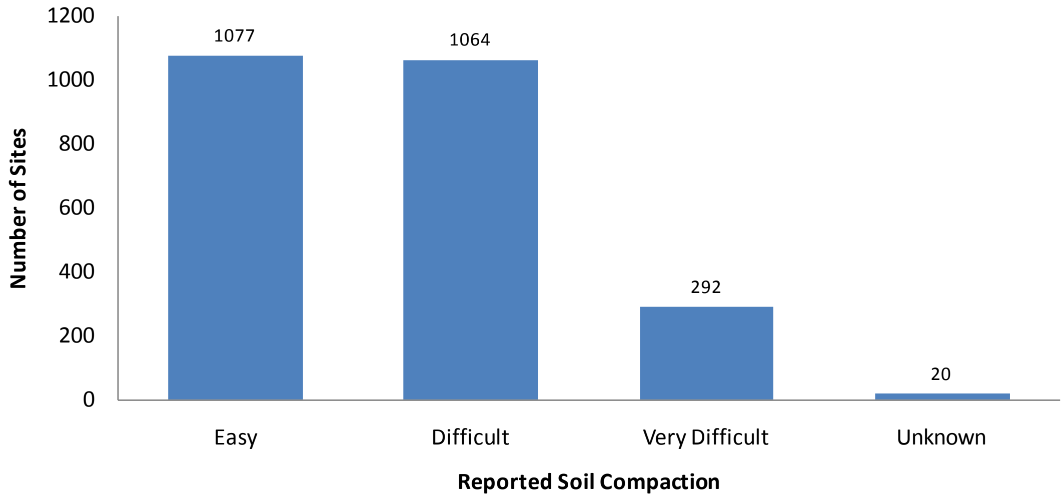


Figure 4.15 *Soil Compaction.*

Participants were asked to record the abundance of roots in the soil, the majority of respondents reported a few or lots of roots (Figure 4.16). There was a small amount of sites where no roots were reported, this information being useful in further investigation of particular sites and areas.

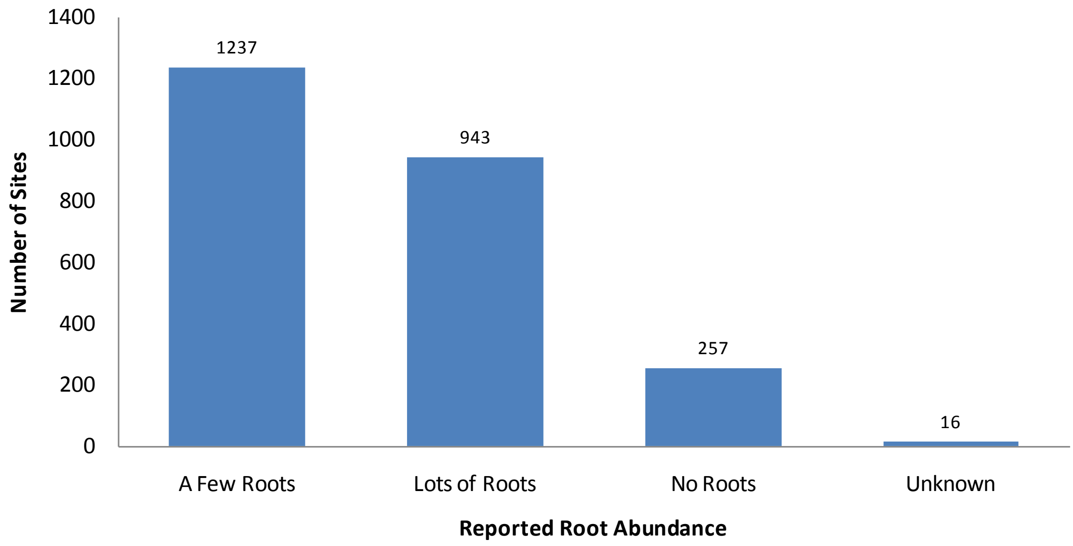


Figure 4.16 *Root abundance at sample sites.*

The rate of infiltration of 750ml water and mustard solution is an indicator of the infiltration rate of the soil where the survey took place. This is useful information for many soil issues and when used in combination with other indicators can inform on the potential for environmental issues such as flooding. Of the results that were reported by participants by far the largest number of responses timed over 3 minutes for the solution to infiltrate the soil (Figure 4.17).

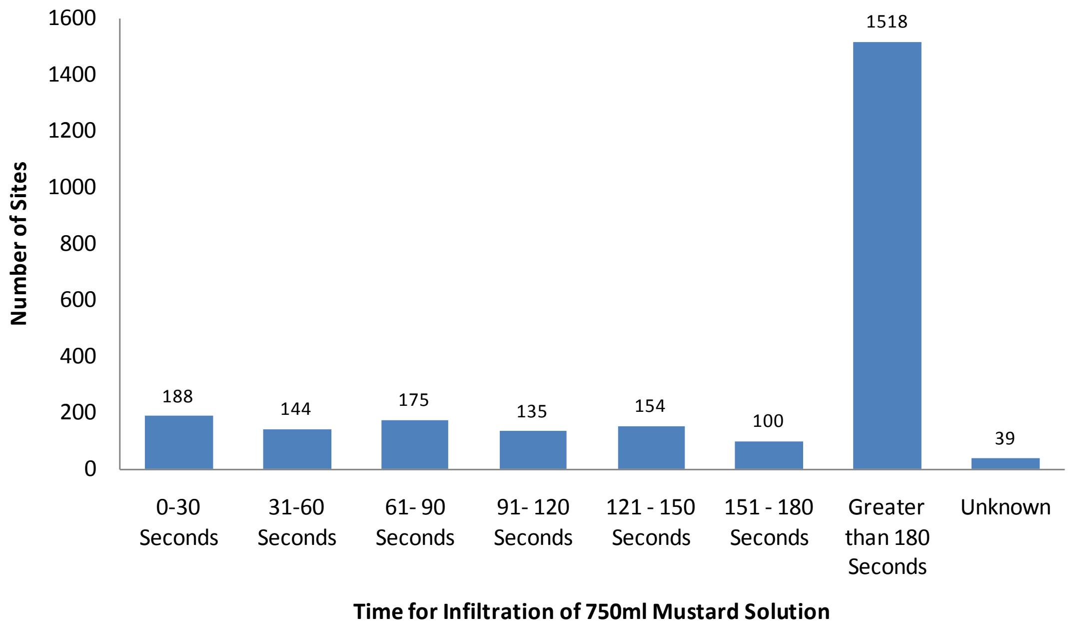


Figure 4.17 *Infiltration rate of 750ml of water/mustard solution.*

The “Soil Fizz” test was designed to indicate soils with elevated levels of carbonate ions (CO_3), with calcium carbonate ($CaCO_3$) being the most widely expected, with carbonate rich soils effervescing on contact with an acid (vinegar). The majority of soils were reported as not fizzing on application of vinegar, indicating carbonate levels below the “detection limit” for this test (Figure 4.18).

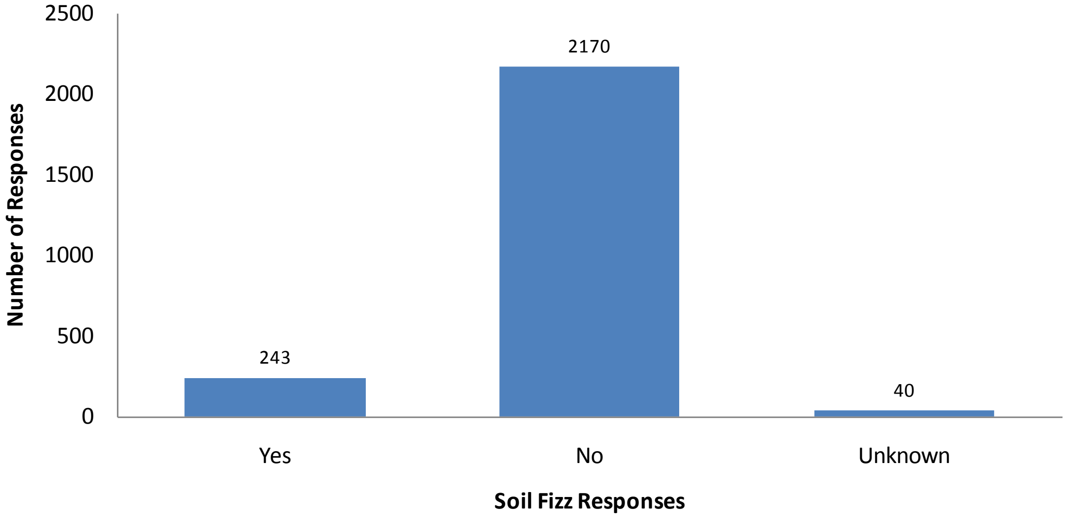


Figure 4.18 *Soil fizz test on application of vinegar.*

The soil odour can indicate the level of microbial activity in a soil or it can indicate anaerobic conditions and contamination. Of the responses received from the survey the most frequent was from sites with an earthy, sweet, fresh smell indicating healthy microbial activity (Figure 4.19). A high number of sites were recorded as having no smell, indicating that microbial activity maybe low in these sites. A small number of sites indicated sour, putrid or chemical smells and these can be considered in further investigation.

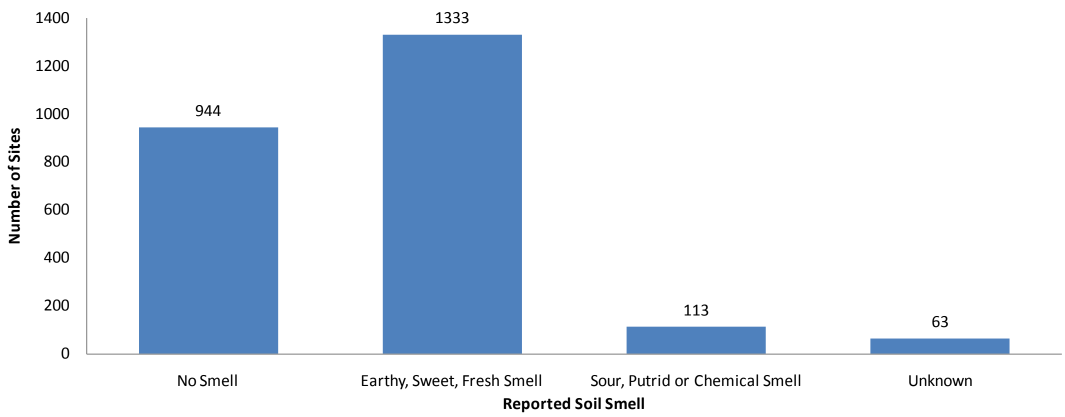


Figure 4.19 *Soil odour as reported by respondents of the survey.*

Finding objects in the soil can be an indicator of soil disturbance by human activities and may indicate what is known as made ground or fill. At the majority of sites no soil objects were found during the survey exercise, which could indicate that the majority of soils were likely not to have been fill materials (Figure 4.20). Of soil objects found the most common was construction material, this may be due to the high number of gardens sampled where construction material is often found (Figure 4.21).

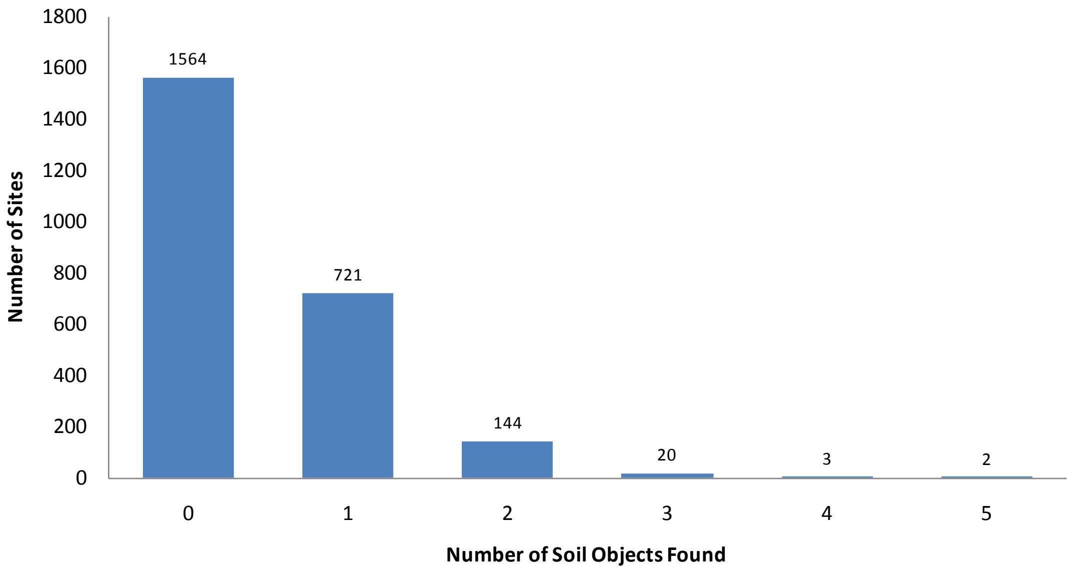


Figure 4.20 *Number of objects found in the soil at sampling sites.*

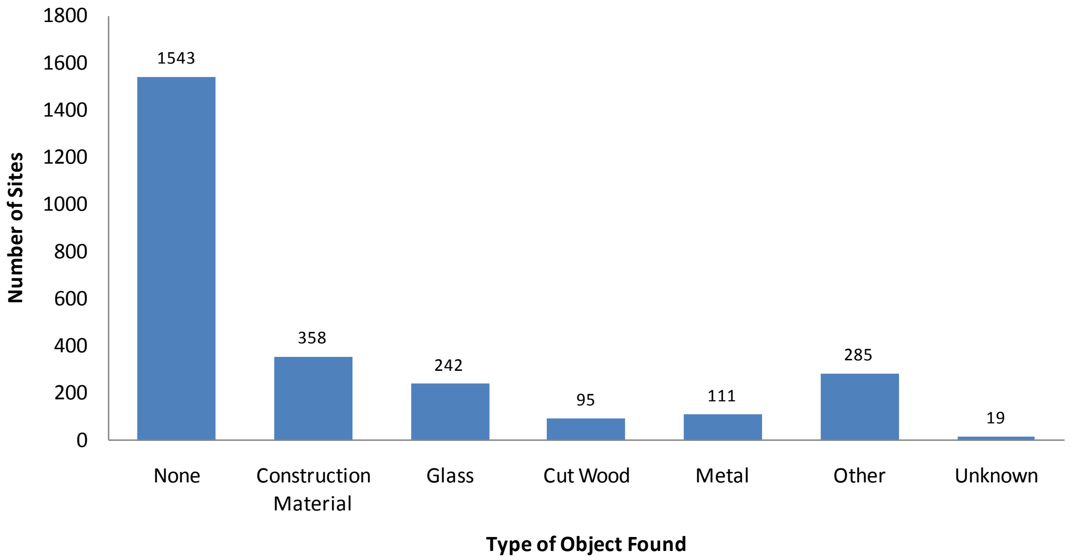


Figure 4.21 *Type of objects found in the soil at sampling sites.*

4.7.2 EARTHWORM RESULTS

The number of earthworms found and the species were recorded by participants of the survey (Figure 4.22). A total of 17215 earthworms were found including both adult and juvenile earthworms of all species. Less than 10 earthworms were found in 79.86% of sites; however 479 sites had between 11 and 88 earthworms.

Identification to a species level can take place only for adult earthworms. Adult earthworms were distinguished from juvenile earthworms by identification of a saddle that characterises mature earthworms. A total of 5646 adult earthworms were found, 32.8% of the total. The maximum amount of adult earthworms found was 20 (Figure 4.23), and over 80% of sites had between 1 and 5 adult earthworms.

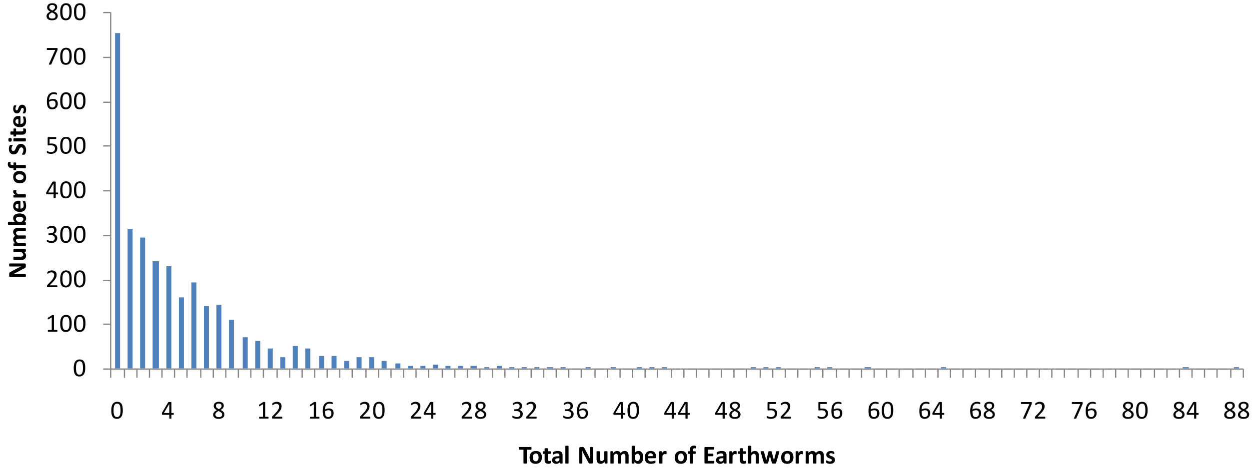


Figure 4.22 *Total number of earthworms found per site.*

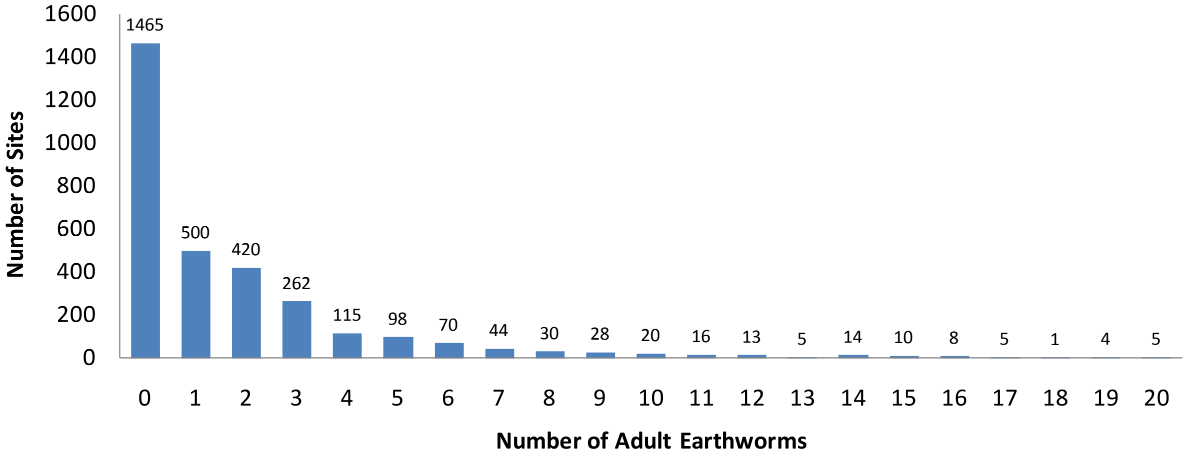


Figure 4.23 *Number of adult earthworms found per site.*

The number of species found per sampling pit was a maximum of nine (Figure 4.24). The earthworm species found included all featured on the OPAL Soil and Earthworm guide. The most frequently found species were the redhead worm (*Lumbricus rubellus)* and black headed worm (*Aporrectodea longa*) (Figure 4.25).

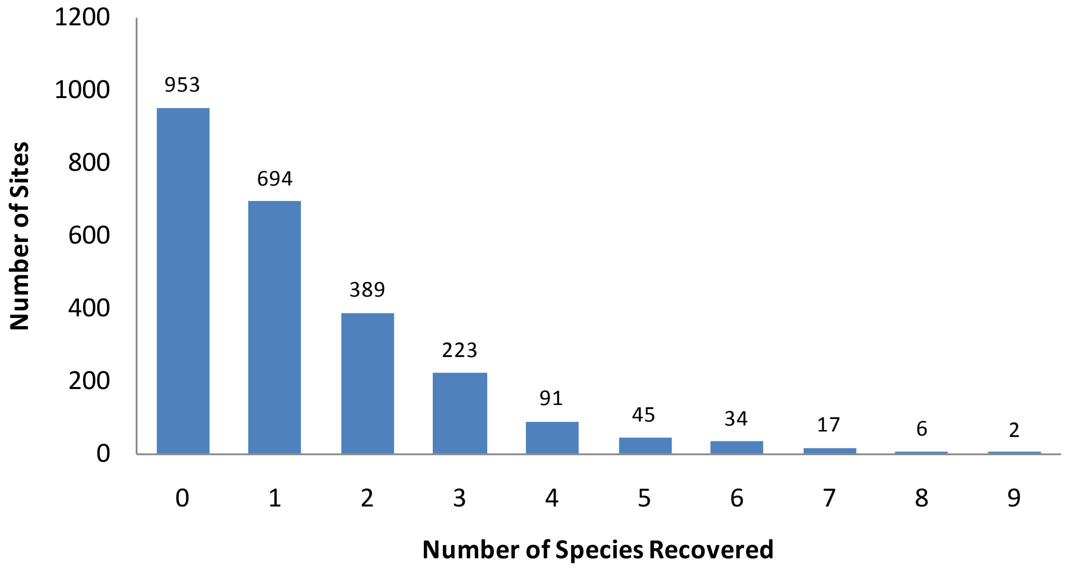


Figure 4.24 *Number of adult earthworm species found per site.*

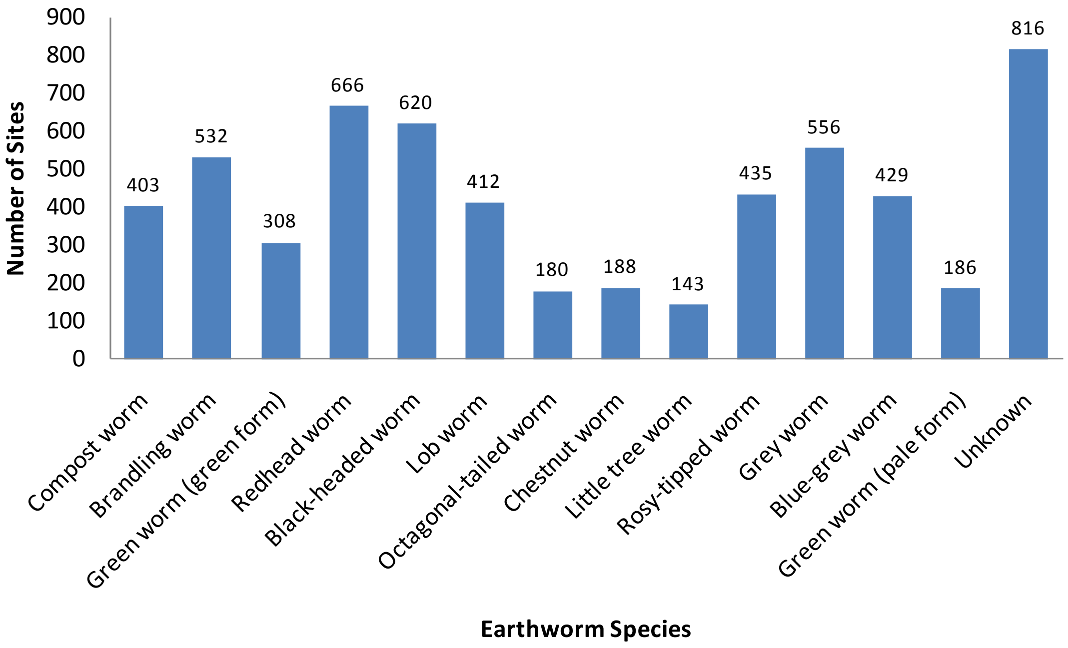


Figure 4.25 *Total numbers of adult earthworms found.*

4.8 CLUSTERING

Point similarities based on both the location and value of the point, at the same time, allows evaluation of the spatial clustering of responses to a given question. This provides an understanding of confidence levels in identification of areas of interest based on original values and interpolated plots.

The Moran's I geostatistical tool evaluates whether the sample pattern is clustered, dispersed, or random. The tool calculates the Moran's I Index value, a Z score and p-value evaluating the significance of that index. In general, a Moran's Index value near +1.0 indicates clustering, while an index value near -1.0 indicates dispersion. A result that is not statistically significant signifies that the observed pattern is just one of the many possible random versions.

The null hypothesis states that "there is no spatial clustering of the values associated with the geographic features in the study area". When the p-value is small and the absolute value of the Z score is large enough that it falls outside of the desired confidence level, the null hypothesis can be rejected. If the index value is greater than 0, the set of features exhibits a clustered pattern. If the value is less than 0, the set of features exhibits a dispersed pattern. An illustration of a range of data patterns from dispersed to clustered is shown in Figure 4.26.

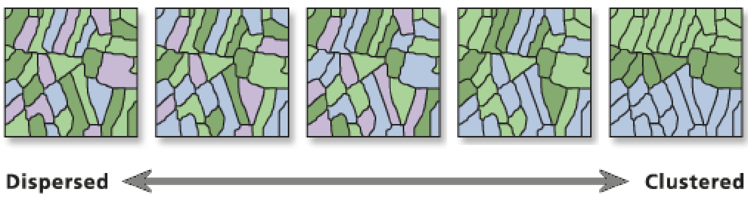


Figure 4.26 *Illustration of a scale of patterns of data, from dispersed to clustered.*

The Moran's I tool was used to test the clustering of data received from the survey. The tool demonstrates that for each of the indicators tested, the results showed that clustering is statistically significant (i.e. the clustering of results did not happen at random) (Table 4.2). This indicates that it is valid to use the data to determine areas of high/low values for further investigation.

Table 4.2 *Results of the Moran's I test, to test clustering of values for different questions asked in the OPAL Soil and Earthworm Survey.*

	pH	Infiltration	Sand Cont.	Clay Cont.	Plant Roots	Moisture	Hardness	Total EW	Compost	Epigeic	Endogeic	Anecic
Moran's I	0.5	0.2	0.3	0.4	0.3	0.3	0.2	0.2	0.6	0.1	0.4	0.1
Z Score	14.7	6.4	10.1	10.4	9.6	7.9	6.1	7.9	20.5	2.7	13.9	3.4
p-value	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Significant (95%)	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔
(C) lustered (D) ispersed (R) andom	C	C	C	C	C	C	C	C	C	C	C	C

4.9 INTERPOLATION PLOTS

A number of plots that illustrate the interpolated results on a national basis using Kriging are presented below. The topsoil pH interpolation plot (Figure 4.27), indicates that lower topsoil pH values are predicted in the North West and South West of the country, while higher topsoil pH values are predicted in the east and centre of the country. The predicted soil moisture (Figure 4.28) appears higher in the west and south west of England and lower in the north east, east and south east of England. Clay content (Figure 4.29) is predicted to be higher in the north and centre of England and lower in East Anglia and the western central area. The predicted sand content shows reverse trends to the predicted clay content, with high predicted sand content in East Anglia, the extreme southwest and the western central areas (Figure 4.30). The level of plant roots (Figure 4.31) appears to be higher in the north east, eastern central, East Anglia and south west, while the west of England and the south East appear to have lower predicted levels of plant roots.

There are a number of areas where there appear to be lower predicted total numbers of earthworms present (Figure 4.32), including adjacent to the Welsh border and the east and south east of England. There appears to be higher predicted levels in the north of the country and the south west.

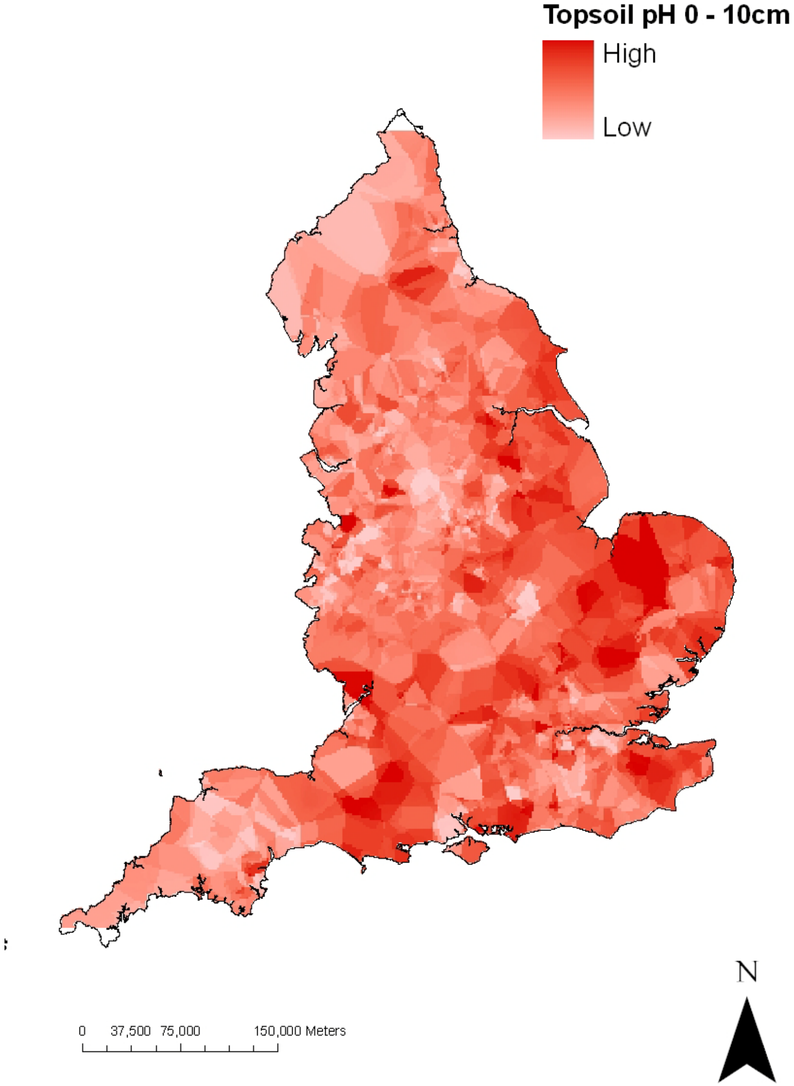


Figure 4.27 *Plot showing Kriging interpolation of topsoil pH values.*

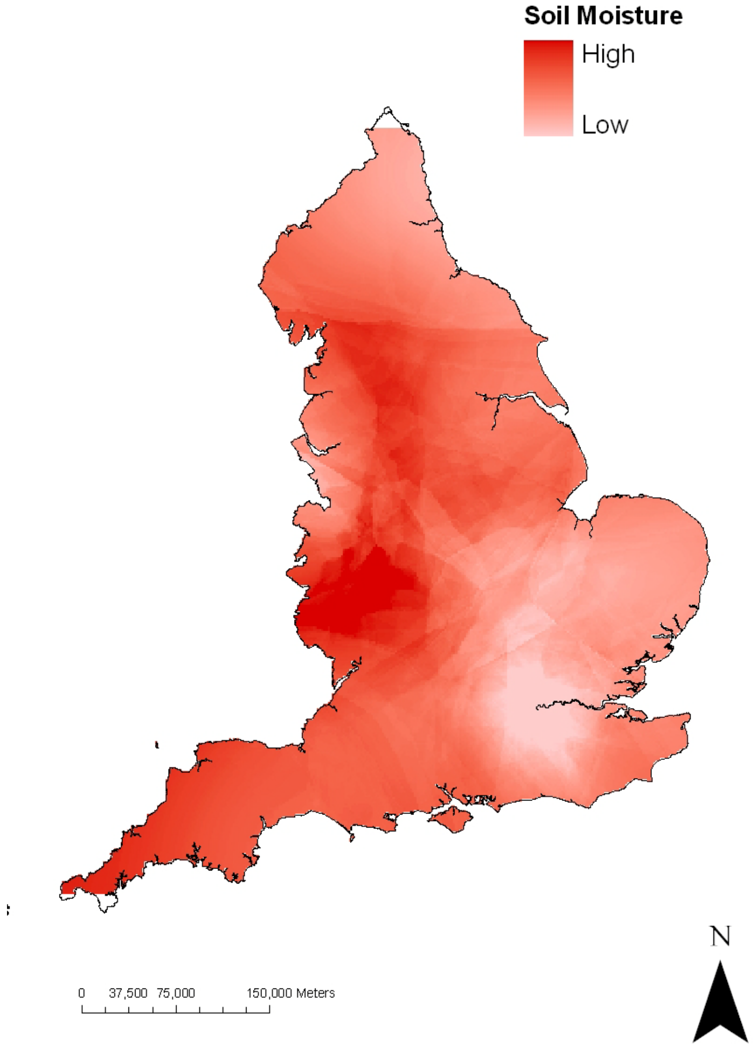


Figure 4.28 *Plot showing Kriging interpolation of soil moisture values.*

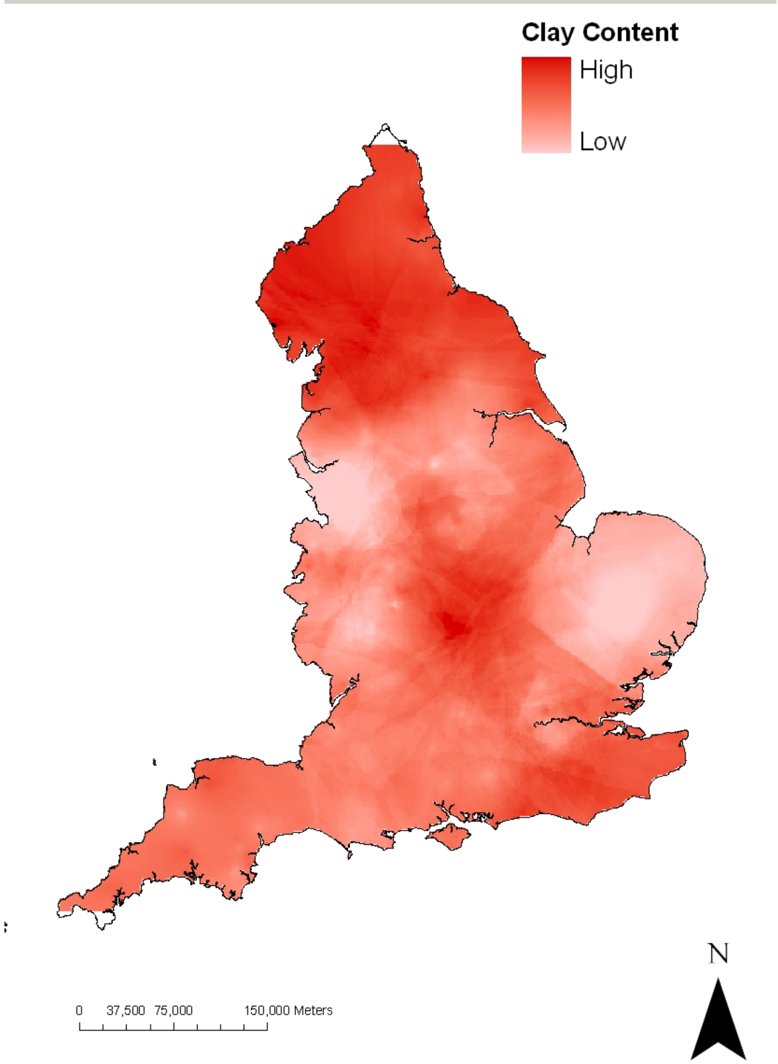


Figure 4.29 *Plot showing Kriging interpolation of reported clay content.*

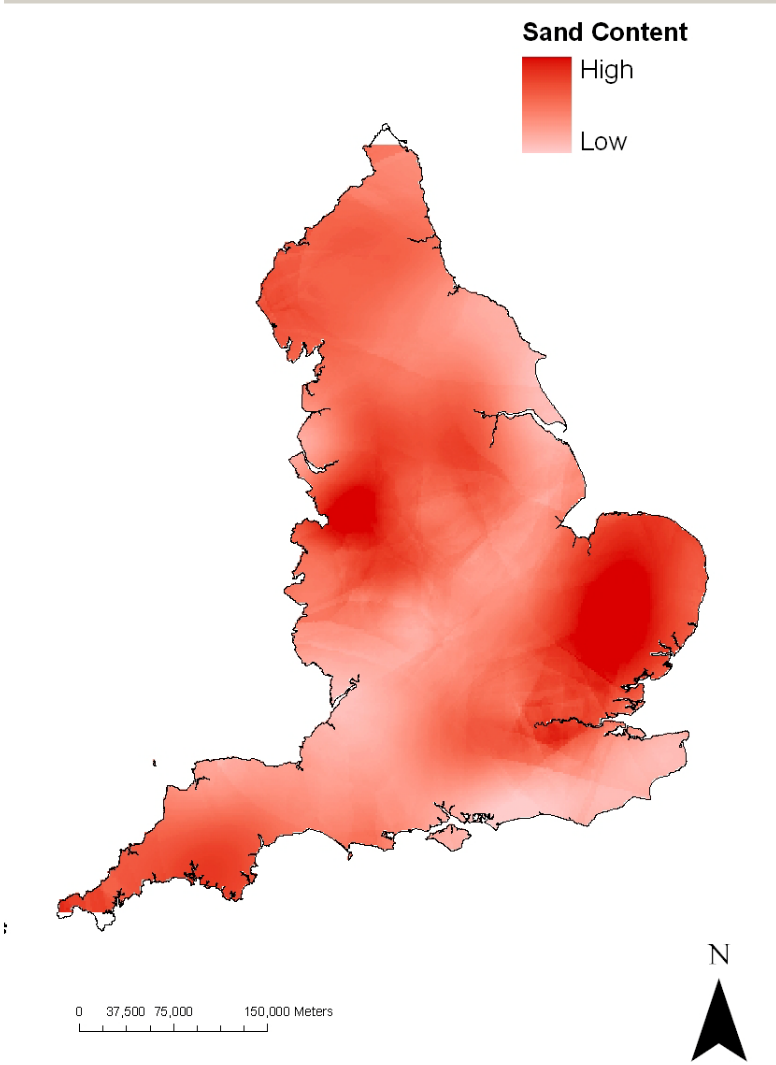


Figure 4.30 *Plot showing Kriging interpolation of reported sand content.*

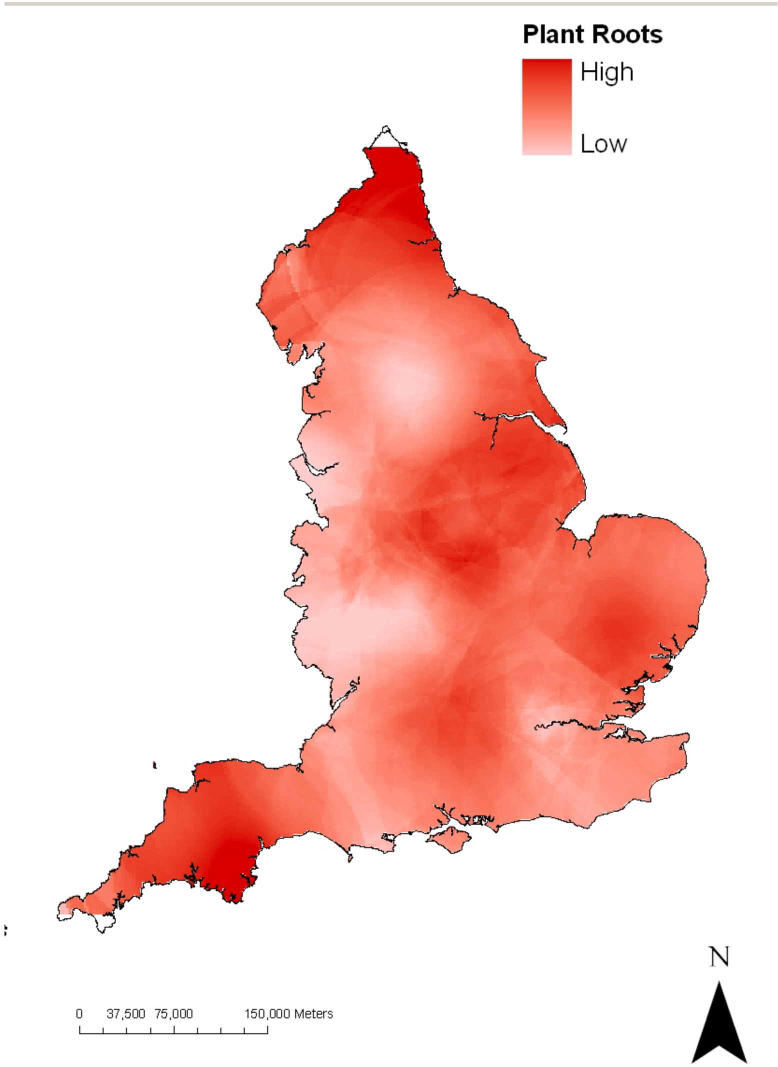


Figure 4.31 *Plot showing Kriging interpolation of reported levels of plant roots.*

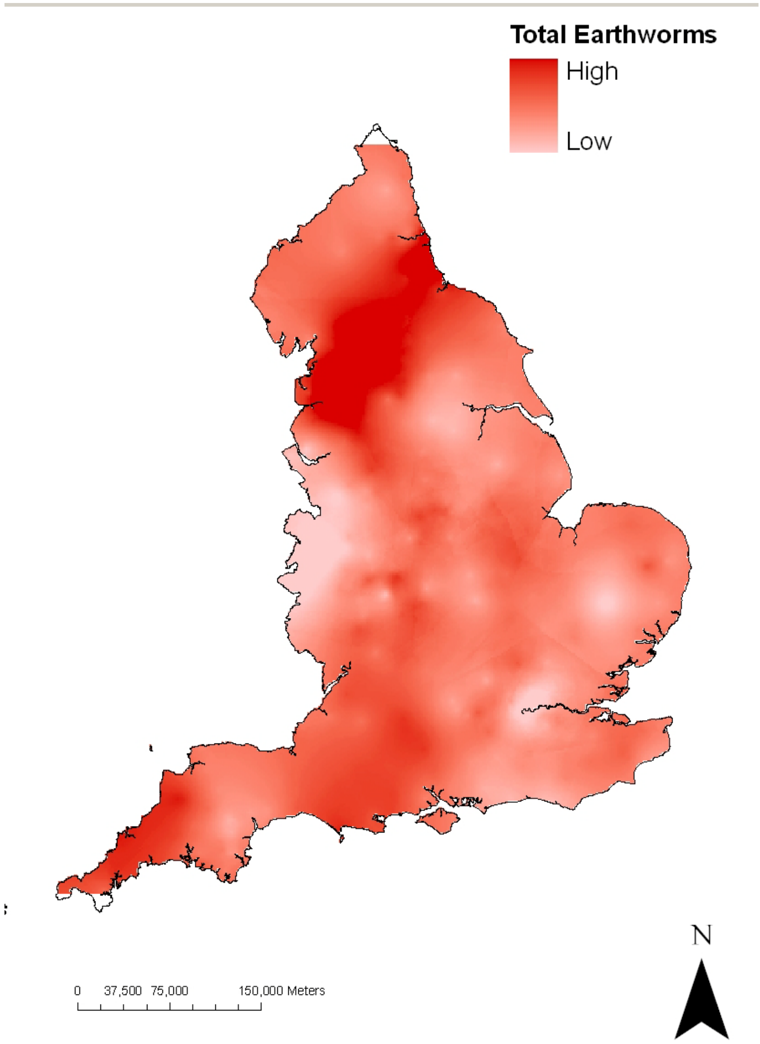


Figure 4.32 *Plot showing Kriging interpolation of total earthworm numbers.*

Earthworm species can be placed into ecological groups that describe how the earthworms live. Traditionally there have been three ecological groups:

- surface soil and litter '*Epigeic'* species (*Lumbricus rubellus, Dendrobaena octaedra, Lumbricus castaneus, Satchellius mammalis*),
- upper soil '*Endogeic'* species (*Allolobophora chlorotica, Octolasion cyaneum, Aporrectodea caliginosa, Aporrectodea rosea*) and
- deep-burrowing '*Anecic'* species (*Aporrectodea longa, Lumbricus terrestris*).

For this presentation of results another ecological group is included: the 'compost' earthworms, which contains two species *Eisenia fetida* and *Eisenia veneta*. It is predicted that there may be ecological group-specific responses and species-specific responses to environmental factors, giving rise to different spatial distributions (Figure 4.33). However, insufficient research has been published to date on earthworms to indicate clearly what these patterns will be. Therefore, it is not possible to assess to validity of the spatial patterns produced from the OPAL survey.

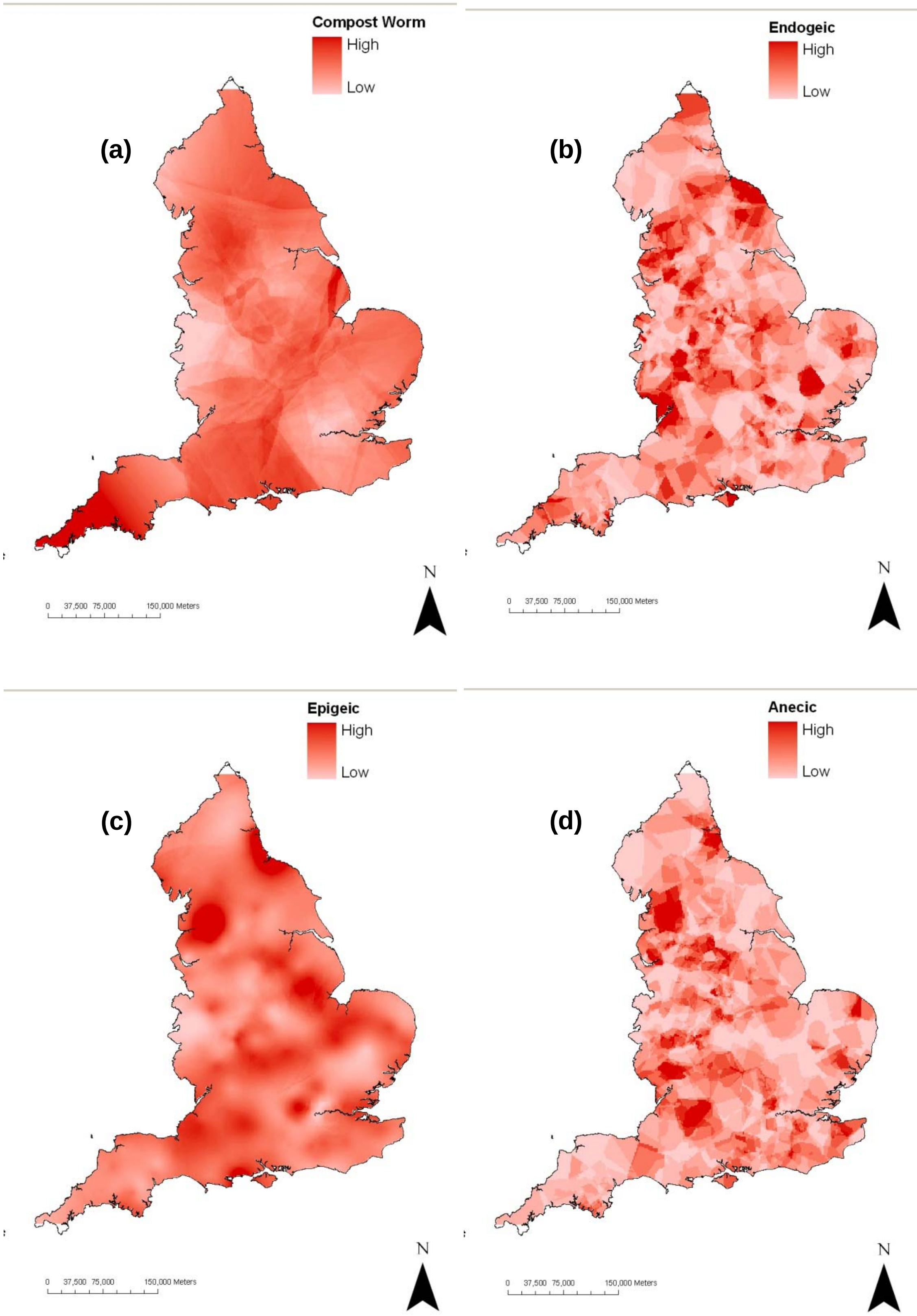


Figure 4.33 *Plots showing Kriging interpolation of (a) compost earthworms, (b) endogeic earthworms, (c) epigeic earthworms and (d) anecic earthworms.*

4.10 VALIDATION

The method that has been used in this report to display the results of the OPAL Soil and Earthworm Survey can also be used to display results from other sources. For a number of attributes, previously recorded data allows us to compare the results to the findings of the OPAL Soil and Earthworm Survey so far. The National Soil Resources Institute (NSRI) digital soils information was used to compile a topsoil pH map (Figure 4.34). As with the prediction plot from the OPAL Soil and Earthworm Survey data, the NSRI plot shows lower pH vales in the north west and south west of England and higher pH values in the east, south east and central England.

The clay content plot using the OPAL Soil and Earthworm Survey data predicts low clay content in the east of England and near the north Welsh border, as well as high clay content in central and south west England. The OPAL data predicts high clay content in the north of England that is not seen in the NSRI data (Figure 4.35). This may be due to a lower sampling density in this area.

The predicted sand content using OPAL Soil and Earthworm survey data identifies areas of high sand content in East Anglia, to the north of the Welsh border and northwest of England. This was also seen in plots produced using the NSRI data (Figure 4.36). The OPAL Soil and Earthworm Data plots predicted low levels of sand in the south east and central England which were also seen in the NSRI data. The OPAL plot did however predict high levels of sand in the south west which was not seen in the NSRI data.

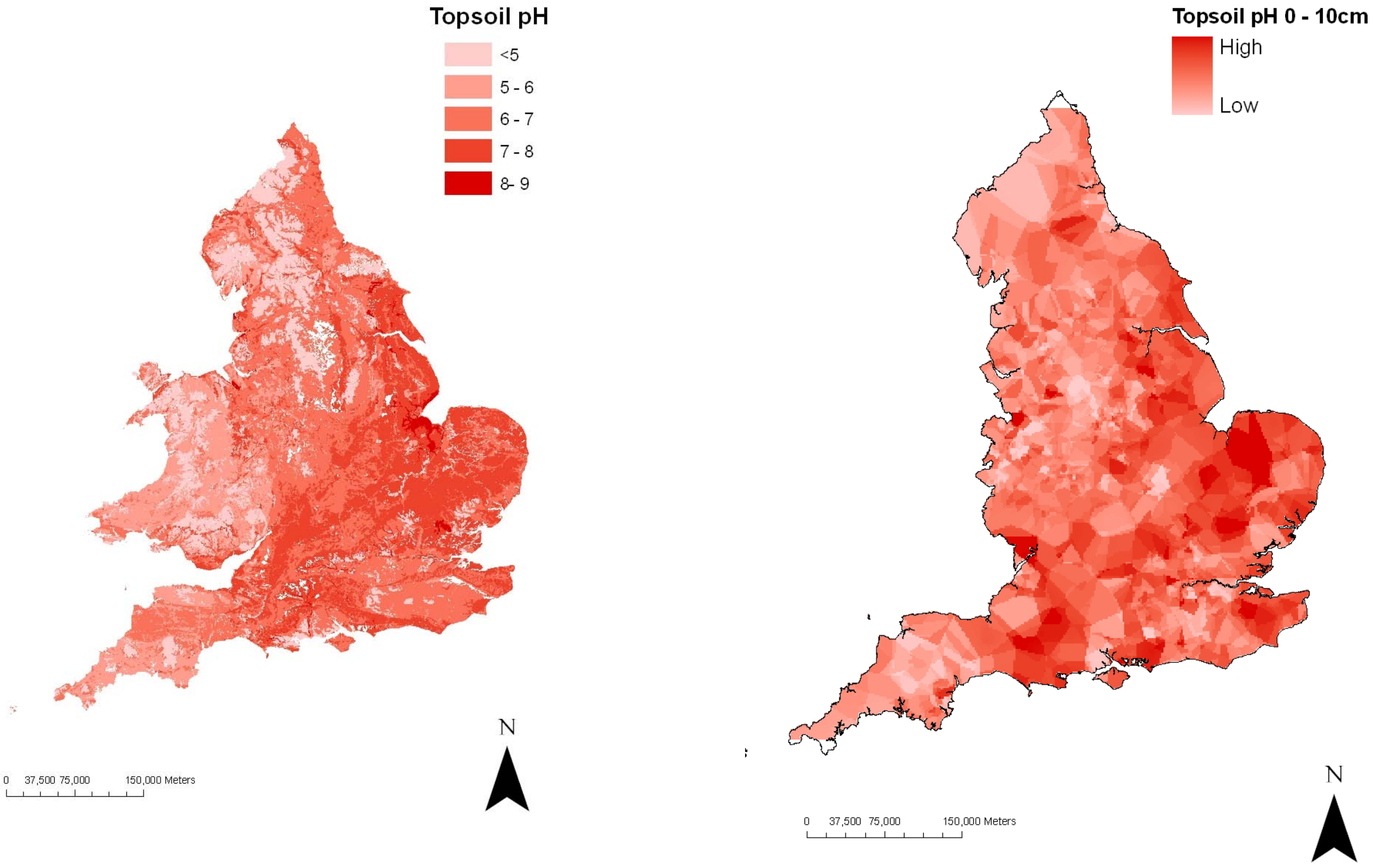


Figure 4.34 *pH plot produced using data from the National Soil Resources Institute (NSRI) left and predicted topsoil pH plot using OPAL Soil and Earthworm survey data, right.*

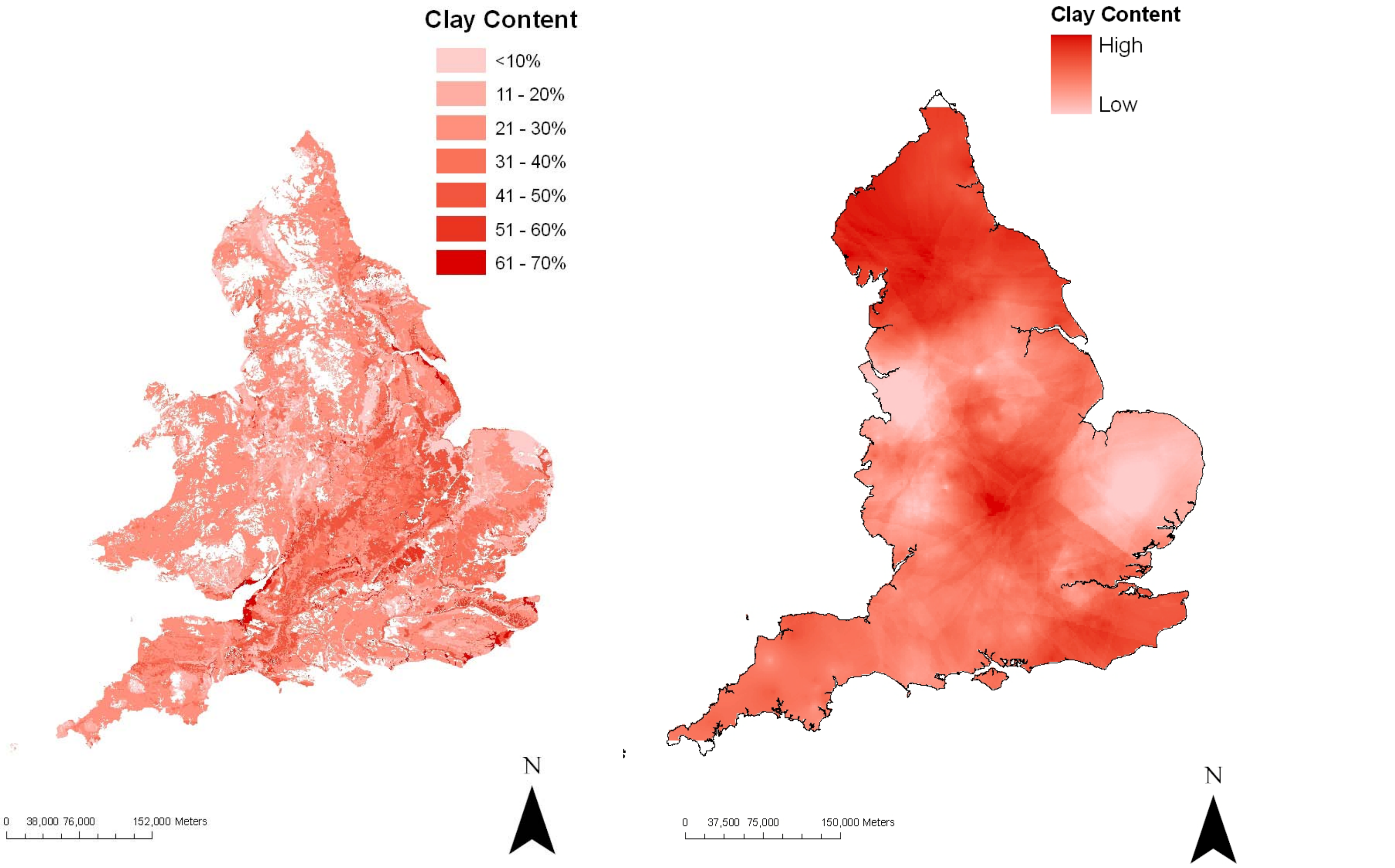


Figure 4.35 *Clay plot produced using data from National Soil Resources Institute (NSRI) left and predicted clay content plot using OPAL Soil and Earthworm survey data, right.*

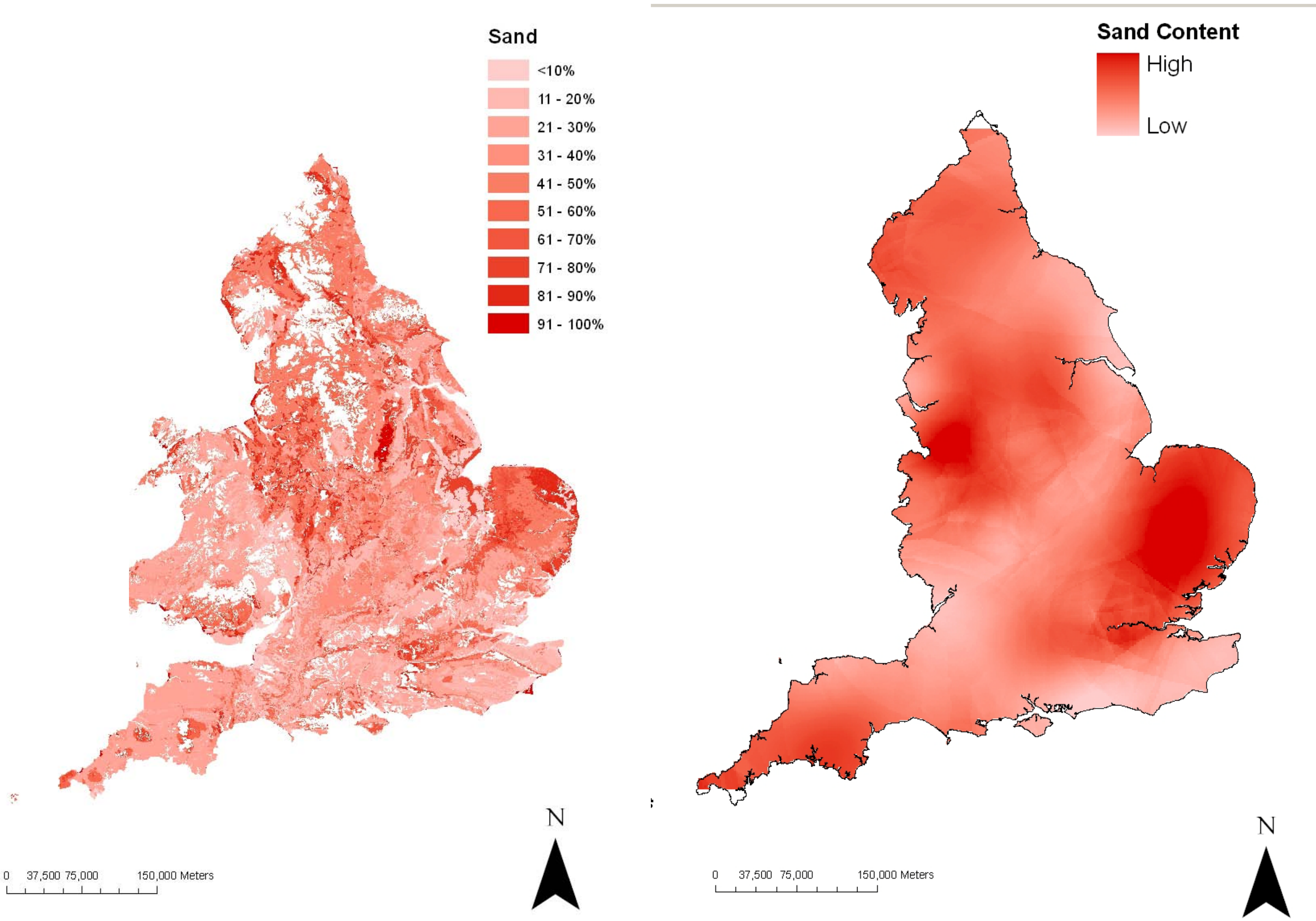


Figure 4.36 *Sand plot produced using data from National Soil Resources Institute (NSRI) left and predicted sand content plot using OPAL Soil and Earthworm survey data, right.*

4.11 INITIAL COMPARISONS

Initial visual comparison of a number of the results indicates that there may be relationships between them.

When you compare total earthworms with infiltration, there are some similar spatial patterns in the predicted values such as an apparent inverse relation in the south west and the east of England (Figure 4.37).

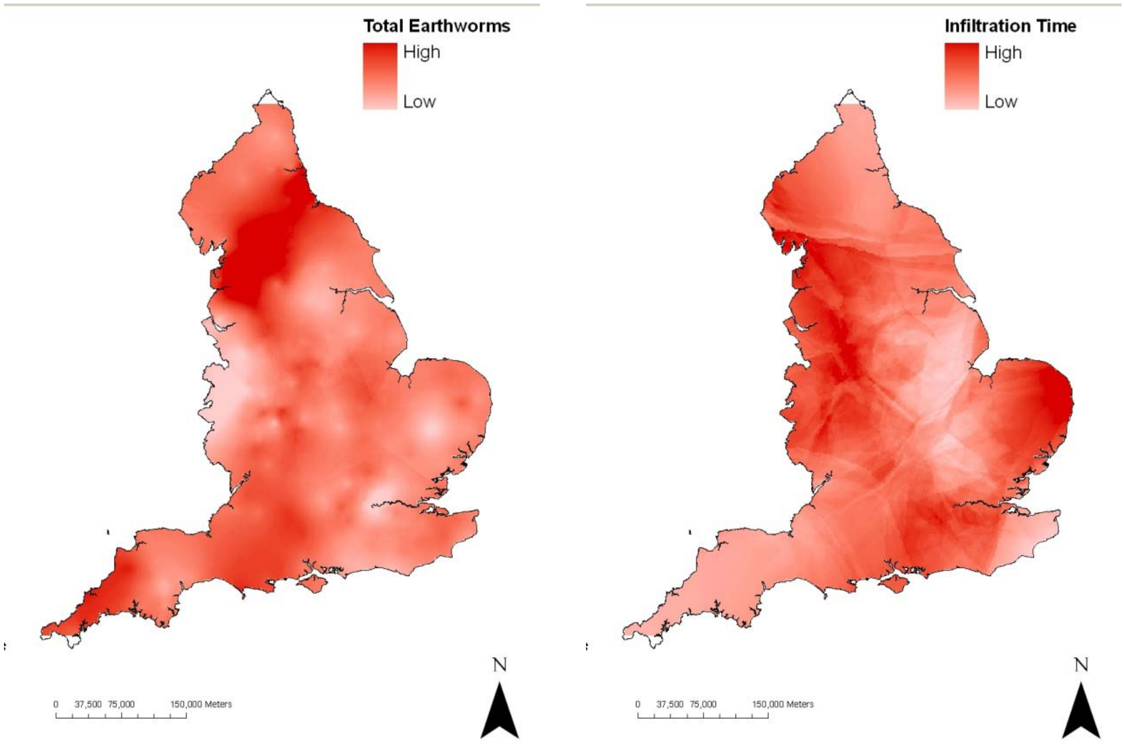


Figure 4.37 *Total Earthworm prediction plot and infiltration rate prediction plot produced using data from the OPAL Soil and Earthworm Survey.*

There is a general correspondence between high sand content (from NSRI) with high infiltration rates, especially in the east of England and the west Midlands (Figure 4.38).

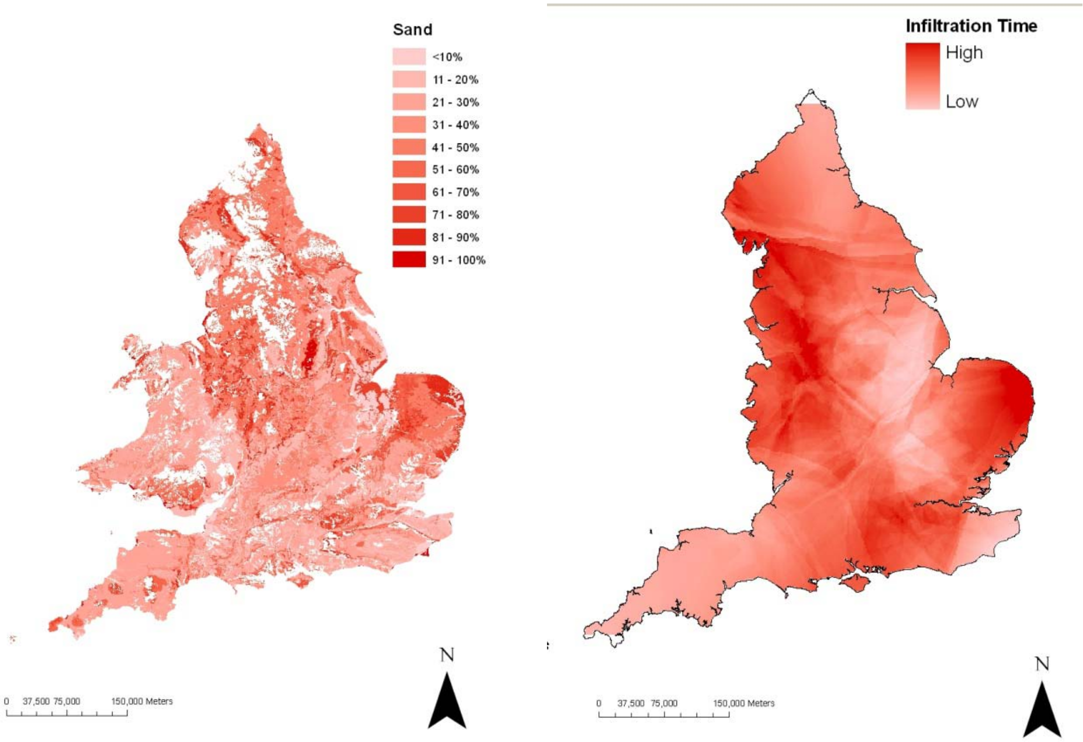


Figure 4.38 *Sand plot produced using data from National Soil Resources Institute (NSRI) left and infiltration prediction plot produced using data from the OPAL Soil and Earthworm Survey.*

This initial visual comparison of the data suggests that lower earthworm presence might occur in predominantly sandy soils. When the data is inspected numerically this is not found to be the case. This could indicate that useful data is being created but to reduce the patchiness of the predicted maps and to allow better comparison to existing data future work needs to be targeted to areas of highest and lowest predicted worm population and fieldwork should be more closely managed and supervised. Further work is explained in more detail in the following sections.

5 FURTHER ANALYSIS AND METHOD POTENTIAL

This report has presented some of the initial findings of analysis of data collected from the OPAL Soil and Earthworm Survey. The data collected will contribute to a large amount of further, more detailed analysis to be undertaken in the next phases.

Use of spatial prediction maps like those presented in this report will allow areas of further investigation to be identified. These areas will be investigated using multiple indicators collected in the survey as well as existing datasets.

Trends indicated using the data will be compared not just with like-for-like indicators, as presented here, but also to other related parameters from existing datasets. An example of this is presented below, where groundwater level data provided by the BGS[8] (Figure 5.1) has been plotted for the country. The potential of such data in combination with some other indicators used in our survey (i.e. particle size, compaction, moisture, and infiltration times) could provide a very useful tool in identifying areas prone to flooding.

[8] BGS. 2005. BGS Web Atlas. Available from http://www.bgs.ac.uk/britainbeneath/land_groundwater_level.html. Accessed 17th November 2009.

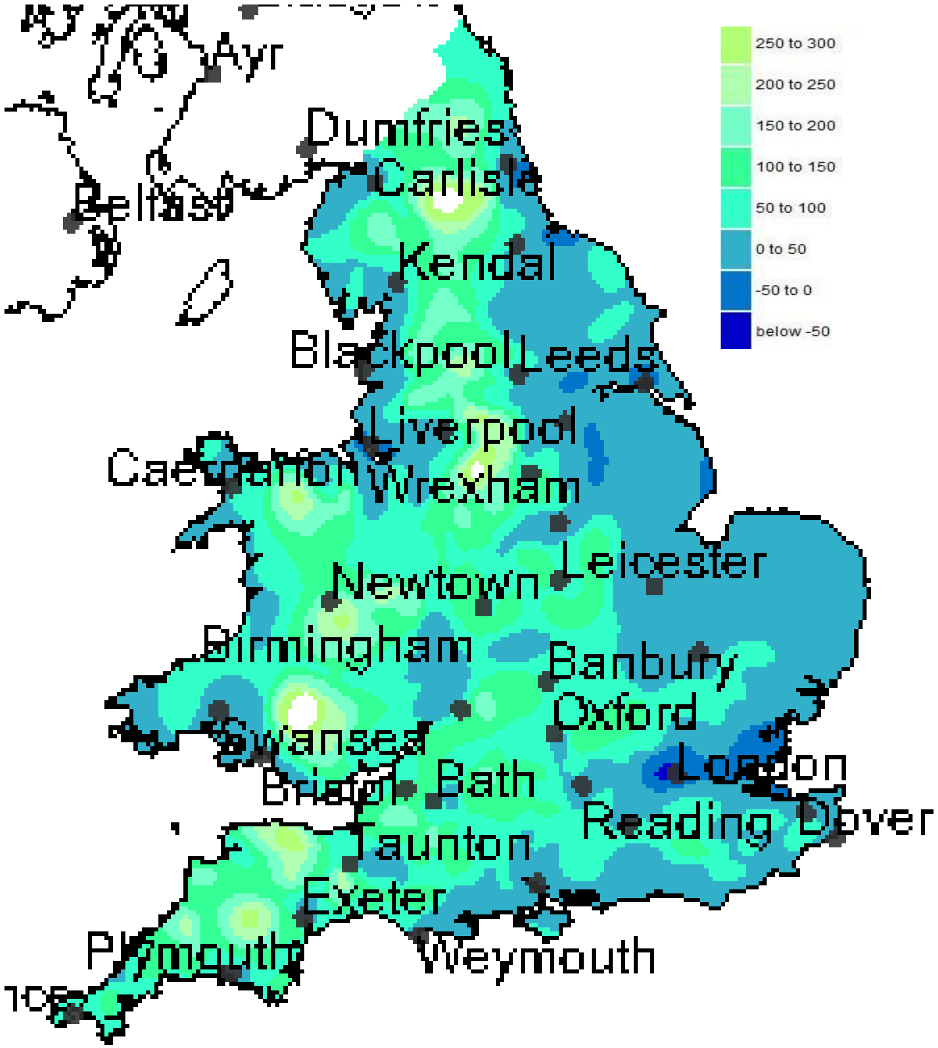


Figure 5.1 *UK Groundwater levels - British Geological Survey © NERC, 2005 (Scale = height of water table above sea level - metres).*

The factors influencing earthworm species and ecological group presence or absence will be investigated. Information on soil properties collected from the OPAL Soil and Earthworm Survey will inform an increased understanding about what influences earthworm distribution and the preferred conditions of different species and ecological groups. For example, the predicted number of soil objects appears to be higher in the north and east of England and London and lower in the west and southwest of England. This is similar to the pattern shown in the total earthworm numbers distribution map (Figure 4.32) and may require further investigation, as this could provide a good indication of human impact or even industrial activity (Figure 5.2).

The spatial analysis presented in this report is not the only way in which the data will be used. Although the data quality assessment (see section 4.6) demonstrated that comparing specific attributes on a point by point basis may not allow valid analysis, the integration of selected attributes per site could provide useful and valid information about the typology or even soil degradation at each site. Developing this methodology is the subject of the EPSRC funded PhD research, which is vital to the success of the next phases of our work. For that reason, one of the criteria to be used for selecting sites for future work, where extensive site specific research is planned, is the ability of the site to provide data on all parts of the survey.

In addition, our analysis has demonstrated that confidence in findings for areas with a low sample density is lower than for areas with a high sample density and good coverage. As more samples are submitted, the confidence in the trends occurring across the country is likely to improve. Taking into account that the extent to which identified trends agree between analysis using OPAL Soil and Earthworm Survey data and other data appears to improve with sample density and the minimum number of samples required for the Kriging method to work effectively, areas of low density will be further selected for future work. One of the aims of the OPAL Soil Centre's future work is to improve this coverage and therefore to build up a more accurate picture of the soil and earthworm environment across England.

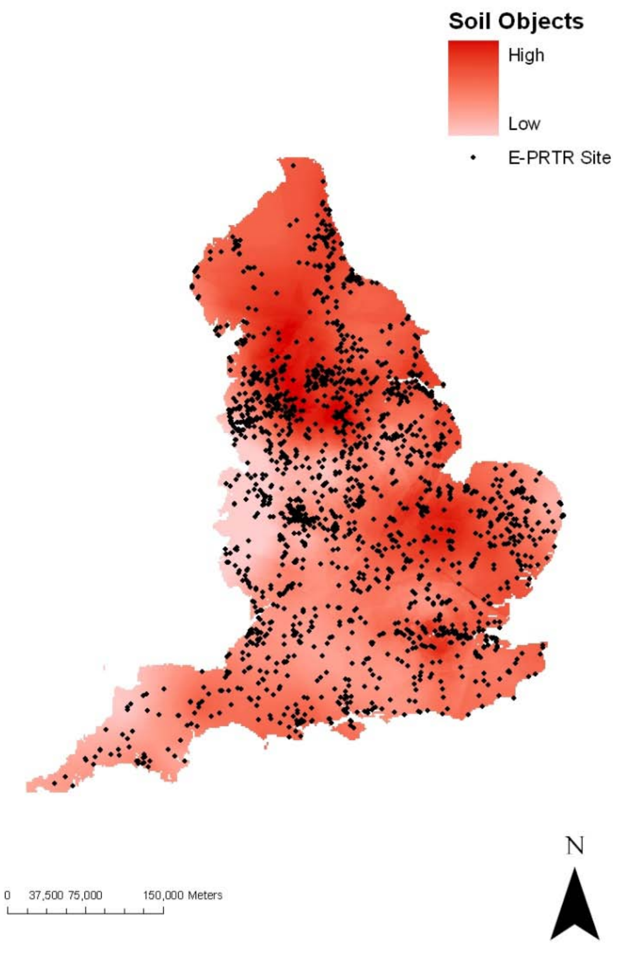


Figure 4.39 *Interpolation of number of objects found in the soil, with European Pollutant Release and Transfer Register (E-PRTR)sites 1*

[1] European Environment Agency (2009) European Pollutant Release and Transfer Register (E-PRTR) data base, Data Update: 09 Nov 2009. European Environment Agency, Denmark

6 NEXT STEPS (PHASES 2 AND 3)

Although distinct in their objectives, Phases 2 and 3 will overlap, with materials collected by soil centre scientists and community groups being used to analyse for heavy metals and organic contaminants. Details of this are as follows;

6.1 PHASE 2

For Phase 2, our intention is to utilise and further test hypotheses developed in Phase 1. Our focus will be on potentially toxic levels of metals in urban soils – utilising existing BGS data as a point of reference for comparing the results of new samples as they come in. This has the advantage of a fairly detailed reference data set that fits well with the urban focus of the survey to date and the laboratory costs for analysing heavy metals are relatively low. This phase, in accordance with Appendix A of the project document, will target areas throughout England, selected to cover the OPAL regional areas with activities targeted toward urban centres. We will also select areas where previous survey response rates have been comparatively low.

Research activities will be selected to test specific hypothesis that result from the findings of phase one of the research program. The survey will be directed toward more specialist groups to investigate hypotheses and to fill in gaps from Phase 1 activities. In addition to carrying out the survey, participants will be asked to collect a soil sample, which will be analysed for selected metals of potential environmental concern. Events will be organised in each of the nine regions in association with specialist and/or deprived groups. Schools, colleges and members of the public will undertake fieldwork directed by a member of the soils project team, and each group will submit information on soil properties for a number of designated sites. The sites will be selected in relation to their accessibility and proximity to local communities targeting areas of greatest deprivation wherever possible.

This phase will not be confined to selected plots throughout England, which were originally selected through the Countryside Survey, because of significant problems with access to those sites. As a result the additional cost for 500 samples collected by communities has been covered by restructuring of the budget. In terms of expected milestones and beneficiaries, Table 6.1 below summarises how milestones for Phases 2 and 3 will be used to achieve project targets.

Table 6.1 *Existing milestones and additional tasks for Phases 2 and 3.*

	Year	Project Quarter	Month		Original Project Milestone Dates Revised Project Milestone Dates	Status (e = expected)
Y3	Dec-09	Y3Q1	1	M1	Launch of Countryside Survey (CS) phase	
	Jan-10	Y3Q1	2		Launch of Phases 2 and 3	e
	Feb-10	Y3Q1	3			
	Mar-10	Y3Q2	4			
	Apr-10	Y3Q2	5			
	May-10	Y3Q2	6	M2	Completion of data collection for CS phase	
	Jun-10	Y3Q3	7		Completion of data collection	e
	Jul-10	Y3Q3	8			
	Aug-10	Y3Q3	9	M3	Results of CS phase published	
	Sep-10	Y3Q4	10		Launch of data processing and preliminary results published	e
	Oct-10	Y3Q4	11			
	Nov-10	Y3Q4	12			
Y4	Dec-10	Y4Q1	1	M1	Launch of long-term sludge experiments sites survey	
	Jan-11	Y4Q1	2		Preliminary findings published	e
	Feb-11	Y4Q1	3			
	Mar-11	Y4Q2	4			
	Apr-11	Y4Q2	5			
	May-11	Y4Q2	6	M2	Completion of data collection for CS phase	
	Jun-11	Y4Q3	7			
	Jul-11	Y4Q3	8			
	Aug-11	Y4Q3	9	M3	Results of long-term sludge experiments sites survey	
	Sep-11	Y4Q4	10			
	Oct-11	Y4Q4	11			
	Nov-11	Y4Q4	12		EA and BGS data collection and processing	e
Y5	Dec-11	Y5Q1	1		PhD Completion	e
	Jan-12	Y5Q1	2	M1	Completion of integration of previous work for further communication	
					Results of Phase 3 published	e
	Feb-12	Y5Q1	3			
	Mar-12	Y5Q2	4			
	Apr-12	Y5Q2	5			
	May-12	Y5Q2	6	M2	Delivery of Urban Strategy for the EA.	
					Integration of all phases for further communication	e
	Jun-12	Y5Q3	7			
	Jul-12	Y5Q3	8			
	Aug-12	Y5Q3	9		Policy implications of findings	e
	Sep-12	Y5Q4	10			
	Oct-12	Y5Q4	11			
	Nov-12	Y5Q4	12	M3	Contribute to the state of the environment report	

6.2 PHASE 3

In Phase 3, we aim to investigate how common organic pollutants affect soil condition and biodiversity in soils. Research will be directed toward sites of particular interest, selected in collaboration with the Environment Agency and the British Geological Survey. More detailed analytical methods will be used in this research stage to measure soil properties and soil samples will be analysed for specific organic contaminants. The results will have a practical application in directing future land management and determining the effects of chemical and biological contamination of soils. Public participation in practical aspects of this part of the research schedule will be limited due to access issues, sampling locations and due to the need to closely manage detailed sampling procedures in order to obtain representative samples for laboratory analysis. Engagement will be through dissemination of activities and results at national and regional levels. Policy implications of research will be explored throughout the program drawing upon experienced staff of the Centre for Environmental Policy.

The main objective for Phase 3 will be to investigate the pollution of sites with a history of use for disposal of wastes such as sewage sludge, MBT[1] outputs, dredged sediments etc. We will be able to use data from sites that have been studied historically to provide reference data for the results of Phase 3 investigations. The EA's Long Term Sludge Experiments Sites (including 500 sites with both chemical and biological (effects) data) will provide us with a number of hypotheses to test, focusing now on organic contaminants. This phase will focus on organics such as Pesticides and PAHs but sampling will not involve the public to make access to the selected sites less problematic and to ensure that samples are collected following appropriate protocols. However, an element of training will be offered to a few selected communities in order to continue with the other objective of demonstrating how community science can be useful and valid. This will be finalised in consultation with the Environment Agency at the end of Phase 2. In addition to the 'long sludge' experiment sites, we have secured access to soil plots around East Anglia where sediments from the Norfolk Broads have been deposited. The Broads Authority and the regional Environment Agency are supporting us to understand soil pollution from such sources and at a catchment level for that area.

In addition through a second PhD, also funded by EPSRC, we have been studying various disposal and treatment options for Biodegradable Municipal Waste (BMW) and have been reviewing options for treatment and disposal focusing on MBT outputs. As one of the options for the disposal/reuse of such outputs is through application to land as soil conditioner/restoration material, some of our planned work in Phase 3 involves fieldwork at selected sites where this happens and some experiments simulating such conditions. Current research work on MBT outputs supervised by Dr Voulvoulis and Professor Gronow will facilitate this phase.

6.3 SOIL CENTRE ACTIVITIES FOR PHASES 2 AND 3

The Soil Centre will therefore coordinate a range of activities in Phases 2 and 3, facilitated by the production of an additional number of survey field packs in Y3Q1 (5,000 in total expecting about 500 to be returned for analysis, based on our experience with the survey to date). Areas for investigation will be targeted by a process that includes identification of areas of low survey density, as shown previously in Figure 4.5, hard to reach/deprived areas not previously covered and hot/cold spots as identified by analysis of the survey data from Phase 1. A simple plot of areas of low survey density is shown in Figure 6.1 below.

At least one representative of the Soil Centre will attend each event and guide participants through the survey and lead in sampling of the soil for detailed laboratory analysis. This work will also be guided through discussion with our project partners (EA, NHM, BGS) and the Centre's steering group. In this way we will achieve a much better distribution of areas covered by the survey, generate a large new group of beneficiaries and produce more data of a much higher quality and accuracy.

---

[1] MBT (Mechanical and Biological Treatments) refer to the process of mechanically separating the recyclable materials, biodegradable and non-biodegradable waste and then treating the biodegradable fraction to initiate stabilisation, either through composting or anaerobic digestion.

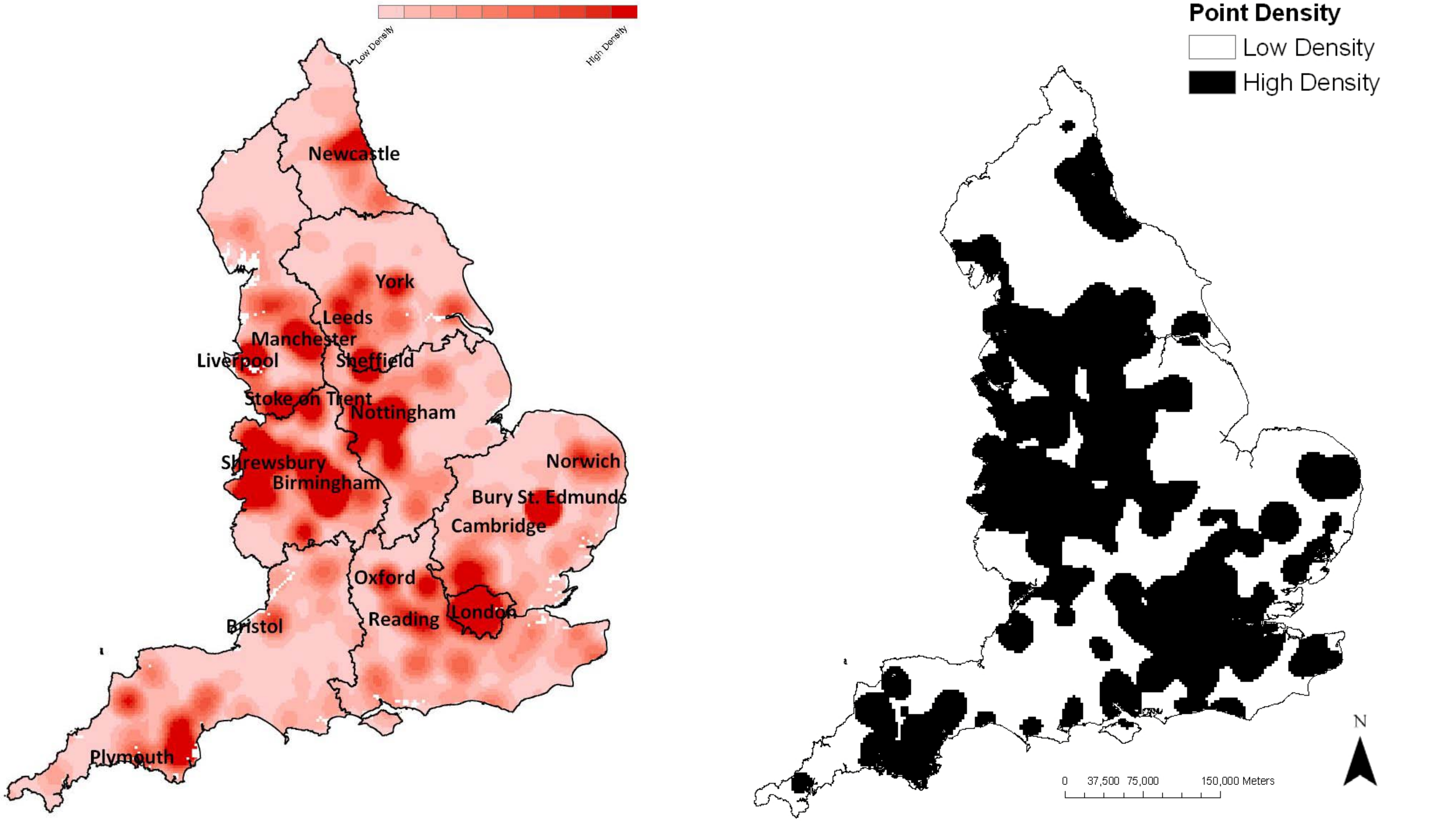


Figure 4.40 *Density of samples received, left, showing clustering around urban centres. Plot highlighting areas of low sample density areas only- right (white regions).*

7 BENEFICIARIES

To date, beneficiaries for the soils centre alone currently stand at over 8,166 community beneficiaries and 1,960 web-based beneficiaries; a total of 10,126 overall. The breakdown is as follows

300	students
160	school children
300	field guide tests during field pack development stage
1,037	direct email enquiries/packs to the Soils Centre
579	regional training events
2,806	packs distributed from soil centre – 40,000 in total
1,960	hits on OPAL and IC websites during launch week
2,984	field pack and 2,755 workbook downloads from OPAL website

As at the end of October 2009, 3,172 survey records have been uploaded to the OPAL survey website, with others coming in on a daily basis.

8 CONCLUSIONS

The OPAL Soil and Earthworm National Survey was launched in spring 2009, as the first of the five national surveys to 'go live' under the OPAL portfolio of projects. The survey was completed by members of the general public who were asked to submit information/observations on;

- identification of the surveyed location (for geo-referencing)
- descriptions of environmental conditions encountered at the time of the survey
- an assessment of basic soil properties
- earthworm species identification
- a count of earthworm numbers and
- a count of the numbers of other macro-organisms

Participants were also asked to indicate the importance they placed on environmental science both prior to and after the completion of the survey.

The survey aimed to achieve both scientific and social beneficial outcomes with many aspects aimed at stimulating involvement of the general public in environmental science for educational purposes, through providing an introduction to the process of observing, measuring and interpreting environmental variables. The main objective therefore, was to develop a method to identify areas of soil degradation through analysis of data on soil conditions and earthworms, as collected by people of all ages and ability.

This report has presented, results from the first 3134 records received from the survey and takes into account the findings of a detailed quality assessment of the data performed during Phase 1. While records will be accepted for the foreseeable future, the rate of receiving records was greatest while the survey was being supported by OPAL's network of community scientists during its 'live' period in spring 2009. The distribution of records per OPAL region ranges from 109 to 532 records and is greatest in the West Midlands. Participation figures show that the majority of responses were from school groups, at 56% of responses.

Site setting and land use data backup the high incidence of data from school groups, with most records from suburban areas and a high number of records from playing fields and gardens. These land uses can have potentially highly variable properties and existing datasets have had little access to collect data about soil properties and earthworm communities in these areas. Analysis of the density of samples, before spatial analysis took place, allowed confidence in the spatial prediction plots to be evaluated, with confidence in results higher where there is a good spatial coverage. The results density plot clearly shows clustering of points around urban centres; this is positive as higher density sampling is required in these heterogeneous environments. Existing programmes aimed at monitoring soil in urban areas have not sampled in as much detail and therefore the data collected from the OPAL Soil and Earthworm Survey can allow us to learn more about these areas.

Use of interpolation allowed predictions to be made about likely indicator results at points across the country by taking into account 'nearest neighbours'. Plotting the results geographically allows spatial trends to be seen in the data. For a number of indicators such as pH, infiltration, sand and clay content, soil objects, soil moisture, root presence, total earthworms and compost and epigeic ecological groups clear trends were visible in the data. For other indicators, such as the ecological groups- endogeic and anecic, however the trend was not so clear. A similar method to identify trends, as used with the survey data, was used on existing datasets for a selection of indicators. For the soil property indicators of topsoil pH, sand content and clay content, the National Soil Resources Inventory (NSRI) data was used to compare findings. There is agreement between findings from analysis of our survey data and information derived from the NSRI dataset.

Through our plans for Phases 2 and 3, our project will continue to provide opportunities for developing in-depth knowledge of soil chemistry and biology and communicating this knowledge at the societal level through engagement with local community groups and publication of results in scientific journals.

9 ***APPENDIX 1:*** FIELD GUIDE AND WORKBOOK

The OPAL **Soil** and **Earthworm Survey**

Imperial College London

Introduction

Soil is one of the world's most precious natural resources. It is made up of water, air, minerals and organic matter, and is vital for plant survival and crop production. Soil also provides a home for a vast array of animals including earthworms, stores and filters water and provides a foundation for buildings, and therefore is important in many ways.

This fold-out guide is designed to take you through the process described below, and will refer you to the accompanying workbook for further guidance or to record data. Before you start the survey read pages 2-3 of the accompanying workbook. The survey starts by selecting your location, and recording some site characteristics (Section A). You are then asked to dig a soil 'pit', and collect and separate immature and adult earthworms into groups (Section B). The next step focuses on soil properties (Section C). Following this, all adult earthworms from the soil and the pit can be studied (Section D). If you still have more time available, search for earthworms elsewhere or report any other organisms you encounter in your pit (Section E). Submit all data to the OPAL website (Section F).

The survey should preferably be performed in pairs. You are provided with enough material to sample 2 locations. You can photocopy pages 6 and 7 of the workbook for data from the second location. Try to locate your second pit in an area close by, but which looks different from the first.

The survey starts here

A Site characteristics

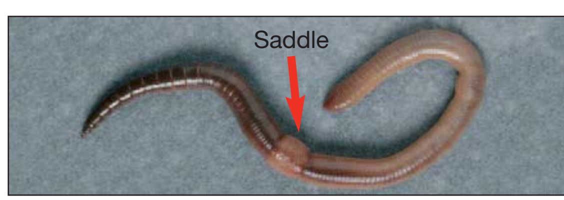
Choose a location to carry out your survey. Select a position to dig your soil pit. Now go to the workbook and record the pit's location, site characteristics and other information on page 6.

B Dig the soil pit

If you find glass, metal or other sharp objects, stop immediately and dig another pit elsewhere

Measure a 20cm x 20cm square and dig the soil pit to a depth of 10cm. For details on how to do this refer to page 4 of the workbook. Place the removed soil on a plastic bin bag and put any earthworms in a container.

Look at each earthworm and see if it has a well-developed saddle. Sort all earthworms found in the removed soil into 2 groups, those with saddles (adults) and those without saddles (immatures), and count the numbers in each group. Now go to page 7 of the workbook and record these numbers in Questions B1 and B2. Please rinse all earthworms with water, and return the immatures to the soil (not the pit).



If you have a camera, when you see this symbol take a photo to upload to the website

To extract the deep burrowing earthworms, mix one of the mustard sachets provided into 750ml of water and pour into the pit (this is not toxic to the earthworms). Time how long it takes until the water has drained away (up to 3 minutes). Now go to page 7 of the workbook to record this (Question B3). Collect any earthworms that emerge. Sort, count and rinse them as previously. Now go to page 7 of the workbook to record this (Questions B4 and B5).

(C) Soil properties

Test the properties of the soil (Questions **7**-**15**, record on page 7 of the workbook).

7 How many plant roots are there in the soil that you have removed?

(a) No roots (b) A few roots (c) Lots of roots

8 Can you see any objects in the soil that do not look like they should naturally be there?
Remember to take care when handling the soil.

- (a) Construction material e.g. brick, concrete, cement, mortar
- (b) Metal e.g. wire, sheeting, tin
- (c) Glass e.g. broken bottles, other glass
- (d) Cut wood
- (e) Other
- (f) None

9 Push the pointed end of a pencil or pen into the soil surface. How hard was it to push it into the soil?

(a) Easy (b) Difficult (c) Very difficult

10 Take a small amount of soil from the pit about the size of a 2p piece and put it on something waterproof. Open the sachet of vinegar and pour a few drops onto the soil.

If the soil fizzes it means it contains a mineral salt called calcium carbonate $CaCO_3$.

Does the soil fizz? Record 'yes' or 'no' in the workbook.

11 Take a handful of soil in the palm of your hand and squeeze it. How moist is the soil?

(a) Dry – no water (loose soil does not stick together when squeezed)

(b) Moist – no visible water (water does not drip out of the soil when squeezed)

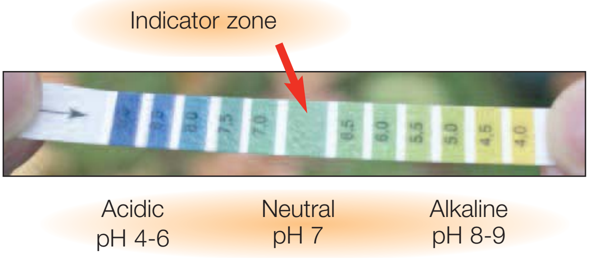
(c) Wet – water visible (water runs/drips out of the soil when squeezed)

12 Find out the soil's pH. Place 1cm of the removed soil into a container. Add enough water to cover the soil and stir the mixture for about a minute.

Holding the pH test strip by the arrow, completely immerse the strip in the soil solution for roughly three seconds.

Remove and quickly rinse with fresh water from the same bottle.

Hold the strip up to the light and compare the indicator zone (unprinted area) to the colour scale. Read off the printed pH value and record it.



13 Follow the **Key to soil texture** (see right) to find the texture of the soil.

Record the soil type in the workbook.

FSC

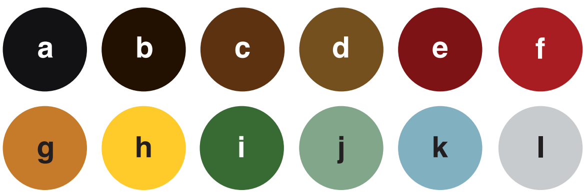
14 Smell the soil ribbon, does the soil have:

a A sour, putrid or chemical smell?

b No smell?

c An earthy, sweet, fresh smell?

15 What colour is the soil ribbon? Choose the nearest colour match.



D Earthworms

Using the earthworm record sheet provided on page 7 of the workbook, record the length (using the ruler provided on the guide) and colour of each adult earthworm. Using the key overleaf, and with the help of the magnifier provided in the pack, identify and record the species of each adult earthworm found.

E Additional search

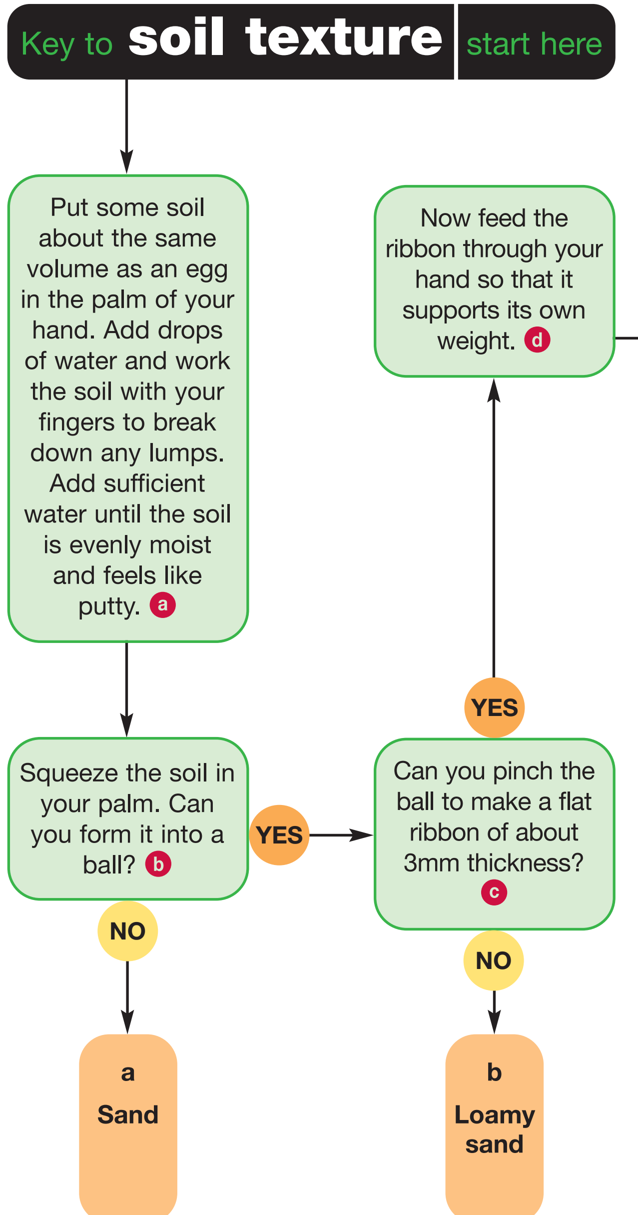
If there are no earthworms in your pit and you still have more time available record the other organisms in the pit (page 8 of the workbook). Then search for earthworms in habitats within 5 metres of your pit as described on page 4 of the workbook. Follow the process outlined in Section D for any earthworms found.

When you have finished return the soil to the pit, replace any turf carefully and leave the area tidy. Take any litter away with you.

F Data submission

Upload your results and images to the OPAL website:

www.OPALexplorenature.org



Safe fieldwork

We don't advise you to work on your own. Make sure that you know what to do in an emergency. Take a responsible friend who can help if things go wrong. Ensure that you have permission from the landowner to dig holes on their land. Wear plastic gloves and wash your hands before eating. Cover any open wounds before starting the activity.

Designed by FSC Publications
www.field-studies-council.org

a

b

c

d

Is the soil 'ribbon' less than 2.5cm long before it breaks? — **NO** → Is the soil 'ribbon' between 2.5cm and 5cm long before it breaks? — **NO** → Is the soil 'ribbon' longer than 5cm before it breaks?

Less than 2.5cm — YES

Take a pinch of soil and add water to make it very wet. Rub it between your fingers. How gritty does the soil feel?

- Very gritty → **c Sandy loam**
- In between → **d Silty loam**
- Very smooth → **e Loam**

Between 2.5cm and 5cm — YES

Take a pinch of soil and add water to make it very wet. Rub it between your fingers. How gritty does the soil feel?

- Very gritty → **f Sandy clay loam**
- In between → **g Silty clay loam**
- Very smooth → **h Clay loam**

Longer than 5cm — YES

Take a pinch of soil and add water to make it very wet. Rub it between your fingers. How gritty does the soil feel?

- Very gritty → **i Sandy clay**
- In between → **j Silty clay**
- Very smooth → **k Clay**

OPAL EXPLORE NATURE

Open Air Laboratories (OPAL) is a new partnership initiative which is encouraging people to spend more time outside understanding the world around them. OPAL wants to get everybody involved in exploring, studying but most of all enjoying their local environment. OPAL will be running a programme of events and activities until the end of 2012. To find out more about events in your region please visit the website: **www.OPALexplorenature.org**

Supported by The National Lottery® through the Big Lottery Fund

BIG LOTTERY FUND

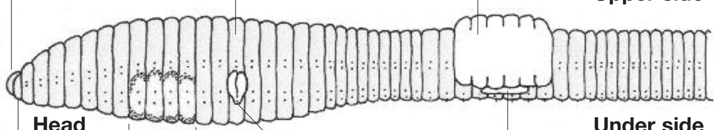
Photographs by: Martin Head[1], Simon Norman[4], Louise Parker[4]. Text by: Martin Head[1], Nick Voulvoulis[1], James Bone[1], Laura Edwards[1], Elizabeth Stevens[1], Declan Barraclough[3], Tatiana Boucard[3], David Jones[2], Paul Eggleton[2], Stephen Brooks[2], Simon Norman[4], Louise Parker[4], Rebecca Farley[4], Mark Dowding[4], Linda Davies[1], Carolina Bachariou[1]. [1] Imperial College London. [2] Natural History Museum. [3] Environment Agency. [4] Field Studies Council.

Key to common British earthworms

EXPLORE NATURE

By David T. Jones and Chris N. Lowe

These are the earthworm features used in this key



Start here

Is it more than 2cm long, **AND** does it have a clearly developed saddle?

The saddle is usually a different colour to the rest of the body, and slightly wider

NO → It is not a mature earthworm – you can't identify it with this guide. At least 50% of the earthworms you find will be immature

YES → Is the whole body clearly stripy on its upper surface when moving?

It has dark red bands, with a narrower pale pink or yellowish band in between

NO → Is it greenish (dark green, yellowish green or muddy green)? **NO** →

YES ↓

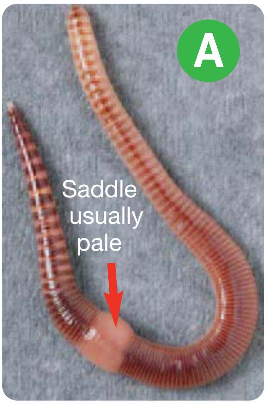
3. Green worm green form *Allolobophora chlorotica*

Hints
Often curls up in the hand
Yellow ring on body
Has 3 pairs of sucker-like discs (see 13)
Can exude a yellow fluid when handled

YES ↓

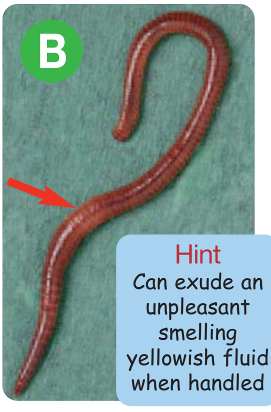
Stripy earthworms

Which description best matches your worm? Is the body: Ⓐ Longer and wider or Ⓑ Shorter and narrower?



1. Compost worm *Eisenia veneta*

Saddle usually similar colour to the rest of the body



Hint
Can exude an unpleasant smelling yellowish fluid when handled

2. Brandling worm *Eisenia fetida*

Hint Line drawings show the typical sizes of the adult earthworms

FSC

Is the body from the first segment to the saddle partly or entirely pale in colour (whitish, pink or grey)? It may have some reddish or dark segments

YES → **Pale earthworms**

NO – Return to start

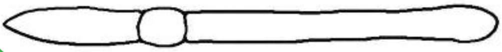
NO ↑

Is the upper surface of the body, from the first segment to the saddle, entirely dark in colour (dark red, purplish red or chestnut brown)?

YES → **Red earthworms**

Is the earthworm longer than 8cm when **NOT** moving?

NO ↑



Hint
Sometimes slightly flattens its tail into a paddle shape

YES →

Are the male pores visible?

NO ↑

YES ↓

Hint
Often a dark purplish head, the rear end of the body is often much paler

5. **Black-headed worm** *Aporrectodea longa*

Which description best matches your worm? Is the body:
A Long and relatively thin or B Long and relatively fat?

Hint
A stout worm, often as thick as a pencil

6. **Lob worm** *Lumbricus terrestris*

OPAL

FSC

Are the male pores visible?

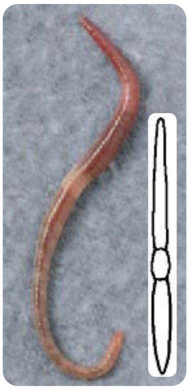
Not visible

Visible

YES →

Is the swelling around the male pore covering only one segment?

YES →

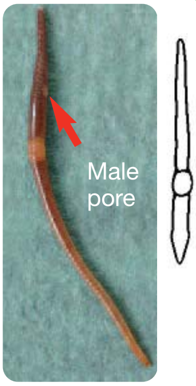


7. Octagonal-tailed worm *Dendrobaena octaedra*

NO ↓

Is the swelling around the male pores broad, covering the entire width of adjacent segments?

YES →



9. Little tree worm *Satchellius mammalis*

NO ↓

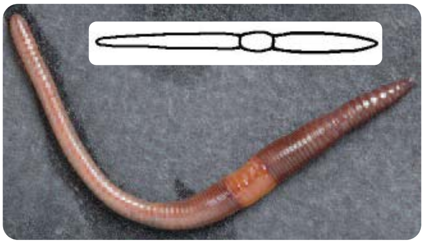
You have probably found a rare worm which is not in this key. Record it as unidentified

NO (Are the male pores visible?) ↓

NO

Is a raised whitish gland visible on the underside between the saddle and head?

YES →



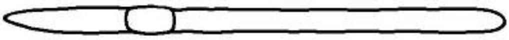
8. Chestnut worm *Lumbricus castaneus*

Hints

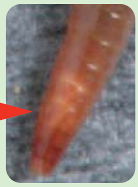
The front end up to the saddle is usually in three distinct shades: pink or pale grey, then whitish, and then darker grey

The saddle pads usually form a two-humped ridge across three segments, but these can be difficult to see

11. Grey worm *Aporrectodea caliginosa*



Are the last four or five segments distinctly yellow?



YES → 12. Blue-grey worm

NO ↓

Does it have a yellow ring towards the head?

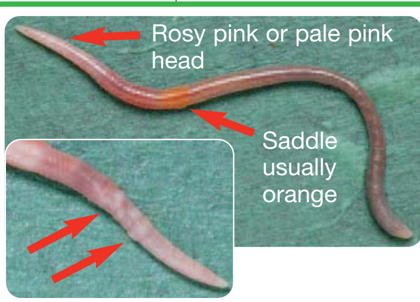
YES → 13. Green worm

NO ↓

Does the worm have this colour combination?

YES

NO ↓



10. Rosy-tipped worm *Aporrectodea rosea*

Hints

The head is usually rosy pink or pale pink up to the male pores

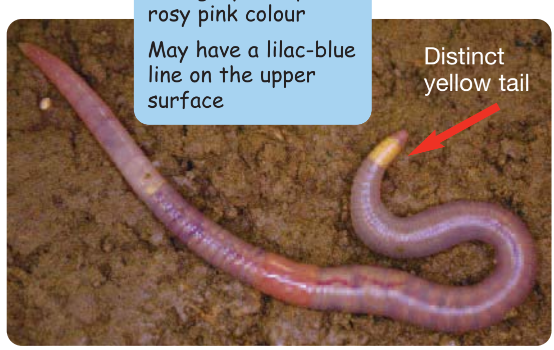
Often has 2 or more whitish raised pads before the male pores. The saddle is usually orange, and can be wider towards the rear end

Hints

Distinct yellow tail

Can vary from faint blue-grey to a pale rosy pink colour

May have a lilac-blue line on the upper surface



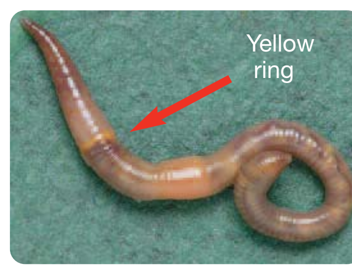
12. Blue-grey worm *Octolasion cyaneum*

Hints

Has 3 pairs of sucker-like discs on the underside of alternate segments of the saddle, **not always easy to see**. The yellow ring can be faint

Often curls up in the hand

Can exude a yellow fluid when handled



13. Green worm
pale form
Allolobophora chlorotica

Photographs by: Harry Taylor[2] and Chris N. Lowe[5]. Illustrations by: David T. Jones[1,2]. Text by: David T. Jones[1,2], Chris N. Lowe[5], Harry Taylor[2], Paul Eggleston[2], Stephen Brooks[2], Emma Sherlock[2], Simon Norman[4], Louise Parker[4], Rebecca Farley[4], James Bone[1], Martin Head[1], Nick Voulvoulis[1], Linda Davies[1], Carolina Bachariou[1]. [1] Imperial College London. [2] Natural History Museum. [3] Environment Agency. [4] Field Studies Council. [5] University of Central Lancashire. Supported by the Esmee Fairburn Foundation.

OPAL **Soil** and **Earthworm** Survey

Workbook to accompany fold-out field guide

OPAL EXPLORE NATURE

OPAL (Open Air Laboratories) is an exciting new initiative which has received a grant from The Big Lottery Fund. It is encouraging people to get in touch with nature by enabling them to explore and study their local environments. Through partnerships nation-wide, OPAL is running fun, free projects which anyone can get involved with.

From playing fields and window boxes to backyards or beaches, all spaces are different and all are important. The five year programme will bring scientists and the public closer together, allowing environmental issues to be explored which have both local and global relevance. OPAL aims to inspire a new generation of nature-lovers by encouraging people to spend more time outdoors understanding the world around them.


Alan Scragg

"You may seen me before, but do you know much about me? Thousands of us live beneath your feet but you don't even notice us. I don't mean to brag, but in soil world we are classed as superheroes! Take a closer look..."

A day in the life of an earthworm

I eat on the move, churning dead plant material, and leave worm casts behind that help to fertilise the soil. I help to keep the soil healthy by breaking things down and recycling plant nutrients. I burrow into the soil which improves its structure and adds air to the soil. The burrows also help water to run through the soil improving the drainage. Plenty of nutrients, air and water in the soil mean that plants grow well which is good news for you because plants provide most of your food.

If you have a camera, when you see this symbol take a photo to upload to the website

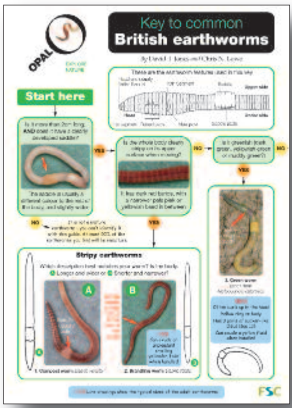
The survey

This survey aims to find out more about soil and earthworms across England. The results will help scientists to see whether each species is found in a particular habitat or soil type.

There are 26 different species of earthworms in Britain. Some are common and found in lots of places whilst others are rare. Earthworms are sensitive to many environmental factors, and these will influence where they live. If you find lots of earthworms in your soil it can be a sign of good soil quality.

Survey steps

- **A** Choose your location and record the site characteristics.
- **B** Measure a 20cm x 20cm square, dig the soil pit and search for earthworms.
- **C** Test the properties of the soil.
- **D** Identify the earthworms.
- **E** Search for more.
- **D** Enter all your results on the OPAL website **www.OPALexplorenature.org**



Hints for using the key

- 12 of the most common earthworm species in England are illustrated in the key
- This key should identify about 90% of adult specimens
- Immature worms cannot be identified but you should still record the total number found in the topsoil and in the pit using the mustard water
- Use your magnifier to help see key earthworm features (this will help you with species identification)
- If you have a digital camera you can take a picture and zoom in to see the details

Essential items to take outside

- This pack which contains:
  this workbook
  the fold-out field guide
  magnifier, 2 mustard sachets, 2 vinegar sachets, 2 pH strips
- Two 750ml bottles of water We recommend that you re-use old plastic bottles filled with tap water. Please remember to recycle
- A small shovel, spade or trowel
- Protective gloves
- Bin bags (for the soil removed from the pit) These can also be useful for kneeling on. Please remember to recycle
- Suitable containers (e.g. plastic cups, sandwich bags) for the soil tests and for storing earthworms

Useful items to take outside

- A map and GPS device if available
- Waterproof pen
- A mobile phone
- A camera
- A watch

Health and safety

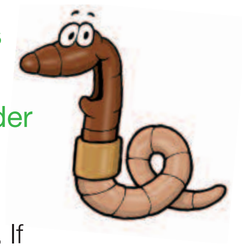
We don't advise you to work on your own. Make sure that you know what to do in an emergency. Take a responsible friend who can help if things go wrong. Ensure that you have permission from the landowner to dig holes on their land. Where possible wear plastic gloves and wash your hands before eating. Cover any open wounds before starting the activity. Don't handle soil if you can see sharp objects (e.g. glass, wire). If the site has sharp objects then choose another site elsewhere. Be careful not to disturb local wildlife (e.g. adders). This survey is designed for use in England. Check local conditions if you intend to use it outside of England. Ensure that you have performed a risk assessment where applicable. The mustard and vinegar sachets supplied in the field pack are not for human consumption.

Preparing your sampling pit

1. Use the ruler on your fold-out field guide to measure a 20cm x 20cm square
2. Mark each corner of the square with a marker so that you know where to dig
3. Use a spade or trowel to cut out and dig the pit. Try and keep the pit as square as possible
4. Place all the removed soil on a bin liner
5. Use the ruler on your fold-out field guide to make sure your pit is 10cm deep

Earthworms – other habitats

"Earthworms like to live in damp and dark places. Our main habitat is soil but we can be found in other places too. These are called microhabitats. These microhabitats can include compost heaps, under logs and branches, under leaves and plant pots."



Alan Scragg

Search for earthworms in a variety of microhabitats within 5 metres of your pit. If you find any, place them in a sandwich bag or cup to identify later (step D).


compost heaps


logs and branches


leaves


plant pots

Earthworms can be found in moist, dark microhabitats that usually have some contact with the soil. Typical places where they occur include: 1. lawns 2. in bare soil such as flower beds or vegetable patches 3. compost heaps 4. organic-rich microhabitats such as piles of decaying leaves 5. inside or beneath highly decayed logs or branches 6. beneath flowerpots and other loose surfaces such as planks of wood or plastic sheets.

There are 26 British species of earthworm, all of which are from the family Lumbricidae. The 12 species listed below are common and thought to be widespread, while the other 14 species are rarer and may have limited geographical distributions. More information about how to identify all the British species can be found in Sims and Gerard (1999): *Earthworms*.

Earthworm factfile

1. **Compost worm** *Eisenia veneta*. Usually found in garden compost but can also occur in wet decaying leaf litter, organic-rich soils and manure heaps. Eats rotting vegetation.

2. **Brandling worm** *Eisenia fetida*. Usually found in garden compost but also occurs in wet decaying leaf litter, organic-rich soils and manure heaps. Eats rotting vegetation.

3. **Green worm** *Allolobophora chlorotica*. Very common and widespread. There are two colour varieties: a 'greenish' variety (3) and a pale variety (13). Lives in the topsoil, often among plant roots. Eats soil.

4. **Redhead worm** *Lumbricus rubellus*. A widespread species, found in most habitats. Lives in the topsoil and leaf litter, and is thought to feed on decaying leaf litter fragments.

5. **Black-headed worm** *Aporrectodea longa*. A large worm. Abundant and widespread. Builds permanent vertical burrows up to 60cm deep and deposits casts on the surface. Eats soil.

6. **Lob worm** *Lumbricus terrestris*. The largest British earthworm, common and widespread. Builds permanent vertical burrows up to 3m deep. Emerges at night to pull leaf litter into its burrow.

7. **Octagonal-tailed worm** *Dendrobaena octaedra*. The tail is octagonal in cross-section but this is difficult to see in live earthworms. Can be locally abundant. Lives and feeds in leaf litter.

8. **Chestnut worm** *Lumbricus castaneus*. Common and widespread, found in many habitats. Lives in leaf litter and under logs.

9. **Little tree worm** *Satchellius mammalis*. Widespread in many habitats, from woodlands and field margins to marshy habitats and river banks but is seldom abundant. Lives and feeds in leaf litter.

10. **Rosy-tipped worm** *Aporrectodea rosea*. The first 10 or 15 segments are rosy pink or pale pink in colour. Widespread, and found in most habitats. Can be locally abundant. Lives in the topsoil and eats soil.

11. **Grey worm** *Aporrectodea caliginosa*. Very common and widespread. Lives in non-permanent horizontal burrows in the topsoil. Rarely found in leaf litter. Eats soil.

12. **Blue-grey worm** *Octolasion cyaneum*. Occurs in pasture and arable land, gardens and woodlands. Lives in the topsoil and feeds on soil.

13. **Green worm** *Allolobophora chlorotica*. See (3)

Ⓐ Site characteristics

✔ Please tick the appropriate boxes

ⓐ Do you think soil and earthworms are important? [yes] [no] [not sure]

ⓑ Do you like outdoor activities? [yes] [no] [not sure]

ⓒ How did you participate in the Survey today? [school] [volunteer group] [on my own]

ⓓ Record the postcode and name of your site ______________ ______________________________

1 What is the surrounding area like? [a] Urban [b] Suburban [c] Countryside

2 Choose the best description of your sampling site.

a Garden, b Parkland, c Playing field, d Wood or forest, e Heath or moorland, f Open, grassy field, g Ploughed field, h Grassy verge, i Industrial site

[j] Other (please describe) ______________________________

3 How far is the nearest road? [a] less than 20m [b] 20-100m [c] more than 100m [name of road]

4 Can you see any of the following signs of pollution?

a Storage tanks (oil, fuel, chemicals), b Rubbish, c Industrial chimneys, d Discharge (waste) pipes, e Foam on the surface of any ponds, lakes or rivers, f None

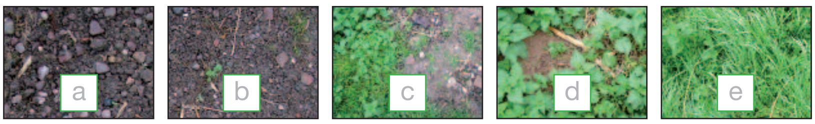
[g] Other (please describe) ______________________________

5 What is the weather like today?

a No clouds, sunny, b Some clouds, no rain, c Many clouds, no rain, d Many clouds and rain

[e] Other (please describe) ______________________________

6 How much of the ground in your sample square is covered in plants / grass?



a All bare earth, b Mostly bare earth, c Half earth, half plants, d Mostly covered with plants, e Totally covered with plants

Now go to step Ⓑ of the fold-out field guide

B The soil pit and earthworms

B1 Immatures [numbers] **B2** Adults [numbers]

B3 Water drainage: [a] less than 3 minutes? ________ minutes ________ seconds

[b] more than 3 minutes

B4 Immatures [numbers] **B5** Adults [numbers]

C Soil properties

7 Plant roots: [a] [b] [c]

8 Objects in the soil: [a] [b] [c] [d] [e] [f]

9 Soil hardness: [a] [b] [c]

10 Soil fizz: [yes] [no]

11 Soil moisture: [a] [b] [c]

12 pH value: [pH4] [pH4.5] [pH5] [pH5.5] [pH6] [pH6.5] [pH7] [pH7.5] [pH8] [pH8.5] [pH9]

13 Soil texture: [a] [b] [c] [d] [e] [f] [g] [h] [i] [j] [k]

14 Smell: [a] [b] [c]

15 Colour: [a] [b] [c] [d] [e] [f] [g] [h] [i] [j] [k] [l]

D Earthworm record sheet

Use the following table to record the earthworms you find.

	Where was worm found?			Length (cm)	Colour (if species unknown)				Earthworm species (ID number from key)													
	Soil from pit	Mustard water	Other		Red	Stripy	Pale	Green	1	2	3	4	5	6	7	8	9	10	11	12	13	
Adult earthworms (one line per worm)									Compost worm	Branding worm	Green worm (green form)	Redhead worm	Black-headed worm	Lob worm	Octagonal-tailed worm	Chestnut worm	Little tree worm	Rosy-tipped worm	Grey worm	Blue-grey worm	Green worm (pale form)	Unidentified adult worms

Write length here

Ⓔ Other organisms in your pit

Insects

E1 Beetles numbers **E2** Flies numbers **E3** Larvae numbers

E4 Bugs numbers **E5** Other numbers

Non insects

E6 Snails numbers **E7** Slugs numbers **E8** Arachnids (spiders) numbers

E9 Other numbers

Ⓕ Submit your results

Enter your results onto the OPAL website: **www.OPALexplorenature.org**

Thank you for taking part in the OPAL Soil and Earthworm Survey! Now you have gathered your results it is important that you input them onto the OPAL website so they can be shared and used to map the soil quality and earthworm species across England.

Once you have entered your results online you can browse maps showing the results of the national survey so far.

This pack has been developed by:

Martin Head[1], Nick Voulvoulis[1], James Bone[1], David T. Jones[1,2], Chris N. Lowe[6], Laura Edwards[1], Elizabeth Stevens[1], Declan Barraclough[3], Tatiana Boucard[3], Dee Flight[4], Harry Taylor[2], Paul Egglestone[2], Stephen Brooks[2], Emma Sherlock[2], Simon Norman[5], Louise Parker[5], Rebecca Farley[5], Linda Davies[1], Carolina Bachariou[1].

Photographs by: Martin Head[1], Harry Taylor[2], Chris N. Lowe[6], Louise Parker[5] and Simon Norman[5].

Earthworm illustrations by: David T. Jones[1,2]. Cartoons by: Alan Scragg. Design by Mark Dowding[5].

[1] Imperial College London. [2] Natural History Museum. [3] Environment Agency. [4] British Geological Survey. [5] Field Studies Council. [6] University of Central Lancashire.

10 APPENDIX 2: DATA QUALITY ASSESSMENT REPORT

Data Quality Assessment Report[1]

OPAL Soil and Earthworm Survey

Prepared by the OPAL Soil Centre to accompany any data released to 3rd parties

[1] based on the first 2856 survey responses

LOTTERY FUNDED

The main contributors to this report include: Michael Archer (ERM), Declan Barraclough (EA), James Bone (IC), Paul Eggleton (NHM), Martin Head (IC), David Jones (NHM/IC), Nick Voulvoulis (IC).

TABLE OF CONTENTS

1 INTRODUCTION

1.1 BACKGROUND

The OPAL Soil and Earthworm Survey was launched in spring 2009 with the aim of improving our understanding of both soil characteristics and earthworm populations within England. This was the first time that an investigation of this scale has centred on contribution by the general public and aimed to develop an understanding of the distribution of different earthworm species, assess preferred soil conditions and evaluate responses to environmental variables.

The survey was completed by the general public utilising a field guide prepared by the Imperial College OPAL Soil Centre in collaboration with staff from the Natural History Museum (NHM), the Environment Agency (EA), the Field Studies Council (FSC), the University of Central Lancashire (UCLAN) and the British Geological Survey (BGS). The survey data included information on the importance the respondent placed on environmental science, identification of the surveyed location, descriptions of environmental conditions encountered, basic soil property assessment, earthworm species identification and counts of earthworms and other macro-organisms.

The survey aimed to achieve both scientific and socially beneficial outcomes. Many aspects of the survey were aimed at stimulating involvement of the general public in environmental science for educational purposes through providing an introduction to the process of observing, measuring and interpreting environmental variables. The degree to which this objective was met was evaluated in terms of public participation numbers and will not be discussed in this report. This data quality assessment aims to evaluate whether the scientific objectives of the survey were met, specifically, whether the survey data was of suitable quality for the development of a baseline understanding of earthworm distribution and response to soil condition. It aims to accompany all data released from the national survey of soil and earthworms and provide an assessment of their quality.

1.2 RECORDS RECEIVED AND SPATIAL DISTRIBUTION

The data quality assessment presented in this report has been based on records as of the 13 August 2009 when a total of 2,856 survey records had been submitted by respondents. The survey records provided spatial coverage of much of England; however a greater density of respondents were located in urban centres, primarily around London and Birmingham. OPAL operates over nine regions and the number of samples received from each of these regions up until 13 August is detailed in *Table 1.1* and *Figure 1.1* below. The only data that have been filtered out and excluded from our survey and therefore its quality assessment are from records where we have sufficient evidence that the location information has been incorrectly provided (explained in section 1.3).

1.3 LOCATION VALIDATION USING POSTCODES

Prior to all analysis, a ground-truthing exercise was completed to compare the postcode entered by respondents with the coordinates at which they placed their site marker when submitting their responses. The purpose of this was to exclude comparison of survey data with mapped reference data where there was uncertainty over the location at which the survey was completed.
The postcode for the site, where given by the participant, was geocoded to give latitude and longitude coordinates. This latitude and longitude from the site postcode was

compared to the latitude and longitude recorded on the database from placement of the site marker. Comparison used the Haversine formula to calculate the distance between the two sets of coordinates.

As it was not mandatory to provide the postcode of the sampling location during the survey, a total of 1224 postcodes were supplied, representing 43% of responses. Of these records a total of 118 locations (4.13% of the entire dataset) were excluded from the quality assessment of the data as presented in this report. This was based on the submitted coordinates falling more than one kilometre from the submitted postcode.

Table 1.1 Number of Samples received by OPAL region up to 13th August 2009.

OPAL Region	Number of Samples
London	371
Yorkshire and The Humber	242
South East	399
North West	225
East Midlands	337
East of England	189
South West	273
West Midlands	708
North East	122

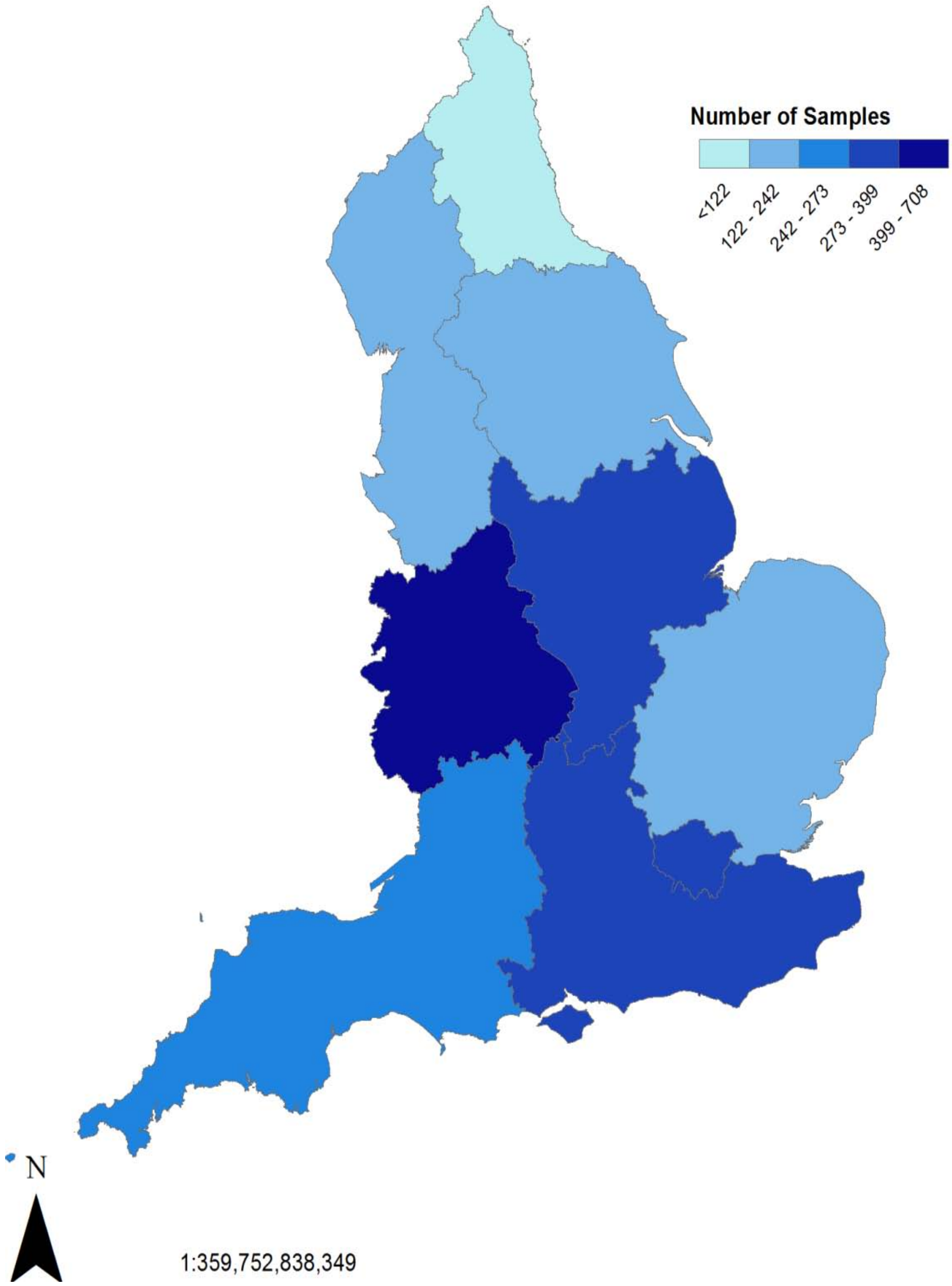


Figure 1.1 Choropleth map illustrating responses received within each of the OPAL regions up to 13 August 2009

1.4 DESCRIPTION OF SURVEY RECORDS

Within a single site (defined in the survey as an area with 5 m radius), survey respondents were prompted to collect information on a number of environmental variables. The survey records can be described as either *measurements* or *observations* depending on how the data was collected. To develop a robust baseline, the survey aimed to collect data with the minimum level of detail specified in *Table 1.2*.

Table 1.2 Survey data groups

Survey field	Desired Level of Detail
Quantitative or semi-quantitative (Measurements)	
Soil pH	Differentiate between acid, alkaline and neutral soils
Water drainage time	Differentiate between slow and fast drainage
Worm numbers	Accurate total count
Worm length	To fall within the recognised species body length
Distance to nearest road	<20m, 20-100m or >100m
Soil texture	Differentiate between sand, loamy sand and soils of increasing clay content
Vegetation coverage	Differentiate between no plant cover, 50% plant cover or 100% plant cover
Qualitative (Observations)	
Surrounding area	Differentiate between urban, suburban or rural areas
Sampling site	Identify land use by closest match to example image
Weather	Identify predominant weather condition
Plant roots	Identify presence or absence
Soil moisture	Differentiate between dry, moist or wet
Soil hardness	Differentiate between compacted or not compacted
Signs of pollution	Identify presence or absence of potential pollution sources
Soil objects	Identify presence or absence of anthropogenic inclusions
Soil fizz	Identify presence or absence of CO_3^{2-} reactivity to vinegar
Soil smell	Identify presence or absence of odour associated with high organic matter or chemical impacts to soil
Earthworm species identification	Differentiate between epigeic, endogeic or anecic species.
Soil colour	Differentiate between the major colour groups commonly observed

1.5 OBJECTIVES OF DATA QUALITY ASSESSMENT

The scientific objective of the survey was to develop a baseline understanding of the distribution of earthworm species and associated soil conditions in England. As well as providing the minimum resolution presented in *Table 1.2*, it was necessary that the data could be demonstrated to be: representative of previously established environmental conditions, reproducible following the established methodology, provide suitable spatial coverage and form a complete data set for future comparison. *Table 1.3* presents typical control measures employed to meet these data objectives and comments on how they were adopted in this investigation.

Table 1.3 Data Quality Targets

Control measures	Comments
Reproducibility	
Investigation conducted following a standard methodology.	A field guide was prepared to direct respondents. As typical respondents lacked formal training there was potential for individual deviation from the standard methodology. In some cases, respondents were supervised by community scientists, however variation from the formal procedures was not routinely documented.
Replicate measurements collected to assess standard deviation.	IC conducted a trial with repeat measurements of soil pH and texture at a single site to assess reproducibility within and between participants. Results used to establish acceptable limits for evaluating survey data. During the survey, respondents were asked to excavate two soil pits at each site.
Representativeness	
Investigation conducted following a standard methodology.	See above comment regarding standard methodology.
Control samples collected from locations with previously determined attributes.	IC conducted a trial to assess local variation in soil properties at a single sampling site. IC conducted targeted sampling at locations where soil conditions had previously been assessed by BGS. National soil and land use mapping provided by EA was used to compare survey records with existing data. NHM conducted cross checking of earthworm species identification and length measurement during a number of workshops.
Check measurements/identification performed by a second analyst.	No check measurements conducted for soil attributes.
Comparability	
Investigation conducted following a standard methodology.	See above comment regarding standard methodology.
All sampling conducted by an appropriately qualified and experienced sampler. Consistent types of samples collected.	Although respondents typically did not have formal training, the field guide is considered to have provided sufficient background understanding to complete the required tasks.
Completeness	
Acceptable spatial coverage achieved.	Community scientists established at key locations to achieve participation in major regional areas.
Investigation conducted following a standard methodology (including description of samples).	See above comment regarding standard methodology.
All sampling conducted by an appropriately qualified and experienced sampler.	See comment above.
Documentation of field works provided.	Survey results submitted via online portal.

The preparation of the standard field guide for the survey was therefore considered to be the primary means of meeting data quality targets for comparability of samples. The support provided by community scientists was considered a critical element in ensuring the completeness of the survey results, including spatial coverage and submittal of entire records.

The data quality assessment therefore focused on the reproducibility and representativeness elements described above. This assessment has been divided into a number of tasks to achieve this aim, as follows.

Task A: Assessment of soil pH and texture reproducibility at selected control sites.

Task B: Assessment of soil pH and texture representativeness using NSRI reference data.

Task C: Assessment of survey representativeness using BGS reference data.

Task D: Assessment of land use observation representativeness using LCM2000 reference data.

Task E: OPAL sampling event-based assessment of earthworm species identification.

2 TASK A: SOIL MEASUREMENT REPRODUCIBILITY

2.1 INTRODUCTION

During the survey a "site" was defined as an area of 5 m radius within which up to two soil pits would be excavated. Prior to comparing the results to reference data, two trials were conducted by IC to provide checks on the reproducibility of measurements within this area.

2.2 TRIAL 1

The first trial aimed to demonstrate that on a site with low soil heterogeneity, variability in repeat measurements taken by a single participant was not significantly different to variability in measurements between participants. The subject site for this trial was a playing field, selected for this trial based on a visual inspection that indicated a relatively homogenous soil type and uniform land management practices within the area. Over a nine-week period, two participants visited the site on a weekly basis and two soil pits were excavated each week within the defined area with a 5 m radius.

A total of 18 measurements were made by each participant, with soil pH and texture results presented in *Table 2.1*.

Table 2.1 Summary of Trial 1 Results

Measurement	Number of responses: Participant 1	Number of responses: Participant 2
Soil pH		
pH 5.0	2	0
pH 5.5	9	10
pH 6.0	7	8
Soil texture		
Silty clay	8	6
Sandy clay	1	0
Clay loam	2	2
Silty clay loam	7	9
Sandy clay loam	0	1

The pH values recorded ranged between 5 and 6 and all values fell within 0.5 pH units of the mean for each participant. The means for the two participants differed by approximately 0.1 pH units. A two-way analysis of variance with replication was conducted on this data, as summarised in the table below. As the F-value was less than the critical value for both sources of variation, there was no significant difference (at a 95% level of probability) identified in mean soil pH measurements either within or between samplers.

Table 2.2 ANOVA comparison of Trial 1 soil pH results

Source of Variation	SS	df	MS	F	P-value	F crit
Week	1.513889	8	0.189236	0.879032	0.551918	2.510158
Sampler	0.0625	1	0.0625	0.290323	0.596616	4.413873
Interaction	0.625	8	0.078125	0.362903	0.926824	2.510158
Within	3.875	18	0.215278			
Total	6.076389	35				

A comparison of soil texture observations indicated that in over 80% of assessments, both participants recorded the soil texture as silty clay or silty clay loam with the remainder identified as soil textures with the same range of clay content but differing sand/silt ratios.

Overall, the results of Trial 1 indicate that for repeat measurements made at a single site, no greater variability is expected for different samplers than for a single sampler.

2.3 TRIAL 2

The second trial aimed to identify the likely variability in survey results due to the inherent heterogeneity of soil conditions. A garden site (NHM Meadows) was selected as representative of conditions likely to be encountered during the survey and an area with 5 m radius designated for the trial. Over a nine-week period, a total of 18 participants visited the site and each completed the survey at two locations within the defined area.

Soil pH measurements ranged from 4.5 to 7 as presented in *Figure 2.1*, with a mean of 6.05 and standard deviation of 0.56 pH units. Overall, 86% of results fell within 0.5 pH units of the mean and 97% fell within 1 pH unit of the mean. The distribution of soil textures was examined in relation to their sand, silt and clay content, as illustrated below. Texture was predominantly described as a silty clay loam, with 91% of descriptions falling within neighbouring texture classes on the soil texture triangle (*Figure 2.2*).

These results are considered to indicate that site-based variation of soil pH by up to 1 pH unit should be considered likely when comparing results recorded in the survey to sources of reference data (*Section 3*).

Likewise, a variation in soil texture at a single site between adjacent classes on the soil texture triangle is considered feasible due to local heterogeneity. This is because each texture class represents a range of sand, silt and clay values and although boundaries between classes are defined on the soil texture triangle, in practice the transitions are much less distinct. Where the percentage of sand, silt and clay lie on or near the boundary between texture classes, it is therefore feasible that it may be described as either texture in the field. Furthermore, this is a subjective assessment which is informed by the experience of the assessor.

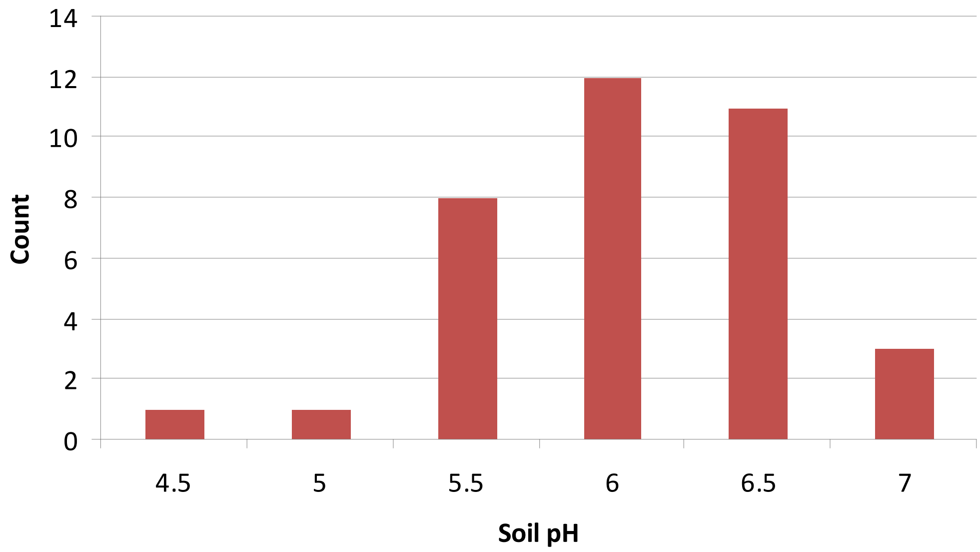


Figure 2.1 Trial 2 soil pH results

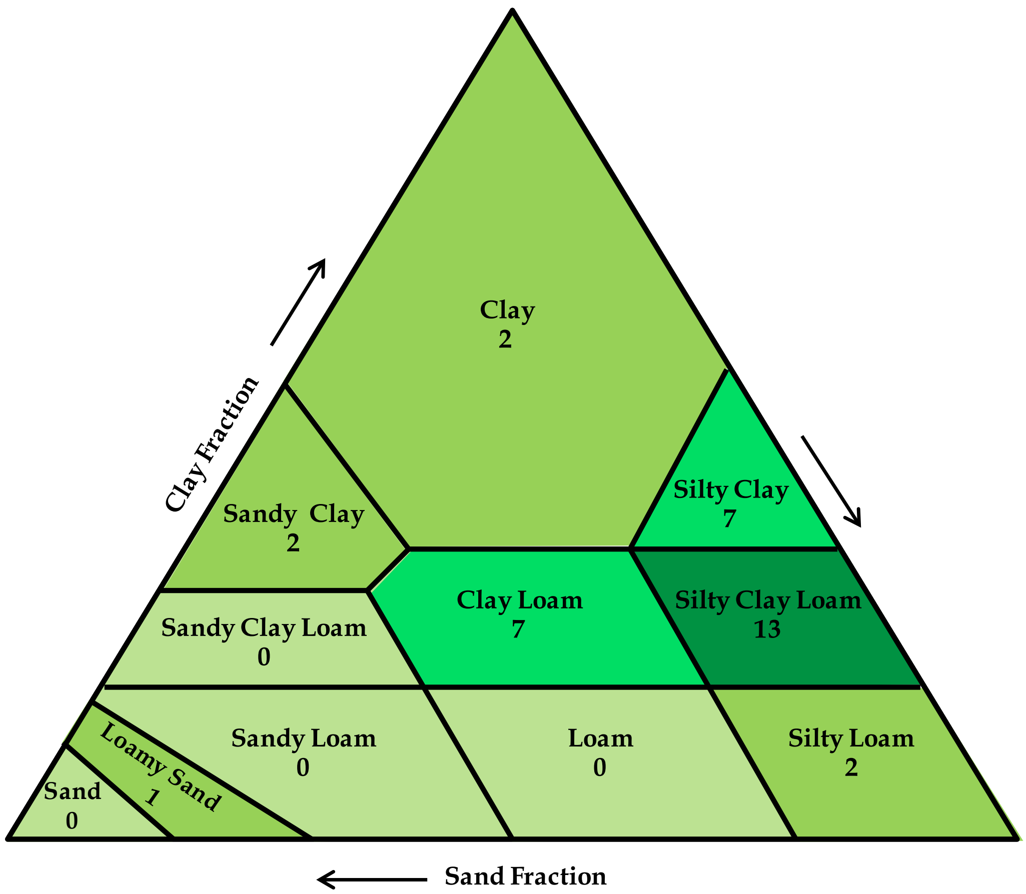


Figure 2.2 Trial 2 soil texture results

3 TASK B: SOIL PH AND TEXTURE REPRESENTATIVENESS

3.1 REFERENCE DATA SOURCE: NSRI NATIONAL SOIL MAP

The NSRI National Soil Map is a 1:250,000 scale vector map of geographic Soil Associations, based on published soil maps which cover a quarter of the land at scales of 1:25,000, 1:63,360 or 1:100,000 and on reconnaissance mapping of previously unsurveyed areas (Cranfield University, 2004).

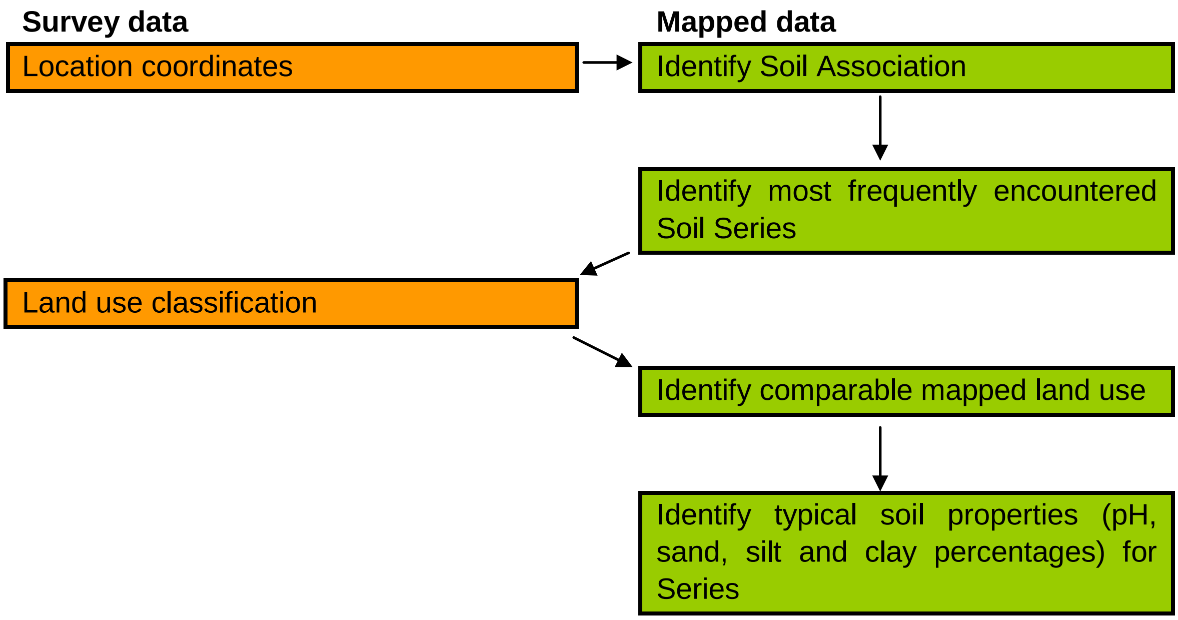
Each Soil Association comprised varying percentages of a number of Soil Series. The Soil Series forms the lowest division of the hierarchical system used to describe soil profile characteristics – in descending order these are *Major Group*, *Group*, *Subgroup* and *Series*. The three higher divisions are based on the pedogenic characteristics of the soil profile and the Soil Series is based on precisely defined particle-size subgroups, parent material type, colour and mineralogical characteristics[2]. Typical properties have been compiled for each horizon in each Soil Series under one of four land uses (Arable, Permanent Grassland, Ley Grassland or Other). Mapped land uses were considered comparable to the survey land use description as follows:

- *Arable*: “ploughed field”;
- *Permanent Grassland*: “grassy verge”, “heath or moorland”, “parkland” and “playing field”;
- *Ley Grassland*: “open grassy field”; and
- *Other*: “industrial”, “other”, “garden” and “wood or forest”.

These data therefore form a basis for understanding the spatial variation in soil properties within England.

For the purpose of comparison with the OPAL survey data, it is necessary to identify an expected or likely set of soil properties at each location. A deterministic approach was adopted for the initial comparison. Although the database supporting the NSRI map provides values for the percentage contribution of each Soil Series to the Soil Association, it does not provide similar information on the land use split within each Soil Series. A probabilistic approach to identifying soil properties was therefore not adopted. This identification of likely soil properties at each location involved the steps in the following flow chart:

[2] Clayden, B. and Hollis, J.M. (1984) Criteria for Differentiating Soil Series. Soil Survey Technical Monograph No. 17. Harpenden



3.2 SOIL PH

Soil pH was measured in the survey using universal indicator paper strips graduated from pH 4 to pH 9 in increments of 0.5 pH units. This measurement methodology was standardised across the survey. Soil pH was not reported by 53 respondents. Overall, the soil pH results appear to be close to normally distributed around a mean pH of 5.8, as shown in *Figure 3.1*.

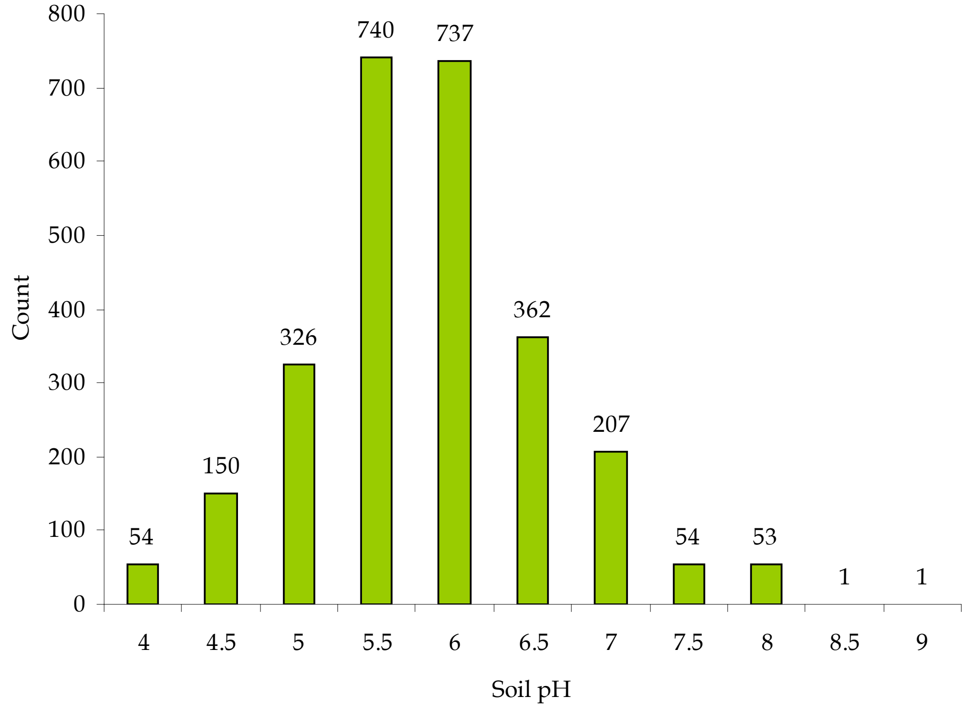


Figure 3.1 Distribution of Soil pH Values - Survey

A different trend was observed in the distribution of the mapped (NSRI) soil pH for the same locations, with a trend towards sites with more acidic soil pH. The mean pH for the mapped data was 5.5, as shown in *Figure 3.2*. A limitation of the methodology is apparent from this data, as the indicator strips did not allow identification of soil pH less than 4, however the NSRI indicates that only approximately 2% of locations have soil pH between 3.5 and 4. This high-level comparison indicates a tendency for many sites with mapped soil pH between 3.5 and 4.5 to have been reported in the survey with higher pH values.

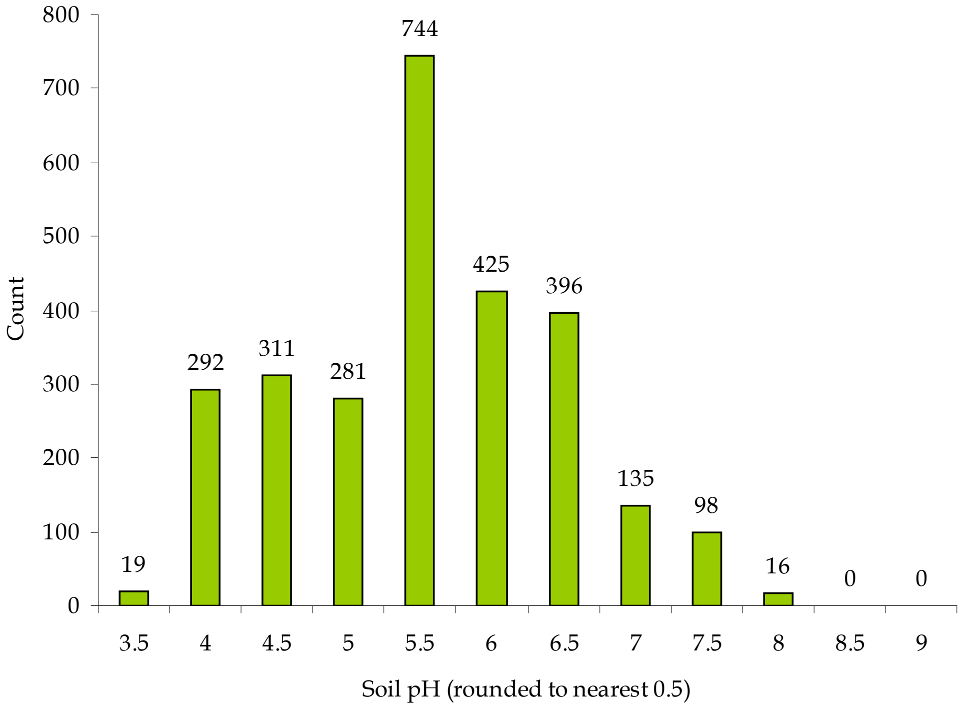


Figure 3.2 Distribution of Soil pH Values – NSRI Map

To further investigate the discrepancies between *Figures 3.1* and *3.2*, the mapped pH has been subtracted from the survey pH to obtain an "apparent error" for the survey results. A frequency histogram displaying this information is presented in *Figure 3.3*.

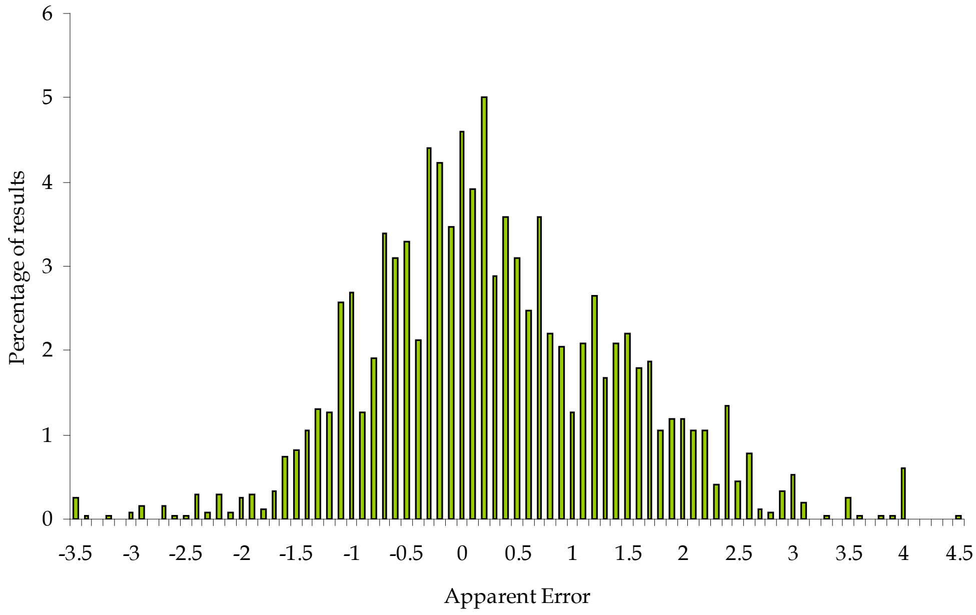


Figure 3.3 Apparent error frequency histogram

From this chart it is apparent that 40.6% of survey results were reported within 0.5 pH units of the expected value determined from the NSRI map. This is not considered to be problematic as the indicator paper used to measure pH in the field only allowed a resolution of 0.5 pH units. Within the remaining 59.4% of results, the majority of these were locations where the pH range was reported to be higher than that determined from the NSRI map.

The "apparent error" observed in the pH measurements is likely to be a result not only of the measurement technique but also as a limitation of the baseline data used to conduct the comparison. To investigate potential limitations in the NSRI map data, the dataset was divided into two groups, one with an "apparent error" less than or equal to 0.5 pH units and the second with an "apparent error" greater than 0.5 pH units. A comparison of the relative proportions of different land uses within each group was subsequently conducted, as illustrated in *Figures 3.4a & 3.4b*.

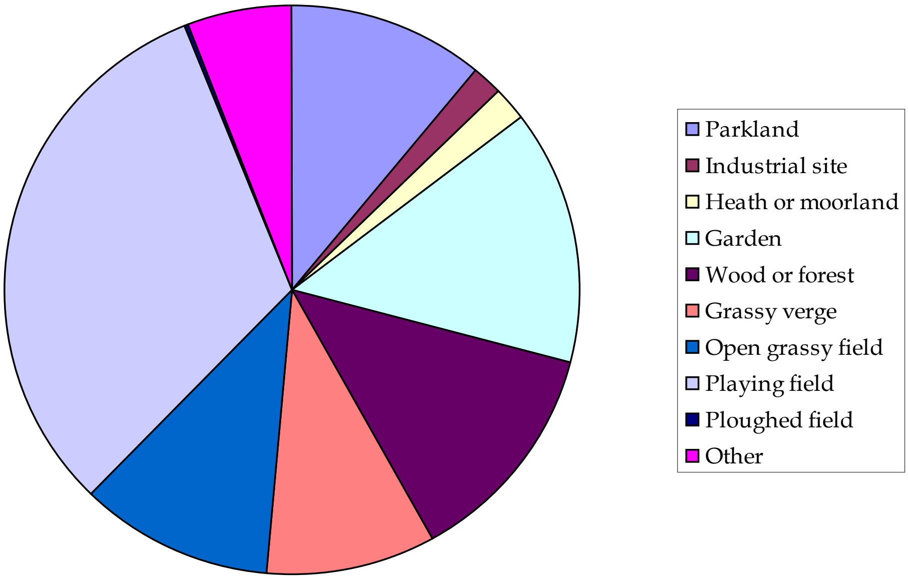


Figure 3.4a Land-use breakdown ("apparent error" <0.5 pH units)

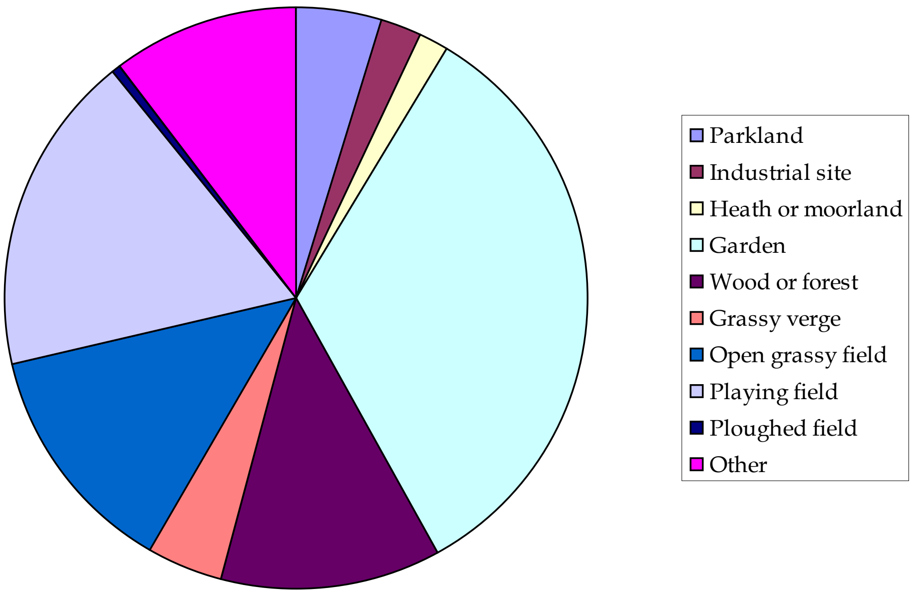


Figure 3.4b Land- use breakdown ("apparent error" >0.5 pH units)

It is apparent from this comparison that the locations described as gardens form a large proportion of the locations where the pH reported in the survey was more than 0.5 pH units different to that determined from the NSRI map. This indicates a limitation of the mapping in urban areas. It appears that the resolution of the mapping is poorer than the spatial variability in land-uses and soil conditions. Furthermore, surface soils in urban areas are typically highly disturbed and sourced from backfill not derived from the local area. As the Soil Series profiles are primarily derived in relation to the underlying geology, it is likely that surface soils in urban and suburban areas may not reflect the underlying natural soils.

To investigate this, locations identified as being in countryside areas (excluding gardens, industrial sites and "other") were selected and an "apparent error" frequency histogram produced for these survey results. This demonstrates a greater percentage (48.1%) of results falling within the 0.5 pH unit error range considered to be acceptable than in the previous comparison (*Figure 3.3*). The NSRI map is therefore considered to be a less suitable source of baseline data for urban and suburban areas, where soils are less likely to be indicative of the underlying parent material and local geology.

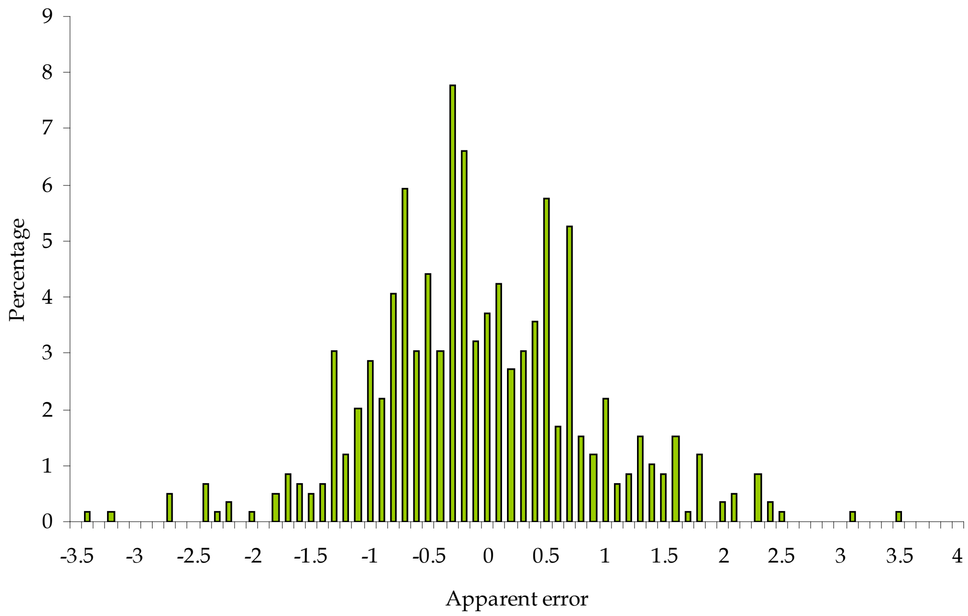


Figure 3.5 Apparent error frequency histogram – urban and suburban areas excluded

Overall, 78.0% of results fall within an error range of +/- 1 pH unit and 90.4% within an error range of +/- 1.5 pH units. Importantly the data appear to follow a normal distributed which indicates that the error was not solely associated with the more acidic soil locations, but was likely to be due to the low resolution of the mapped validation data, the selection of a single representative value for a naturally variable soil property and the limitations of the measurement methodology.

As the data quality objective was to reliably differentiate between acid, neutral and alkaline soils, the survey data for soil pH was therefore considered to be of acceptable quality. To investigate the representativeness of survey data in urban areas in more detail, Task C was completed using data sourced from the BGS.

3.3 SOIL TEXTURE

Soil textures were described during the survey based on a combination of attributes including the ability to form a coherent bolus and a ribbon, followed by measurement of ribbon length and evaluation of smoothness. Ribbon length is proportional to clay content; however the assessment is otherwise subjective. A total of 181 survey respondents did not report the soil texture.

The NSRI map provides typical percentage values for sand, silt and clay for each Soil Series. The procedure described in *Section 2.1* was followed to identify representative values for each mapped Soil Association. Utilising the soil texture triangle, each set of values was subsequently converted into a texture class.

As discussed in *Section 2.3*, where the percentage of sand, silt and clay lay on or near the boundary between texture classes, it was considered feasible that it may be described as either texture in the field. Therefore, for the purpose of evaluating the representativeness of the texture assessments reported in the survey, each texture class was assigned a set of corresponding mapped classes that would be considered consistent. This comparison matrix is presented in *Table 3.2*.

Table 3.1 Texture class comparison matrix

Mapped texture (NSRI)	**Surveyed texture (OPAL)** Silty loam	Silty clay loam	Silty clay	Sandy loam	Sandy clay loam	Sandy clay	Sand	Loamy sand	Loam	Clay loam	Clay
Sandy Clay	-	-	-	-	□	□	-	-	-	□	□
Silty Clay	-	□	□	-	-	-	-	-	-	□	□
Sandy Loam	-	-	-	□	□	-	□	□	□	-	-
Clay Loam	□	□	□	□	□	□	-	-	□	□	□
Clay	-	□	□	-	-	□	-	-	-	□	□
Silty Clay Loam	□	□	□	-	-	-	-	-	-	-	-
Loamy Sand	-	-	-	□	□	-	□	□	-	-	-
Loam	□	□	-	□	□	□	□	-	□	□	□
Silt Loam	□	□	-	-	-	□	□	-	□	□	-
Sand	-	-	-	□	□	□	□	□	-	-	□
Sandy Clay Loam	-	-	-	□	□	□	□	□	□	□	□

The percentages of surveyed textures that were consistent with the texture derived from the NSRI map were subsequently calculated using this matrix and are illustrated in *Figure 3.6*.

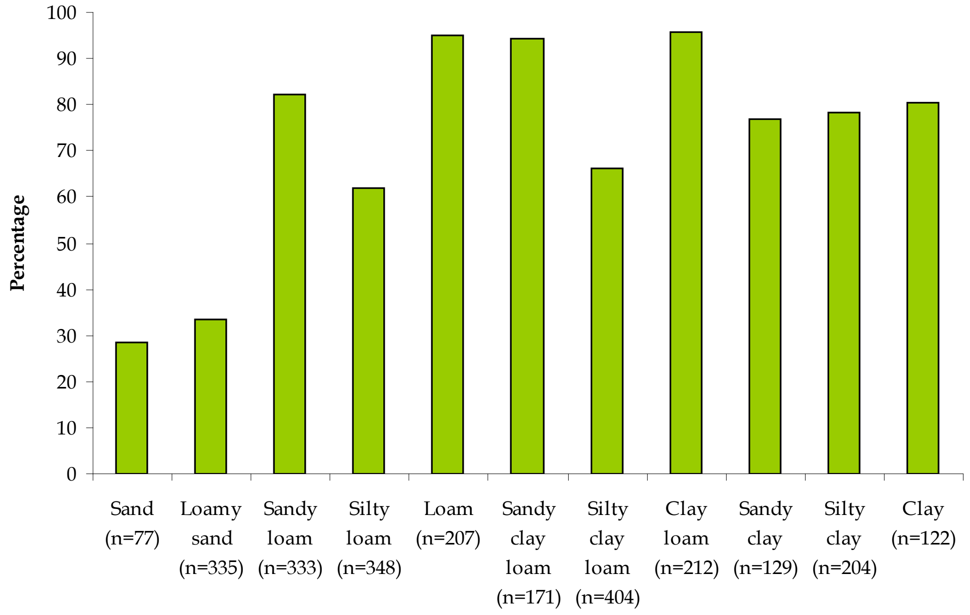


Figure 3.6 Percentage of survey texture classes matching mapped textures

Sand soil types were the least frequently reported and only 29% of these corresponded with similar textures determined from the NSRI map. It was considered likely that this error was due to a misapplication of the initial step of the methodology, as the use of insufficient water can prevent the formation of a coherent bolus. However, sites reported to have sand soil type were primarily also described as garden, open grassy field or playing field and the mismatch between the mapped texture and the surveyed texture could also be due to the presence of sand added as fill materials, for example, to improve drainage on sports fields.

Although a relatively high number of soils were described in the survey as loamy sand, only 33% of these corresponded to similar texture descriptions determined from the NSRI reference data. As discussed above for sand soils, it was likely that any error was due to misapplication of the methodology. Ribbon formation could be difficult if insufficient water was added or if the bolus was not worked for an adequate amount of time to break down the structure.

For the remaining texture classes, survey records were considered to be reasonably representative of texture as determined by ribbon length (which relates to clay content), with an average of 81% of reported textures corresponding with similar mapped attributes. It appears however that respondents were less accurate in distinguishing the soils with intermediate sand content, as silty loam and silty clay loam descriptions only corresponded with similar mapped textures at 62% and 66% of locations, respectively.

Overall, it was concluded that the results of the survey were suitably representative of the soil textures encountered, for the purpose of distinguishing between soils of increasing clay content but less representative of areas where sand or loamy sand soil types were present.

4 TASK C: SURVEY RECORD REPRESENTATIVENESS

4.1 REFERENCE DATA SOURCE: BGS SOIL SURVEY

The British Geological Survey Geochemical Baselines Survey of the Environment (G-BASE) project is a systematic survey to establish a geochemical baseline across the United Kingdom. The survey commenced in the 1960s at which time it was primarily used for mineral exploration. The survey has evolved into a multimedia, high resolution geochemical survey producing baseline data relevant to many environmental issues. The survey is described as high resolution because samples are collected at a high density averaging one sample every 1.5 to 2 square kilometres. The survey has included over 20 urban environments which are systematically mapped at a resolution of four samples per square kilometre.

A number of inorganic analytes, loss on ignition and pH were determined from laboratory analysis of collected soil and stream sediment samples as well as a number of observations made about the sample and the sampling site while in the field. Observations relevant to the OPAL Soil and Earthworm survey include the soil texture, soil colour and non-natural objects in the soil[3].

OPAL Soil and Earthworm survey responses were compared to data from the BGS G-BASE program. For soil pH, urban data was used for the areas of Coventry, Northampton and Derby[4]. For observational data, BGS data for the London part of the London Earth Project[5] was used. Characteristics compared are soil texture, soil colour, non-natural soil objects and land use. Sites sampled in the BGS London Earth sampling program were revisited in two areas, around Camden and Hammersmith in London. As the BGS survey had included a record of site geographic coordinates, high accuracy could be obtain in targeting the BGS locations for repeat sampling. At each sampling site in London the OPAL Soil and Earthworm survey was carried out.

4.2 SOIL PH

Urban soil pH collected in the high resolution G-BASE was compared to values collected in the OPAL Soil and Earthworm Survey. The G-BASE urban data was used as it has a higher resolution than the NSRI National Soil Map, and focuses on urban data where the majority of OPAL samples received so far occur.

The soil pH collected by the BGS from 5 - 20cm depth below ground level was used in three urban centres, Derby, Coventry and Northampton as shown in *Figure 4.1* below.

---

[3] Johnson, C.C. and Breward, N, 2004. G-BASE Geochemical Baseline Survey of the Environment. British Geological Survey, Keyworth, Commissioned Report, CR/04/016N.

[4] Scheib, A.J. and Nice, S.E., in press. Soil geochemical baseline data for the urban areas of Corby, Coventry, Derby, Leicester, Northampton, Nottingham and Peterborough in the East Midlands. British Geological Survey Open Report series, Keyworth, Nottingham. OR/08/075.

[5] Fordyce, F M, Brown, S E, Ander, E L, Rawlins, B G, O'donnell, K E, Lister, T R, Breward, N, and Johnson, C C. 2005. Urban geochemical mapping in Great Britain. *Geochemistry: Exploration, Environment, Analysis 5*, Vol. 4, 325-336

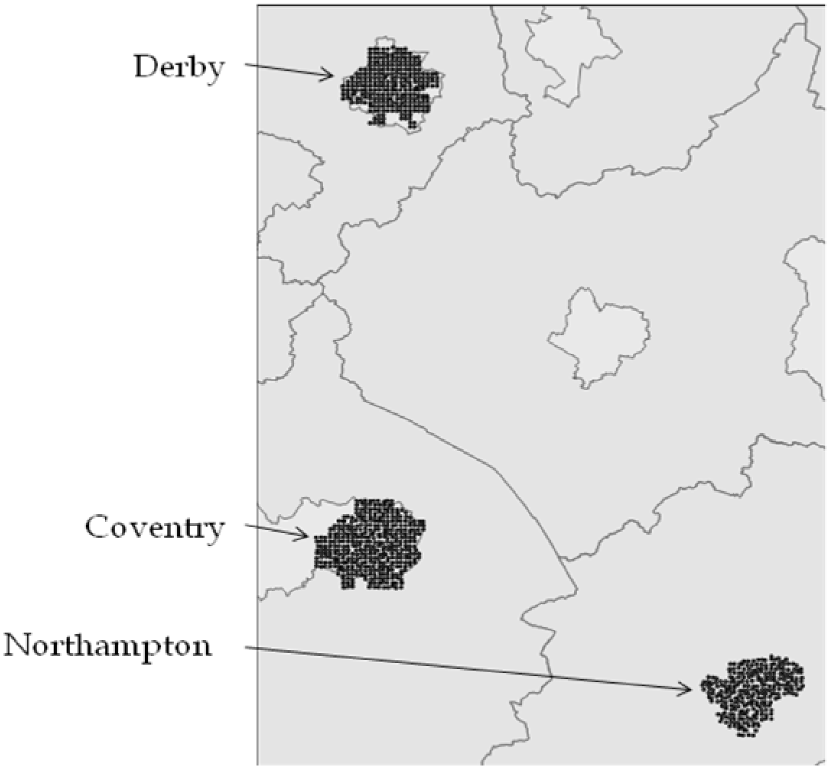


Figure 4.1 Urban areas sampled as part of the BGS GBASE sampling program and used for comparison to OPAL Soil and Earthworm Survey pH values

The number of BGS G-BASE samples within these urban areas as well as the number of OPAL Soil and Earthworm Survey Samples found within the BGS sampling area is detailed in *Table 4.1* below.

Table 4.1 Sample numbers from BGS and OPAL surveys in regional centers

Urban Area	BGS G-BASE Samples	OPAL Soil and Earthworm Survey Samples
Derby	276	46
Coventry	396	27
Northampton	275	3

The soil pH point data from the BGS G-BASE samples were Kriged to create raster plots of the soil pH in each of the urban areas as shown in *Figure 4.2* below.

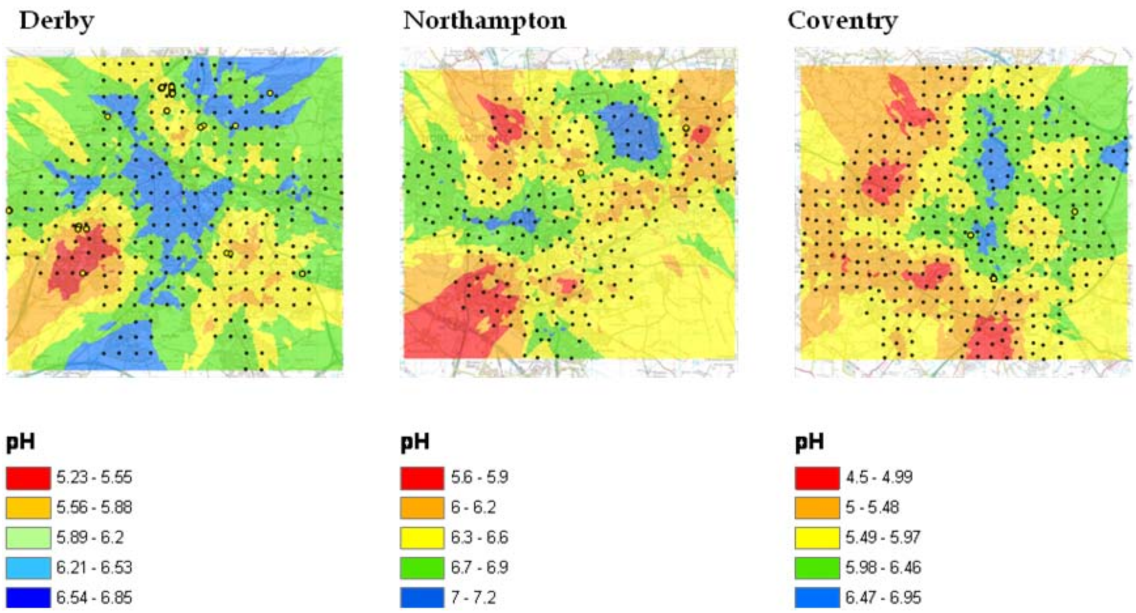


Figure 4.2 Plots for Derby, Northampton, and Coventry showing the raster created by Kriging BGS G-BASE samples (black points). OPAL Locations shown as yellow points

The value reported in the OPAL Soil and Earthworm Survey was compared with the raster value from the Kriged BGS G-BASE data at the location given.

The soil pH results from the OPAL Soil and Earthworm Survey for the three urban areas do not seem to follow a normal distribution as seen with results for the whole survey (*Figure 4.3*); this is likely due to the substantially lower number of samples in this dataset. The mean pH of this dataset is 5.7, very close to the mean pH of the national data set of 5.8.

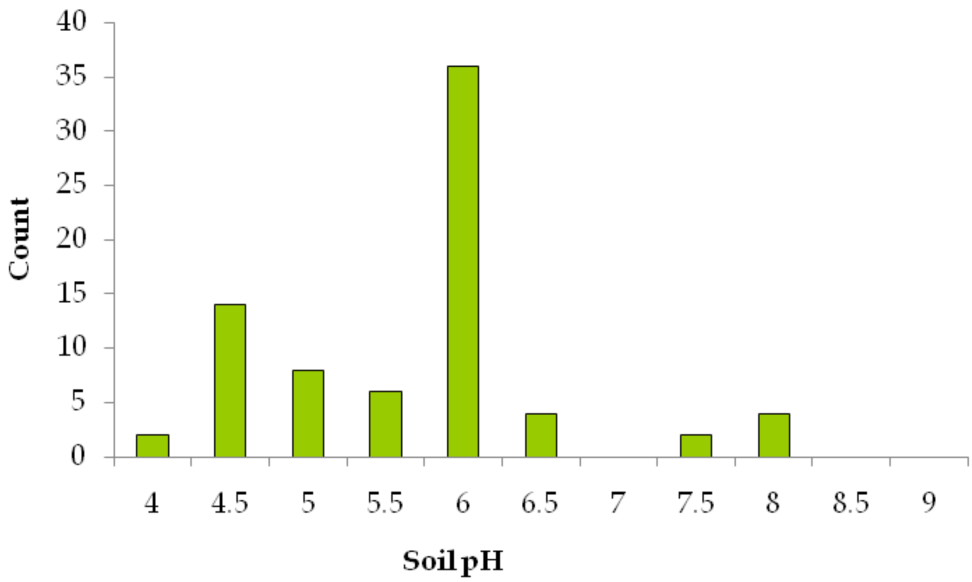


Figure 4.3 Distribution of Soil pH Values- OPAL Soil and Earthworm Survey

A different trend is seen in the distribution of soil pH from the Kriged BGS G-BASE data for the locations were the OPAL Soil and Earthworm Survey took place (*Figure 4.4*). The mean pH in the Kriged data was slightly higher than the survey at 6.1.

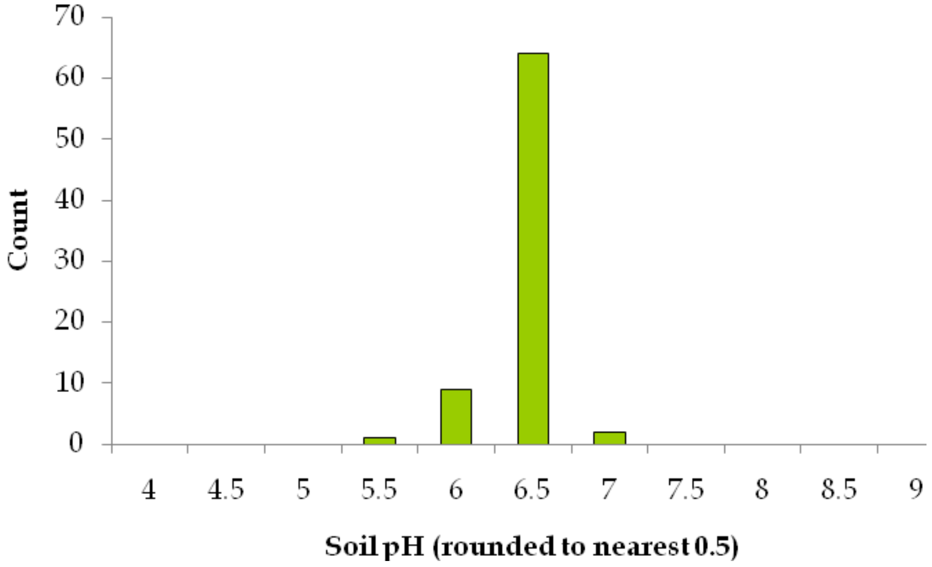


Figure 4.4 Distribution of expected soil pH values obtained from the Kriged raster plots

As for comparison between the survey pH and NSRI values an "apparent error" for the survey result was calculated using the BGS G-BASE data. A histogram displaying this information is presented in *Figure 4.5*.

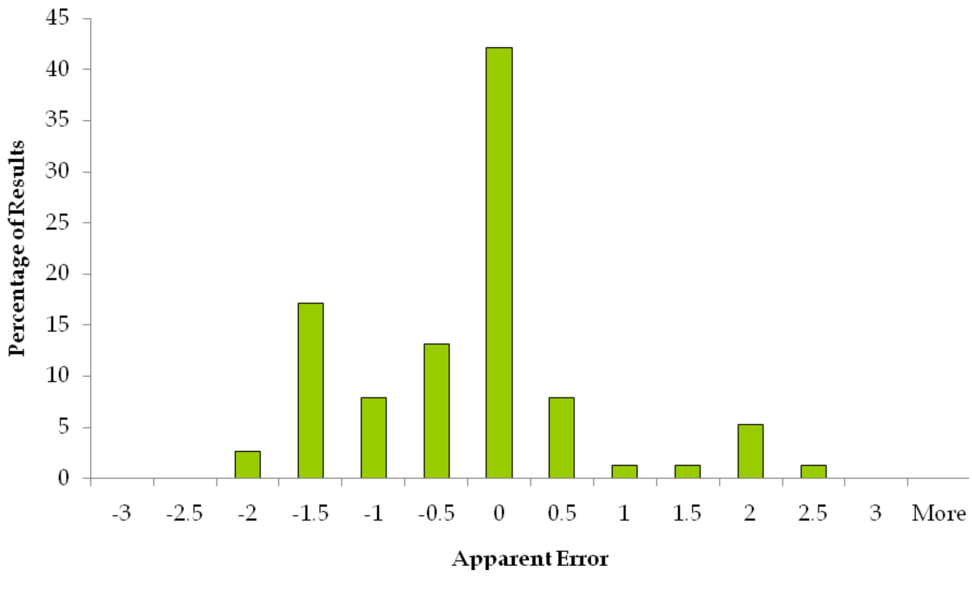


Figure 4.5 Histogram of apparent error between OPAL Soil and Earthworm values and Kriged values from BGS G-BASE samples

It is apparent that 50% of survey results were reported within 0.5 pH units of the expected value determined from the Kriged BGS G-BASE values. The remaining 50% of results were determined to have a different pH to that determined from the Kriged BGS G-BASE values. An apparent error of less than 1pH unit was found for 64.5% of samples and less than 1.5 pH units for 73.7% of samples. Contradictory to comparison with the NSRI, the majority of samples had a reported pH that is lower than the pH determined from the Kriged data.

If the two sets of samples are classed as Acid (<pH 5.6), Neutral (pH 5.6 – 7.5), Alkaline (>7.5) there is 50% agreement between the two datasets.

4.3 SOIL TEXTURE

The OPAL Survey had eleven soil texture classifications whilst the BGS had seven. The OPAL Soil Texture classifications were based on the USGS soil texture triangle whereas the BGS survey uses a simplified soil texture classification.

In order to compare the classifications of soil textures at each location it was necessary to standardise the soil texture classification. In order to do this, the USGS soil texture triangle was modified to form a generalised soil texture classification, into which both the BGS and IC OPAL soil classifications could be reclassified (*Figure 4.6*). For continuity, the principles used to design the generalised Soil Texture classification were the same as those applied by the Environment Agency.

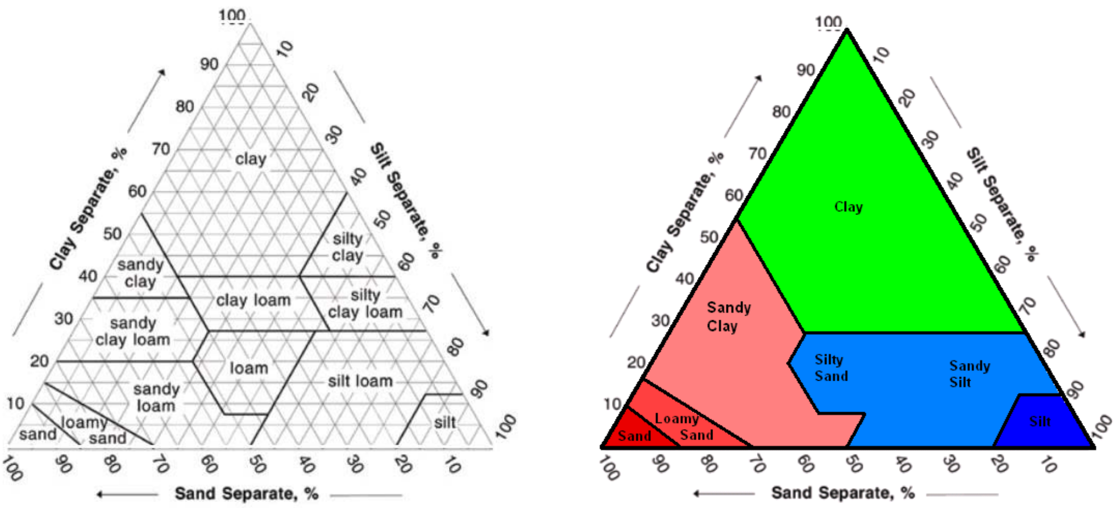


Figure 4.6 USGS Soil Texture Triangle (left) (Soil Survey Division Staff, 1993). Soil texture classifications to facilitate comparison of OPAL Soil and Earthworm and BGS London Earth data (right)

4.3.1 Exact Matches

The surveys were compared for exact soil texture matches at each location. Exact matches were those which appeared in both the OPAL Soil and Earthworm Survey and the BGS London Earth dataset. The list of exact matches being detailed in *Table 4.2* below.

Table 4.2 Table defining soil textures found in OPAL Soil and Earthworm survey and BGS London Earth survey which are defined as exact matches

BGS Soil Texture	OPAL Soil Texture
Sand	Sand
Sand	Loamy Sand
Silt	Silty Sand
Silt	Sandy Silt
Clay	Clay
Sandy Clay	Sandy Clay
Silty Sand	Silty Sand
Sandy Silt	Sandy Silt
Sandy Silt	Silty Sand

NB. *For the purpose of this comparison, “Loamy Sand” was treated as analogous to “Sand” whilst “Silt” was treated as analogous to “Sandy Silt/Silty Sand”.

4.3.2 Narrow Matches

The parameters for a match were then widened to include any location for which the major component of the soil texture was the same - the major component was identified by the noun within the soil texture. For example, in a Sandy Clay the major component is the noun “Clay” whilst the minor component is Sand as reflected by the adjective “Sandy”. The soil textures which matched under these criteria were identified as “narrow matches”.

4.3.3 Moderate Matches

A “moderate match” test carried out for soil texture wherein the parameters for a match were widened to include any location where either the major or minor component of the BGS and OPAL soil textures were the same. For example, for the soil texture Sandy Clay, any soil which was described as “Sandy” or named as “Clay” was considered to be a successful match such that both Sandy Silt and Clay would be considered matches.

The soil textures recorded in the BGS and OPAL surveys were compared to see how often they matched. The parameters of a match were varied and obviously the broader the parameters, the greater the number of matches which were identified.

Table 4.3 Percentage of soil texture matches between OPAL and BGS data

Match Class	Locations which matched
Exact	27 %
Narrow	36 %
Moderate	39 %

The match parameters were designed to compare the soil textures which could be considered as reasonably similar at varying levels of precision. This was carried out to allow for the inaccuracy that the variation in classification terminology used in the BGS and OPAL surveys would contribute to the comparison. By varying the parameters which determined a match, it was possible to negate, at least in part, the arbitrary nature of the soil texture reclassification. The fact that the number of matches did not increase greatly with the widening of the parameters suggest that in the cases where no match occurred, the soil texture descriptions were considerably different. This suggests that at these locations the soil textures were identified differently by the BGS and OPAL surveys for a reason other than the reclassification method used for comparison of soil textures in this research.

4.4 SOIL COLOUR

The OPAL survey had eleven options which could be used to identify the colour of a soil detailed in *Table 4.4*. The BGS Survey had eight colour options which could be used to classify a soil.

Table 4.4 Colours included in the OPAL Soil and Earthworm Survey

Colour Description	Colour Sample
Black	
Brownish Black	
Medium Brown	
Light Brown	
Reddish Brown	
Red	
Brown/Yellow	
Yellow	
Green	
Grey Green	
Blue/ Grey	
Grey/ White	

As the colour ranges were not the same for the two surveys, it was necessary to establish a principle for which colours could be considered as matches. This was achieved by identifying which of the BGS colours could be considered as an acceptable match for each OPAL colour. For example, for OPAL colour "a", the BGS colour Black would be considered an acceptable match; however the BGS colour Orange would not. Two types of matches were developed using this method, the first a "moderate match", in which only those BGS colours that are clearly and distinctly matches for the OPAL colours are considered. The second type of match was a "broader match", in which any colours which could be considered to be a shade of the OPAL colour were considered as matches, for example for Brownish Black, the most likely BGS match would be "Dark Brown", however "Black" was also considered a possibility in the "broader match" category.

Table 4.5 Moderate and Broader Matches between OPAL Soil and Earthworm Survey and BGS London Earth Survey Soil Colour Categories

Moderate Match		**Broader Match**	
BGS Soil Colour	IC OPAL Matches	BGS Soil Colour	IC OPAL Matches
Black	Black	Black	Black, Brownish Black
Dark Brown	Brownish Black, Medium Brown	Dark Brown	Brownish Black, Medium Brown
Light Brown	Light Brown	Light Brown	Light Brown, Brown/Yellow
Red	Reddish Brown, Red	Red	Reddish Brown, Red
Orange	Brown/Yellow	Orange	Brown/Yellow, Yellow
Yellow	Yellow	Yellow	Yellow
Green	Green, Grey Green	Green	Green, Grey Green
Grey	Blue/ Grey, Grey/ White	Grey	Blue/ Grey, Grey/ White

4.4.1 Results

Using the “moderate match” parameter for comparison, 73% of locations showed the same colour in the BGS and OPAL surveys. Very similar results were generated for the comparison using the “broad match” parameter 75% locations showing the same colour in both surveys.

If the non-matching locations that were within 1 colour category of a match were also considered to be a match, this increased the number of matches between the OPAL and BGS survey to 99%. Whilst these were not “exact matches”, given the subjective nature of soil colour identification this could be considered to be well within an acceptable margin of error.

Overall, the OPAL identification of soil colour could be considered to be accurate as there were a high proportion of exact matches between the BGS and the OPAL survey. Similarly, the OPAL identification of soil colour could also be considered to be highly reliable as even when an exact match did not occur.

4.5 SOIL OBJECTS

The OPAL survey had six soil object categories, with cut wood not being found in the data set used for comparison. The BGS survey had thirty-two, however only 16 of these featured in the BGS dataset. Soil Object categories used in the survey were identified and the BGS Soil Object categories were reclassified under those OPAL categories which matched them most closely, as in *Table 4.6* below.

Table 4.6 Comparable non natural soil object categories in OPAL Soil and Earthworm and BGS London Earth Surveys

OPAL Soil Object Categories	BGS Soil Object Categories
Construction Material	Ceramic Waste Pottery Bricks Glazed China China Clay Tailings
Metal	Manufactured Metal Iron, Steel Wire Copper
Glass	Clear Glass Coloured Glass
Cut Wood (Not Found)	
Other	Plastic Fertiliser Sack Rubber Coal Tailings Slag (Furnace Waste)
None	Empty Record

The objects found in soil in the OPAL survey were compared to those found in the BGS survey. Because at some sites multiple objects were found the principle was applied that if one or more of the objects found at a site in the OPAL survey was the same as one or more of those found in the BGS survey this would be considered an "exact match".

The "exact match" comparison of the soil objects found at locations by the BGS survey and IC OPAL survey was 39%. Comparison of the presence of soil objects in the soil or not between locations sampled by the BGS and the OPAL soil and earthworm survey showed 65% agreement.

This suggests that the OPAL soil survey has fairly low reliability in identifying the same soil objects as identified in a soil by the BGS soil survey, increasing to a higher level when the presence or not of soil objects is considered. However, unlike other characteristics evaluated within the two surveys, soil objects is a category which would be expected to have a large amount of variability between small differences in sampling area.

4.6 LAND-USE

The OPAL survey had nine land-use categories while the BGS survey has 57, however only 20 of these were used in the Camden and Hammersmith London Earth data set. The breakdown of survey land-use descriptions compared to BGS observed land-uses are summarised in *Table 4.7*, with inconsistent land-use descriptions identified in bold. On average for all locations the survey land-use was consistent with the BGS land use observation at 96% of locations.

Table 4.7 Breakdown of survey site land-uses by BGS London Earth land use descriptions.

BGS Land use Classifications	Garden	Grassy verge	Heath or moorland	Industrial site	Open grassy field	Other	Parkland	Playing field	Ploughed field	Wood or forest
Domestic Garden (urban)	27	14	-	-	-	7	2	1	-	-
Park	4	2	5	-	-	1	21	-	-	5
Commercial and residential	10	7	-	-	-	-	**4**	1	-	-
Minor Roads/Verge	4	13	-	-	-	3	-	-	-	-
Urban Open Space	5	6	-	-	1	1	4	-	-	1
Recreational	1	3	2	-	-	-	4	3	-	2
Urban Open Space, tended but unproductive	8	2	-	-	-	-	4	-	-	-
Mature Deciduous Forest	**2**	1	1	-	**1**	1	1	-	-	6
Playing Field	1	1	2	-	-	1	1	3	-	-
Major Roads/Verge	-	3	-	-	1	-	-	-	-	-
Recent Deciduous Forest	**1**	-	-	-	-	-	-	-	-	2
Graveyard	1	1	-	-	-	1	-	-	-	-
Rough Grazing	-	1	-	-	-	-	-	-	-	1
School	1	-	-	-	-	-	-	1	-	-
Playground	-	1	-	-	-	-	1	-	-	-
Golf Course	-	1	-	-	-	-	1	-	-	-
Railway	-	-	-	-	-	-	-	-	-	**1**
Urban Open space, cleared, derelict	-	1	-	-	-	-	-	-	-	-
Crematorium	-	-	-	-	1	-	-	-	-	-

NB. Land-use descriptions not considered to be consistent are identified in bold type on a grey background.

In order to compare more closely the land-use identification at each location between the BGS and OPAL surveys it was necessary to first standardise the land-use categories as shown in *Table 4.8* below.

Table 4.8 Comparable land-use categories in OPAL Soil and Earthworm and BGS London Earth Surveys.

OPAL Land-use Categories	***BGS Land-use Categories***
Garden	Domestic Garden (urban)
Parkland	Park Urban Open Space Urban Open Space, tended but unproductive Recreational
Playing Field	Playground Playing Field School Golf Course
Heath or Moorland (Not Found)	
Open Grassy Field	Rough Grazing
Ploughed Field (Not Found)	
Grassy Verge	Major Road/ Verge Minor Road/Verge
Industrial Site	Commercial and residential Urban open space, cleared, derelict
Other	Railway Graveyard Crematorium

In addition to exact matches a comparison was made between moderate matches and broad matches. Land-uses were grouped into categories which reflected their similar characteristics (*Table 4.9*).

Table 4.9 Grouping of Similar Land Uses into Categories

Land-use	**Category**
Parkland Garden Playing Field Grassy Verge	1
Open Grassy Field Ploughed Field	2
Wood or Forest Heath or Moorland	3
Industrial Site Other	4

Category 1 contained all Land-uses that were predominantly grass with few to no trees, managed by people, used primarily for recreation and a common feature of the urban environment.

Category 2 contained all Land-uses that were predominantly grass with few to no trees and managed by people, but were not used primarily for recreation and were not a common feature of the urban environment.

Category 3 contained all Land-uses that were predominantly low growing, shrubs or woody vegetation and trees, semi-managed or unmanaged and an uncommon feature of the urban environment.

Category 4 contained all Land-uses that were associated with a commercial/industrial use or that were classified as "other".

These categories were used to compare the BGS & IC OPAL Land-uses for matches using two different parameters, firstly "Moderate Matches" and secondly "Broad Matches".

Under "Moderate Matches", a match was defined as when the OPAL Land-use and any of the BGS Land-uses were within the same category. For example, an OPAL Land-use of Parkland and a BGS Land-use of Garden would be a match under the "Moderate Match" parameters.

In an analysis of exact matches, 54% of the OPAL land use classifications matched those of the BGS. This increased to 77% under "moderate match" parameters.

These results show that identifications of Land-use during the OPAL survey closely matched those identified during the BGS survey. Even under the most stringent parameters, more than half of all OPAL identifications were exact matches with the BGS.

5 TASK D: LAND-USE REPRESENTATIVENESS

5.1 REFERENCE DATA SOURCE: CEH LAND COVER MAP 2000

The Land Cover Map 2000 (LCM2000) is a digital vector map constructed using satellite data with knowledge based correction and is based on minimum mappable units of half a hectare. The map classifies land-use within one of 16 terrestrial and inshore groups of Broad Habitats. Divisions within some of these Broad Habitats results in 27 Subclasses, however the Broad Habitats provide sufficient detail for the purpose of comparison with the survey data. Each survey land-use could reasonably correspond with more than one Broad Habitat and vice versa.

5.2 LAND-USE COMPARISON

During the survey, respondents were prompted to assign the land-use at the site to one of ten descriptions, by matching the appearance of the area to photos of representative settings. To assess the degree to which these land use descriptions were representative of conditions encountered, the previously identified land-use at each location was identified on the LCM2000 reference map. The breakdown of survey land-use descriptions compared to mapped land-uses is summarised in *Table 5.1*, with inconsistent land use descriptions identified in bold. The percentage of survey land-use descriptions consistent with the mapped LCM2000 habitat are presented in *Figure 5.1*. On average, for all locations, the survey land use was consistent with the mapped land use at 90% of locations.

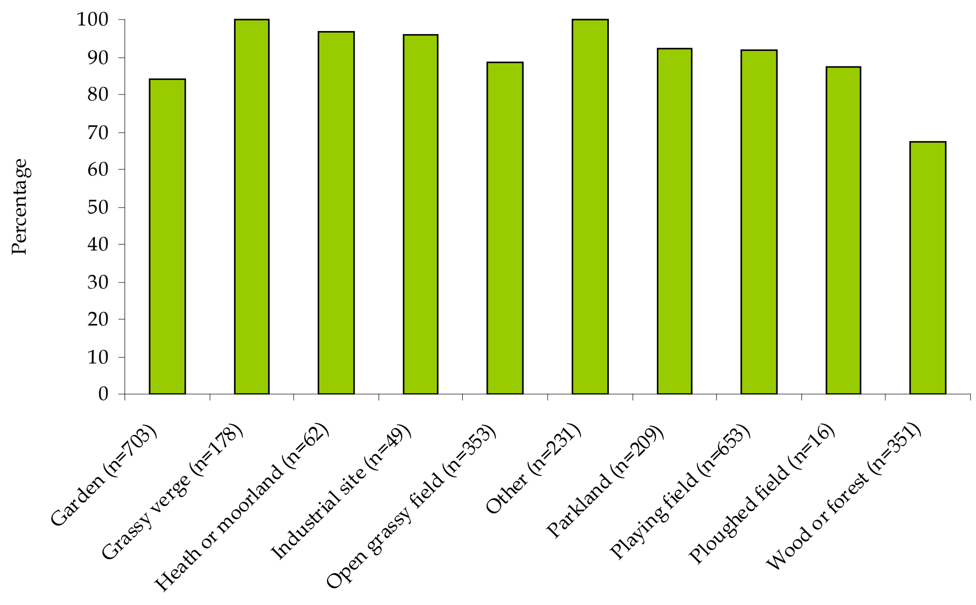


Figure 5.1 Percentage of land-use descriptions matching mapped habitats

Between 88% and 100% of individual land-use descriptions reported during the survey varied were considered to be consistent with LCM2000 mapped habitats, with the exception of the wood or forest areas, where 67% were considered to be consistent. This may be in part due to the limitations of the reference map, which classified land-use based on spectral reflectance data and may not differentiate well between grassland and evergreen woodland. Overall, it was concluded that the results of the survey were suitably representative of the land-uses encountered.

Table 5.1 Breakdown of survey site land-uses by LCM2000 land use description

LCM2000 Land-use description	Garden	Grassy verge	Heath or moorland	Industrial site	Open grassy field	Other	Parkland	Playing field	Ploughed field	Wood or forest
Broad leaved / mixed woodland	**38**	7	5	4	**27**	21	25	**16**	**1**	128
Continuous Urban	166	56	**1**	5	20	41	48	85	-	8
Suburban/rural developed	321	48	**1**	28	78	102	56	273	2	55
Improved grassland	52	19	1	7	130	29	39	132	9	**63**
Calcareous grass	16	12	2	2	24	11	10	48	-	**10**
Neutral grass	27	10	29	1	16	6	9	39	1	**11**
Arable horticulture	**50**	8	-	-	26	8	**11**	**31**	1	18
Arable cereals	**13**	6	-	**2**	4	5	**3**	**4**	1	**21**
Coniferous woodland	**8**	1	-	-	**11**	2	-	-	**1**	27
Setaside grass	2	-	4	-	1	1	2	14	-	**1**
Open dwarf shrub heath	1	-	7	-	-	-	-	-	-	-
Fen, marsh and swamp	1	-	3	-	-	-	1	**1**	-	-
Acid grass	2	9	9	-	12	1	-	5	-	**5**
Water (inland)	**3**	-	-	-	**3**	-	**2**	-	-	-
Dense dwarf shrub heath	2	-	-	-	-	-	1	-	-	-
Inland Bare Ground	1	2	-	-	-	3	1	5	-	**1**
Non-rotational arable and horticulture	-	-	-	-	1	-	-	-	-	-
Bogs (deep peat)	-	-	-	-	-	1	-	-	-	-
Bracken	-	-	-	-	-	-	1	-	-	**3**

NB. Land-use descriptions not considered to be consistent are identified in bold type on a grey background.

6 TASK E: OPAL SAMPLING EVENT-BASED ASSESSMENT OF EARTHWORM SPECIES IDENTIFICATION

6.1 OVERVIEW OF VALIDATION APPROACH

One of the main aims of the OPAL Soil and Earthworm survey is to encourage members of the general public, including school children, to collect and identify earthworms. This requires participants in the OPAL survey to use an identification guide. However, at the inception of the OPAL project the only identification guide to British earthworms was *Earthworms* by Sims & Gerard (1985). This is a technical book aimed at practicing biologists. Non-specialists find it difficult to use because of its reliance on unfamiliar terminology, and the fact that specimens must be well-preserved and examined with a microscope. One of the requirements of the OPAL survey was that participants should release the earthworms after identifying them. Therefore, a major challenge of the OPAL survey was to produce a user-friendly guide that would enable the general public to identify living earthworms. This presented two considerable obstacles: (1) to develop an identification guide that could be used by untrained individuals and deliver meaningful results, and (2) to base the guide on morphological characters that could be easily observed on live and moving earthworms.

The main scientific aims of the OPAL survey are (1) to map the distribution of earthworm species and soil properties across England, (2) to investigate the relationships between species distributions, soil properties and habitat type, and (3) to assess the ecological importance of earthworms in ecosystems by measuring their abundance, species density and functional group composition. OPAL participants were not asked to identify the functional group to which the specimens belonged. The functional groups consist of two or more species, and for the British species these have already between determined by previous research. Therefore functional group composition can be determined from species identifications even if these have a degree of error. The well-established ecological functional group classification given in Sims & Gerard (1985) was adopted: 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 fourth functional group is recognised: compost species (red stripy earthworms that live almost exclusively in compost heaps and other similar accumulations of decaying vegetation).

As the OPAL survey data was collected by school children and members of the public, a precursor to any scientific analyses of the data is an assessment of its quality. It is essential to know the extent to which OPAL participants have correctly identified the earthworms they collected in the survey. As a large proportion of the OPAL participants were school children, we also needed to know whether there was a significant difference in the accuracy of identifications made by adults compared with children.

Two methods were available for assessing the identifications. The first involved an earthworm specialist (ES) examining directly a number of specimens collected by OPAL participants to check if their identifications were correct. The second method used other data recorded in the OPAL survey to assess the identifications. Participants were asked to record the length of the individual earthworms they identified, and these lengths were then compared with the known size ranges for each species.

The assessment produced by the first method was considered more reliable than the second because it was generated by an external expert. In contrast, the second method was considered less reliable because the quality of the verifying data (specimen length) was not independent or objective, as it relied on the competency of the OPAL participant.

6.2 OBJECTIVES OF DATA QUALITY ASSESSMENT

The overall aim was to assess how accurately the OPAL guide could be used by non-specialists. To achieve this, the specific objectives were:

1. to measure the proportion of OPAL earthworms that have been correctly identified to species, based on the direct examination of OPAL specimens;

2. to calculate the proportion of OPAL earthworms that can be correctly assigned to functional groups;

3. to test whether there was a significant difference in the levels of identification between adults and children;

4. to assess the usefulness of the specimen body lengths recorded by OPAL participants.

6.3 IDENTIFICATION METHODS

The Earthworm Specialist and/or OPAL Community Scientists attended numerous OPAL survey events across the country. The ES also organised similar earthworm sampling events in which non-specialist members of the public used the OPAL field guide to identify the specimens they found. Participants were observed while they were collecting earthworms and identifying them using the OPAL guide. After they had made their identifications, the earthworms were collected, preserved in vials of alcohol and labelled with the identification given by the participants. No assistance with identification was given to the participants until after they had recorded their final identifications. In total, earthworms were collected from 149 OPAL surveys or similar sampling events.

Participants were recorded as either adults or children (up to the age of sixteen). In a minority of cases the survey was done by family groups made up of adults and children. These groups were observed carefully to assess whether the adults guided the children to a taxonomic decision, or whether the adults deferred to the decisions of the children. Each group was then recorded as either adult or child depending on which had the biggest influence over the outcome of the identification process.

All specimens were identified at the Natural History Museum by the ES using a microscope and Sims & Gerard (1985). Fisher's exact test was used to compare the proportion of specimens correctly identified by adults versus children. The collated data were compared with the Natural History Museum's Soil Biodiversity Group (SBG) earthworm species database. The SBG database consisted of 5,281 verified species records collected by researchers and PhD students of the SBG during field work at 50+

localities across England. For the purposes of this study, SBG records from rare or extreme habitat types were excluded as these habitats were very unlikely to be sampled during the OPAL survey. The revised SBG dataset consisted mainly of earthworm samples from gardens, amenity grasslands, pasture, broadleaf woodlands and arable fields.

6.4 RESULTS

From the OPAL surveys and sampling events visited, a total of 595 earthworms were collected (hereafter called the OPAL control dataset). Sixteen specimens were excluded because they were too damaged to be identified. Of the remaining 579 specimens, 319 (53.6%) had been identified by adult participants and 260 (43.7%) had been identified by child participants.

6.4.1 Species distribution

All specimens in the OPAL control dataset were examined to verify their species identifications. The species distribution was then compared with the distribution of the SBG dataset (*Figure 6.1*). Overall, the distribution patterns given in *Figure 6.1* were very similar, with Spearman's rank correlation showing no significant difference in the ranked species distributions of the OPAL control and SBG datasets ($r_s = 0.933$, $P < 0.00001$). The 12 species of earthworm illustrated in the OPAL field guide represented 93% of all specimens in the SBG dataset. This proportion was not significantly different from the proportion (95%) in the OPAL control dataset (Fisher's exact test, $P = 0.279$), indicating that the field guide covered all the common species in most habitats in England.

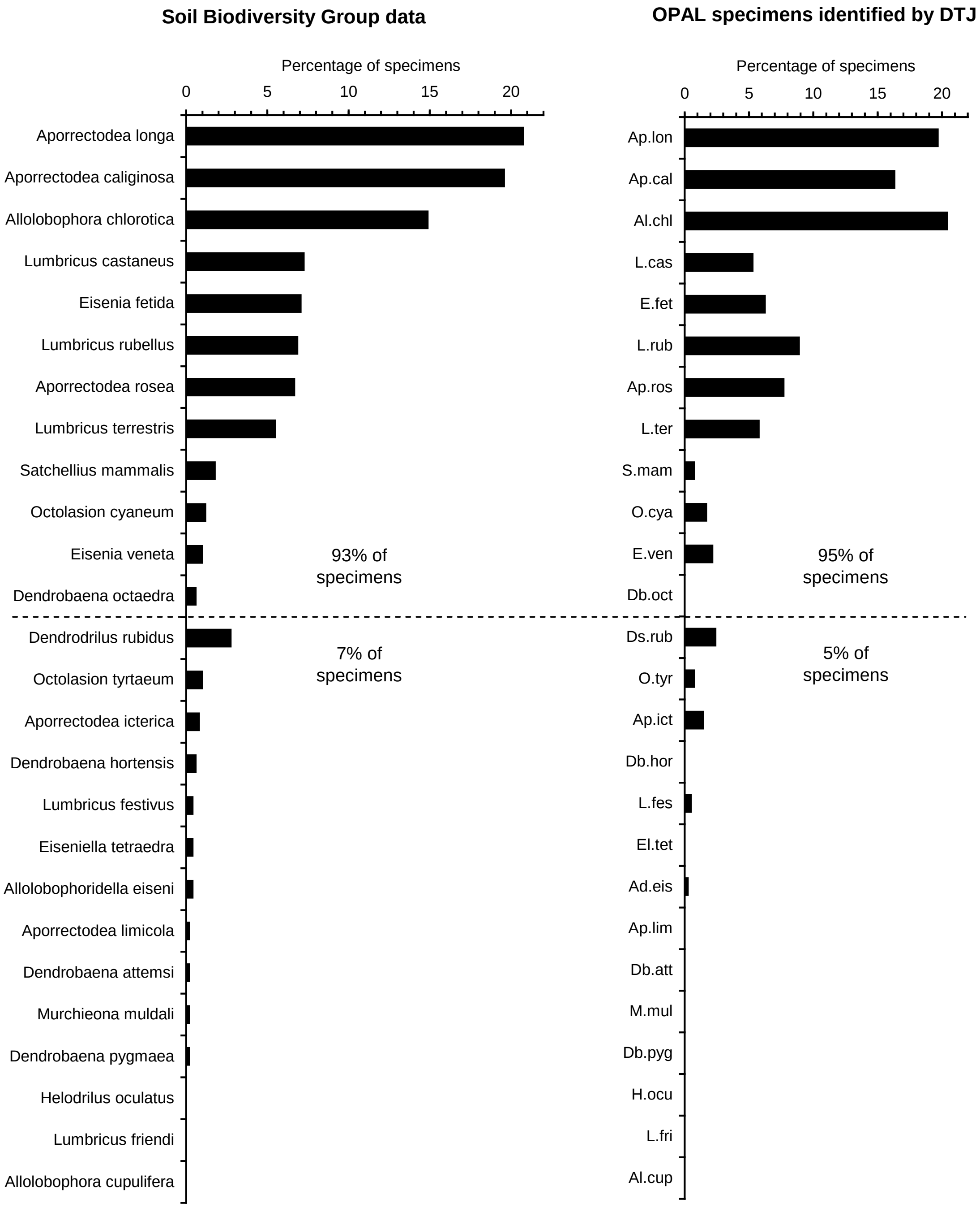


Figure 6.1 Species distributions of earthworm specimens in the SBG dataset and the OPAL control dataset. The species above the dotted line are the 12 species illustrated in the OPAL field guide.

6.4.2 Species identifications

Overall, participants identified 61.1% of specimens to species correctly. However, within this, some species were "easier" to identify than others (*Table 6.1*). At 86%, *Aporrectodea longa* had the highest proportion of correctly identified specimens.

Table 6.1 Percentage of earthworms correctly identified to species using the OPAL field guide.

All specimens	61.1%
Black-headed worm *Aporrectodea longa*	86%
Grey worm *Aporrectodea caliginosa*	69%
Green worm *Allolobophora chlorotica*	81%
Chestnut worm *Lumbricus castaneus*	42%
Brandling worm *Eisenia fetida*	48%
Redhead worm *Lumbricus rubellus*	58%
Rosy-tipped worm *Aporrectodea rosea*	74%
Lob worm *Lumbricus terrestris*	51%
Little tree worm *Satchellius mammalis*	60%
Blue-grey worm *Octolasion cyaneum*	19%
Compost worm *Eisenia veneta*	33%
Octagonal-tailed worm *Dendrobaena octaedra*	0%

Adults were significantly better than children at identifying earthworms (Fisher's exact test, P = 0.0085) with 66.2% of their specimens being correct, compared with the children who correctly identified only 53.3% of specimens. Considering individual species (*Table 6.2*), adults were significantly better than children at identifying *Aporrectodea longa* and *Aporrectodea rosea*.

Table 6.2 Percentages of earthworms correctly identified by adults and children using the OPAL field guide.

	Adults	Children
All specimens	66.2%**	53.3%
Black-headed worm *Aporrectodea longa*	98%***	64%
Grey worm *Aporrectodea caliginosa*	73%^{NS}	64%
Green worm *Allolobophora chlorotica*	78%^{NS}	84%
Chestnut worm *Lumbricus castaneus*	54%^{NS}	17%
Brandling worm *Eisenia fetida*	60%^{NS}	36%
Redhead worm *Lumbricus rubellus*	56%^{NS}	60%
Rosy-tipped worm *Aporrectodea rosea*	93%*	50%
Lob worm *Lumbricus terrestris*	50%^{NS}	55%
Little tree worm *Satchellius mammalis*	75%^{NS}	0%
Blue-grey worm *Octolasion cyaneum*	27%^{NS}	9%
Compost worm *Eisenia veneta*	50%^{NS}	11%
Octagonal-tailed worm *Dendrobaena octaedra*	0%^{NS}	0%

Note: * = P < 0.05; ** = P < 0.01; *** = P < 0.001; NS = not significant

6.4.3 Functional group identifications

Based on the participants' species identifications, 82.3% of specimens could be assigned to their correct functional group. This varied from 92% for epigeic earthworms to only 60% for compost earthworms (*Table 6.3*).

Table 6.3 Percentage of earthworms that could be correctly assigned to functional group based on the species identifications made by participants using the OPAL field guide.

All specimens	82.3%
Anecic (deep burrowing) earthworms:	88.3%
Aporrectodea longa	
Lumbricus terrestris	
Epigeic (surface litter-feeding) earthworms:	67.1%
Lumbricus castaneus	
Lumbricus rubellus	
Lumbricus festivus	
Lumbricus friendi	
Dendrobaena octaedra	
Dendrobaena attemsi	
Dendrobaena pygmaea	
Dendrobaena hortensis	
Dendrodrilus rubidus	
Satchellius mammalis	
Endogeic (soil-feeding) earthworms:	92.0%
Allolobophora chlorotica	
Aporrectodea caliginosa	
Aporrectodea rosea	
Aporrectodea icterica	
Aporrectodea limicola	
Allolobophoridella eiseni	
Eiseniella tetraedra	
Octolasion cyaneum	
Octolasion tyrtaeum	
Murchieona muldali	
Compost earthworms:	60.0%
Eisenia fetida	
Eisenia veneta	

Overall, 88.1% of specimens identified to species by adult participants could be correctly assigned to functional group, which is significantly higher than the 73.4% of specimens identified by children (Fisher's exact test, P = 0.0002). This was due to the fact that adults were significantly better than children at identifying earthworm species (*Table 6.2*).

Comparing functional groups, adult identifications gave significantly higher proportions of correct assignments to three of the groups (anecic, epigeic and compost earthworms) than did the children's identifications (*Table 6.4*). There was no significant difference for endogeic earthworms between adults and children.

Table 6.4 Percentage of earthworms that can be correctly assigned to functional group based on the species identifications made by adults and children using the OPAL field guide.

Functional group	Adult	Children
All specimens	88.1%***	73.4%
Anecic (deep burrowing) earthworms	96%**	73%
Epigeic (surface litter-feeding) earthworms	79%**	45%
Endogeic (soil-feeding) earthworms	92%^{NS}	93%
Compost earthworms	74%*	44%

Note: * = P < 0.05; ** = P < 0.01; *** = P < 0.001; NS = not significant

6.4.4 Earthworm body lengths

The body lengths of adult earthworms collected and measured by OPAL participants and submitted to the OPAL website were compared with the size ranges given in Sims & Gerard (1985). For some species the size range was extended with the inclusion of additional information provided by the examination of preserved material in the Natural History Museum's collections and the SBG specimens. One third of all body lengths recorded by OPAL participants were outside the size range for the species identified. The individual species are given in *Table 6.5*.

Table 6.5 Percentage of OPAL earthworm specimen records that fall outside the known size range for adults of that species.

All specimens	33.3%
Black-headed worm *Aporrectodea longa*	51.8%
Grey worm *Aporrectodea caliginosa*	20.3%
Green worm *Allolobophora chlorotica*	35.4%
Chestnut worm *Lumbricus castaneus*	31.1%
Brandling worm *Eisenia fetida*	16.6%
Redhead worm *Lumbricus rubellus*	8.9%
Rosy-tipped worm *Aporrectodea rosea*	25.7%
Lob worm *Lumbricus terrestris*	52.8%
Little tree worm *Satchellius mammalis*	66.7%
Blue-grey worm *Octolasion cyaneum*	12.7%
Compost worm *Eisenia veneta*	26.9%
Octagonal-tailed worm *Dendrobaena octaedra*	50.9%

If the body lengths recorded by OPAL participants were accepted as being reliable, then rates of misidentification would be substantially higher than the levels of misidentification seen in the ES dataset. As the identification results observed in the ES dataset were considered more reliable, this suggests that many OPAL participants did not measure body length very accurately.

6.5 EARTHWORM QUALITY ASSESSMENT: CONCLUSIONS

The OPAL control dataset was very similar to the SBG dataset in its species distribution. The OPAL survey samples were therefore considered representative in that they captured all the common species and reflected the observed species assemblage structure in most English habitats. 95% of the adult specimens collected using the sampling method employed in the OPAL survey were illustrated on the OPAL field guide, indicating that they were highly suitable species to be included in the guide.

Overall, 61% of specimens were correctly identified to species. However, adults were significantly better than children at making correct identifications, with adults getting 66% of their specimens correct compared with only 53% by children. From observations at OPAL survey events, adults had a longer attention span than children and displayed more understanding of how the key worked. While both adults and children often expressed some uncertainty in their identifications, adults were more sophisticated in how they used the key, frequently exploring both the “yes” and the “no” answers in the guide to arrive at what they thought was a more likely identification. OPAL survey records of earthworms submitted by adults can therefore be considered more reliable than those submitted by children. Adults found some species “easy” to identify, such as *Aporrectodea longa* (98% correct) and *Aporrectodea rosea* (93% correct), whilst other species appeared to be more difficult and had lower levels of identification success.

Using species identifications to assign specimens to functional groups gave reasonable results, even when the species identifications contained a higher degree of error. Again, adult identifications gave a significantly higher level of correct functional group identification compared with the children’s identifications. Functional group identification for specimens identified by adults varied from 74% for compost species, up to 96% for anecic species. If the compost worms were excluded (as they are rarely found outside of compost heaps and are not thought to have a significant ecological impact in other habitats), then the remaining functional group results for adults were considered acceptable for general analyses.

There was a high level of inconsistency for many species between the body length data and the species identifications. This reflects errors in measuring live earthworms that were observed during OPAL surveys, particularly by children. Measuring the length of wriggly earthworms is not an easy task, and appears to be a considerably greater source of error compared with the actual proportions of species misidentifications recorded in the OPAL control dataset. The submitted body length records were therefore not considered to be a reliable data source with which to verify species identifications.

7 CONCLUDING REMARKS

This report is intended to provide an assessment of data quality of the OPAL Soil and Earthworm National Survey. As the scientific objective of the survey was to develop a baseline understanding of the distribution of earthworm species and associated soil conditions in England, it was important to assess if the data collected could be demonstrated to be representative of previously established environmental conditions, reproducible following the established methodology, whether it could provide suitable spatial coverage and form a complete data set for comparability. The output of the assessment aims to provide a level of confidence that could reasonably be attained through analysis of the data. Subsequent analyses would then need to take these limitations into account when investigating the full survey dataset.

Overall, the quality assessment undertaken for this report demonstrated that levels of confidence in the data were of an acceptable level with variations depending on the final use of the data. The results of the quality assessment suggested that some outputs were more sensitive, for example to parameters such as the ability of members of the public to make detailed scientific measurements and observations and to understand the questions that were asked. Interesting findings included that the quality of data depended greatly on participant age group and their reasons for participating, and this is particularly true for identification of earthworms.

The analytical methods presented here did not aim to filter the dataset (with the exception of records with wrong location information) but to provide further information associated with its possible use. It aimed to inform users and enable them to identify whether the data was fit for the purpose they wish to use it for, and the likely levels of uncertainty they can place upon the data. For example for very specific hypothesis testing, targeted filtering could be used to maximise confidence levels in any findings based upon such analysis.