Biological Recording Company

Forest of Bowland Earthworm Survey Report

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Version 1

24 Oct 2024

Produced for

Forest of Bowland National Landscape

YORKSHIRE DALES MILLENNIUM TRUST

Acknowledgements

Earthworm Surveys

The author would like to thank those that contributed to the earthworm surveying that contributed to this report, and particularly for all of the help organising access to the sites, managing volunteer bookings and sourcing equipment.

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This report was produced by the Biological Recording Company and funded by the Yorkshire Dales Millenium Trust.

Suggested citation: Brown, K.D. (2024) Hay Time Project Survey Report [Version 1]. London: Biological Recording Company

1 Introduction

The UK is home to 31 different species of earthworm, which can be broken down into groups based on their morphology, ecology and behaviour.

Traditionally this has been by ecological category based on their morphology using three poles on a triangular scale:

- Anecic earthworms make permanent vertical burrows in soil. They feed on leaves on the soil surface that they drag into their burrows. They also cast on the surface, and these casts can quite often be seen in grasslands. Some anecic earthworm species also make middens (piles of casts) around the entrance to their burrows. Anecic species are the largest species of earthworms in the UK. They are darkly coloured at the head end (red or brown) and have paler tails.
- Endogeic earthworms live in and feed on the soil. They make horizontal burrows through the soil to move around and to feed and they will reuse these burrows to a certain extent. Endogeic earthworms are often pale colours, grey, pale pink, green or blue. Some can burrow very deeply in the soil.
- Epigeic earthworms live on the surface of the soil in leaf litter, deadwood, dung and compost. These species tend not to make burrows but live in and feed on the leaf litter. Epigeic earthworms are also often bright red or reddy-brown, and sometimes even stripy.

Earthworms were selected as an indicator of general soil biodiversity health as they are widely regarded to be of great ecological importance, with different ecological categories of earthworm contributing to soil processes and resulting in a number of ecosystem services (**Figure 1**) (Keith & Robinson, 2012).

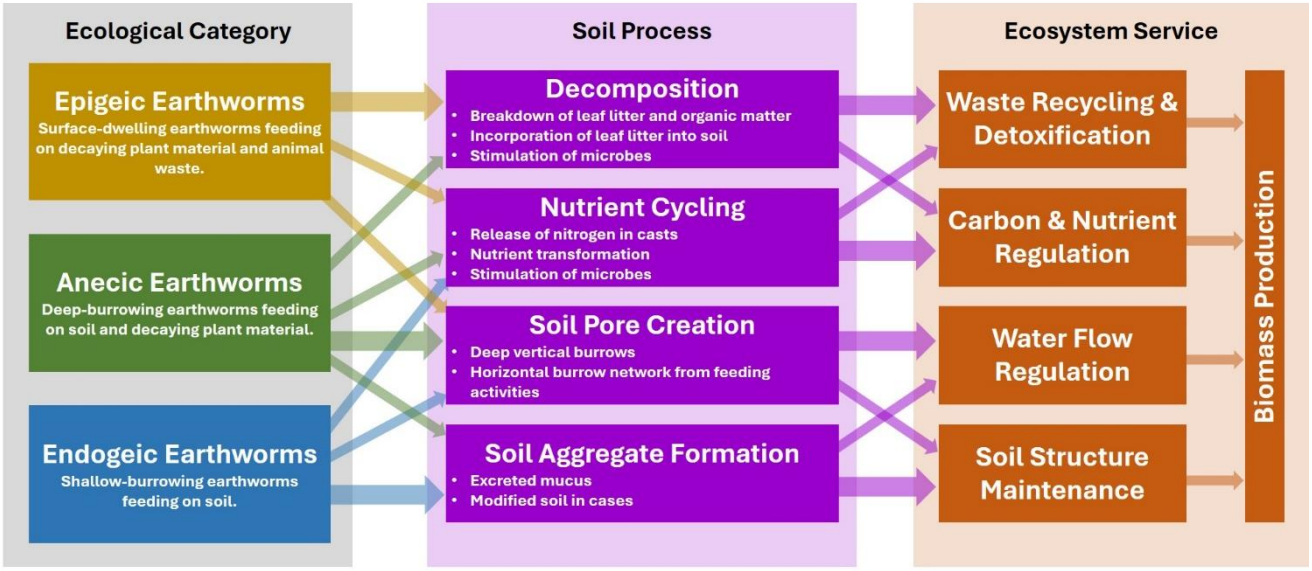


Figure 1: Earthworm ecosystem services adapted from Keith & Robinson 2012.

More recently, earthworms have been categorised into one of 6 functional groups based on their bioturbation behaviour as illustrated in **Figure 2** (and including an additional intermediate grouping) (Capowiez, Marchán, Decaëns, Hedde, & Bottinelli, 2044).

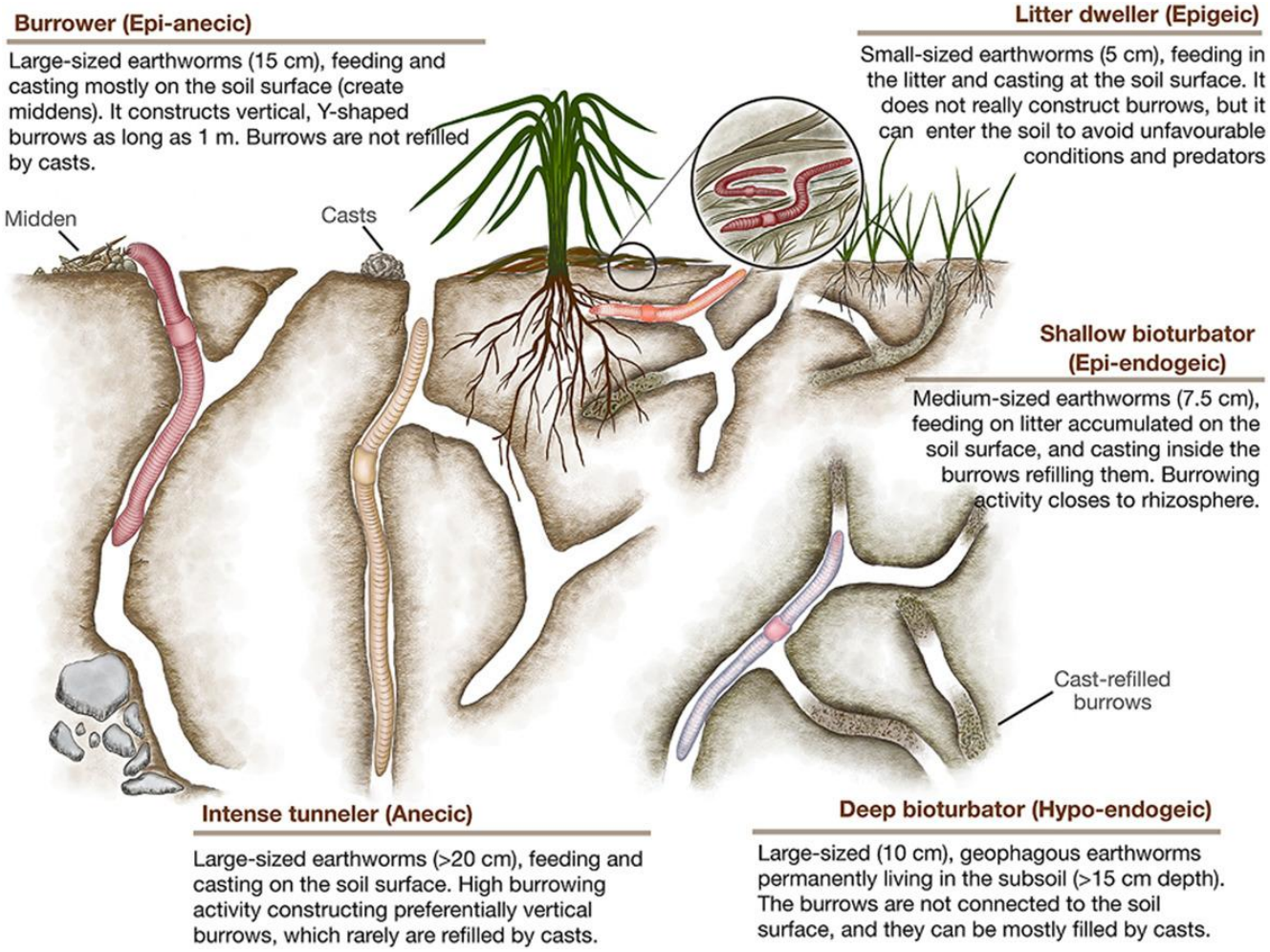


Figure 2: Earthworm Functional Groups taken from Capowiez et al (2024).

Hay meadows are one of our rarest habitats and a priority for conservation and enhancement in the UK Biodiversity Action Plan. In May of 2012, the Forest of Bowland National Landscape joined forces with the Yorkshire Dales Millennium Trust to deliver a Hay Time hay meadow restoration project here in Bowland, funded with help from the Lancashire Environment Fund.

The Hay Time project works with farmers in the Forest of Bowland National Landscape to harvest wildflower seed and 'green hay' from species-rich meadows and use this to restore meadows which have lost some of their characteristic plants. The project also aims to increase public awareness, enjoyment and understanding of the hay meadows found in the area, improve public access to meadows, and survey meadows to record the variety and number of plant species they contain.

The Hay Time earthworm surveys aim to engage the public and farmers with earthworm ecology and improve our understand of the earthworm assemblages associated with hay meadows and how the earthworm communities change over time.

The Forest of Bowland Earthworm Survey consisted of two components:

1. Hay Meadow Soil Pit Survey Transects
2. Forest of Bowland Earthworm Recording

2 Hay Meadow Soil Pit Survey Transects

This survey involved undertaking soil pit survey transects at sample sites in various stages of hay meadow restoration, ranging from potential sites that were yet to begin undertaking hay meadow restoration measures through to sites that have been undergoing restoration for up to 10 years.

2.1 Methodology

18 soil pit survey transects were undertaken across 12 survey sites over a two-year period (2023 to 2024), with 4 transect sites sampled during both years. Some survey sites (i.e. Cockshots Farm and Botton Head) had two transect sites. The number of years that each transect site had been undergoing restoration at the point of sampling was recorded for future analysis (see **Table 1**).

Table 1: Details of transects surveyed for earthworms using the 'NERS 5 pit protocol' soil pit sampling method.

	Transect Site	Survey Date	Grid Reference	Years in restoration
2023	Cockshots Farm (Top Row Field)	17/05/2023	SD778379	0
	Cockshots Farm (Wildflower Meadow)	17/05/2023	SD778378	5
	Field Head Farm	03/05/2023	SD726521	0
	Hermitage Field Community Meadow	03/05/2023	SD521649	3
	Life 4 Life Community Meadow	03/05/2023	SD523645	6
	Little Middop Farm	16/05/2023	SD839457	0
	Midge Home	16/05/2023	SD651639	0
	New Laithe	17/05/2023	SD702487	8
	The Inn at Whitewell	16/05/2023	SD657467	10
2024	Botton Head (The Barn Field)	24/04/2024	SD654632	1
	Botton Head (The Middle One)	24/04/2024	SD653635	1
	Briercliffe Farm (Wildflower Meadow)	25/04/2024	SD846415	2
	Cobble Hey	23/04/2024	SD537451	2
	Cockshots Farm (Top Row Field)	23/04/2024	SD778379	0
	Cockshots Farm (Wildflower Meadow)	23/04/2024	SD778378	6
	Hermitage Field Community Meadow	25/04/2024	SD521648	4
	Life 4 Life Community Meadow	25/04/2024	SD522644	7
	Lower Lythe	24/04/2024	SD662631	0

At each transect site a random point was selected within the target habitat and 5 soil pits were excavated, following the National Earthworm Recording Scheme guidance on soil pit sampling and the 'NERS 5 pit protocol' (Brown, Earthworm Recorders Handbook [Version 8], 2019).

For each soil pit:

1. A soil pit measuring approximately 25cm by 25cm was excavated to a depth of around 10cm was excavated. Always check the empty pit to make sure no earthworms are in the bottom or sides!

2. The soil excavated from the pit was placed on a sorting tray and the pit was checked for any earthworms.

3. Any adult earthworms that were found in the soil were removed and collected into a labelled sample tube.

4. Any juvenile earthworms that were found were returned to the soil pit and the total number of earthworms returned to the soil were recorded.

5. The soil was returned to the pit once the contents has been sorted and compacted down to avoid leaving a hole or uneven surface that people could trip over.

Figure 3: Hand-sorting of excavated soil for earthworms. Image: Anna Rebmann.

For each transect site:

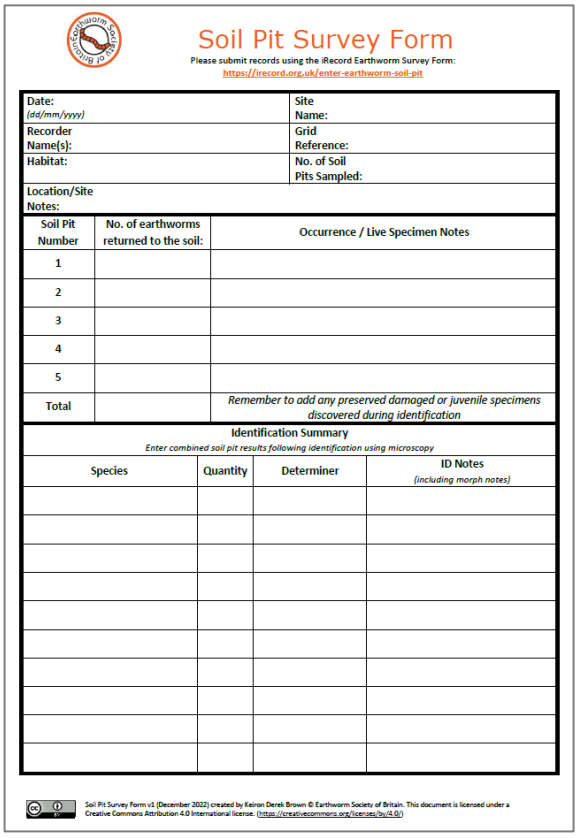
1. 5 replicate soil pit excavations were completed, all within the same 100 m OS grid square.

2. A Soil Pit Survey Form was completed, recording the sampling date, name of the field and location (e.g., Wildflower Meadow, Cockshots Farm), name of the lead surveyor (recorder name), 6-figure OS grid reference, habitat, number of soil pits sampled (i.e. 5) and any other notes regarding the sampling site.

3. All earthworm specimens were examined and identified where possible using a microscope the Key to the Earthworms of the UK & Ireland (2nd Edition).

4. The total number of unidentified earthworms was calculated by adding the number of unidentifiable specimens from the sample tubes to the number of specimens returned to the soil in the field.

5. The data for each site was submitted to the National earthworm Recording Scheme via the Soil Pit Survey form on iRecord. All records have since been accepted to the National Earthworm Recording Scheme and have passed the National Earthworm Recording Scheme verification protocol (Brown, Verification, 2022).



Soil Pit Survey Form

Please submit records using the iRecord Earthworm Survey Form:
https://irecord.org.uk/enter-earthworm-soil-pit

Date: *(dd/mm/yyyy)*	Site Name:
Recorder Name(s):	Grid Reference:
Habitat:	No. of Soil Pits Sampled:
Location/Site Notes:	

Soil Pit Number	No. of earthworms returned to the soil:	Occurrence / Live Specimen Notes
1		
2		
3		
4		
5		
Total		*Remember to add any preserved damaged or juvenile specimens discovered during identification*

Identification Summary

Enter combined soil pit results following identification using microscopy

Species	Quantity	Determiner	ID Notes *(including morph notes)*

Figure 4: Soil Pit Survey Form used to record sample site details and number of unidentified earthworms returned to the soil. Image: Earthworm Society of Britain.

2.2 Limitations of the survey methodology

1. Soil conditions can vary greatly within a single site and are known to have a significant influence on earthworm populations. It is therefore recommended that more than 5 sample points per site are surveyed to gather robust data to inform any conclusions regarding earthworm abundance and diversity at any given location. The budget and capacity for this survey were limited so it was decided to opt for a lower number of replicates per site in order to gather data on a larger number of sites.

2. Weather is an important factor as it has a direct impact on soil conditions, particularly soil moisture. Survey results may need to be taken in context with seasonal and annual weather cycles.

3. Soil pit surveying is effective for extracting soil-dwelling species, particularly endogeic species from the top layers of soil and can easily be standardised and used to gain good qualitative data for research. However, as a sampling method it is biased towards soil-dwelling species (particularly endogeic species) and less effective than mustard sampling for extracting deep-burrowing anecic species.

2.3 Results

A total of 1,833 individual earthworms were recorded across the 18 transects, consisting of 14 different species. Of these specimens, 507 were identifiable to species level. A summary of earthworm abundance and species diversity is provided in **Table 2** and **Figure 5**.

The total number of earthworms recorded within a single transect ranged from 14 to 180, with an average of 102 earthworms per transect. The wildflower meadow at Cockshots Farm was the site with the most earthworms in both 2023 and 2024. Species diversity by soil pit transect ranged from 2 species to 7 species. Species counts by transect are provided in **Table 3** and the total survey species composition is provided in **Figure 6.**

Table 2: Earthworm survey totals and species diversity by transect.

	Transect Site	Adults Total	Unidentified Total	Total Earthworms	Species Diversity
2023	Cockshots Farm (Top Row Field)	42	97	139	7
	Cockshots Farm (Wildflower Meadow)	54	105	159	6
	Field Head Farm	21	118	139	5
	Hermitage Field Community Meadow	4	37	41	2
	Life 4 Life Community Meadow	11	40	51	4
	Little Middop Farm	20	44	64	7
	Midge Home	18	56	74	4
	New Laithe	22	94	116	4
	The Inn at Whitewell	4	54	58	3
2024	Botton Head (The Barn Field)	28	69	97	6
	Botton Head (The Middle One)	8	6	14	4
	Briercliffe Farm (Wildflower Meadow)	52	48	100	5
	Cobble Hey	40	87	127	6
	Cockshots Farm (Top Row Field)	36	102	138	6
	Cockshots Farm (Wildflower Meadow)	45	135	180	7
	Hermitage Field Community Meadow	27	75	102	5
	Life 4 Life Community Meadow	31	59	90	6
	Lower Lythe	44	100	144	6
	TOTAL	507	1326	1833	14

Table 3: Numbers of earthworms determined to species by transect.

		Species												
	Transect site	*Allolobophora chlorotica*	*Aporrectodea caliginosa*	*Aporrectodea icterica*	*Aporrectodea limicola*	*Aporrectodea longa*	*Aporrectodea rosea*	*Eiseniella tetraedra*	*Lumbricus castaneus*	*Lumbricus festivus*	*Lumbricus rubellus*	*Lumbricus terrestris*	*Octolasion cyaneum*	*Octolasion lacteum*	*Satchellius mammalis*
2023	Cockshots Farm (Top Row Field)	25	4		8	2		1	1						1
	Cockshots Farm (Wildflower Meadow)	13	7		24	4				3					3
	Field Head Farm	16	1			1	2					1			
	Hermitage Field Community Meadow		3										1		
	Life 4 Life Community Meadow	1	5	3									2		
	Little Middop Farm	2	8				1				3	1	4		1
	Midge Home	11						1			1			5	
	New Laithe	15	5				1					1			
	The Inn at Whitewell	2	1						1						
2024	Botton Head (The Barn Field)	18	1				4				1	1	3		
	Botton Head (The Middle One)	4					2		1		1				
	Briercliffe Farm (Wildflower Meadow)	38	1			7	4	2							
	Cobble Hey	18	14		3	1	3				1				
	Cockshots Farm (Top Row Field)	8	3		12	11	1								1
	Cockshots Farm (Wildflower Meadow)	19	2		11	3	4				1				5
	Hermitage Field Community Meadow	3	6	1	15						2				
	Life 4 Life Community Meadow		9	13	5	2					1				1
	Lower Lythe	15	18				7				2		1	1	
	TOTAL	208	88	17	78	31	29	4	3	3	13	4	11	6	12

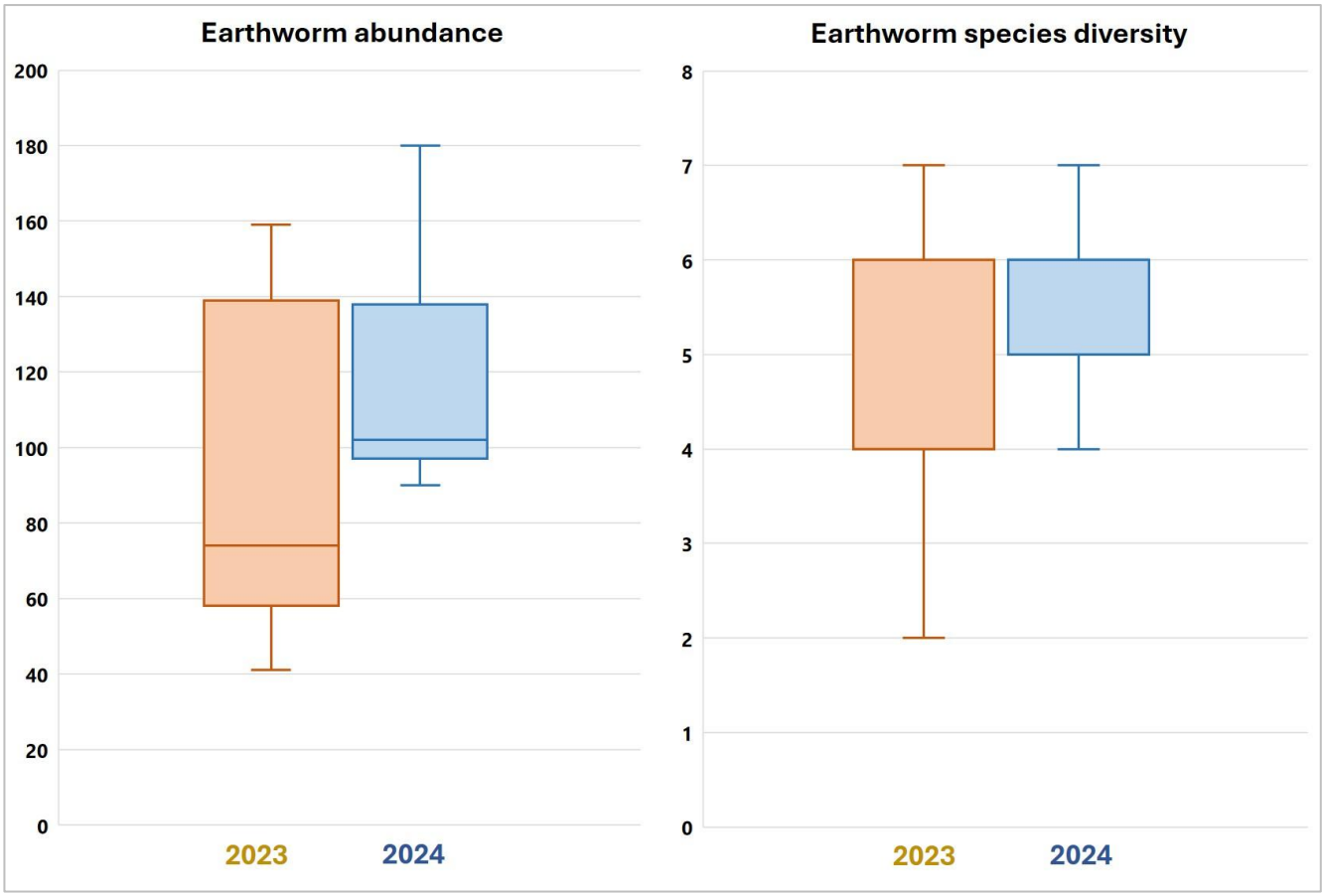


Figure 5: Box and whisker plots illustrating earthworm abundance and species diversity of soil pit survey transects by sampling year. (n = 18)

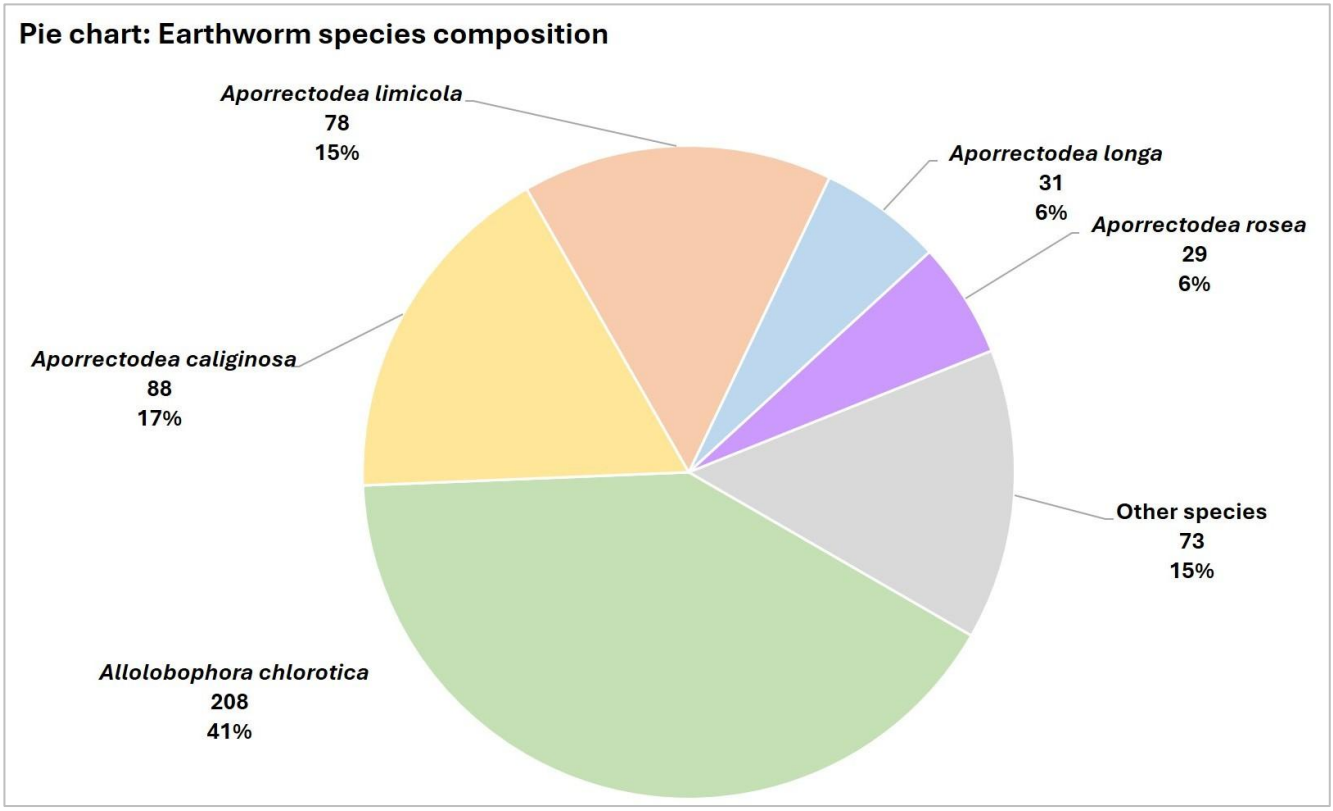


Figure 6: Pie chart displaying the earthworm species composition across all soil pit transects. Species where the composition was less than 5% were aggregated into the 'Other species' category. (n = 507)

3 Forest of Bowland Earthworm Recording

This survey involved searching a range of above and below-ground habitats for earthworms in addition to the hay meadow soil pit survey transects at some sites to increase the number of species recorded. During 2023 and 2024 earthworms were recorded at a total of 13 survey sites.

3.1 Methodology

Any adult earthworms that were found through additional searches were collected into a labelled sample tube for each different location, sampling method and habitat.

1. Biological recording forms were completed for each record, including the following information: sampling date, name of the location, name of the recorder, 6-figure OS grid reference, habitat, sampling method and any other notes relevant to the record.

2. All earthworm specimens were examined and identified by Keiron Derek Brown where possible using a microscope and the Key to the Earthworms of the UK & Ireland (2nd Edition).

3. The data for each record was submitted to the National Earthworm Recording Scheme via iRecord. All records have since been accepted to the National Earthworm Recording Scheme and have passed the National Earthworm Recording Scheme verification protocol (Brown, Verification, 2022).

4. The ad hoc data generated through Forest of Bowland Earthworm Recording was collated alongside the Hay Meadow Soil Pit Survey earthworm species occurrence data and any existing earthworm records held within the National Earthworm Recording Scheme to generate Earthworm Site Species List for each site visited. The results of this are reported n the Results section of this report.

3.2 Limitations of the survey methodology

1. Comprehensive earthworm surveys were not undertaken so resulting earthworm site species lists only convey confirmed presence of a species and do not infer absence.

2. Weather is an important factor as it has a direct impact on soil conditions, particularly soil moisture. Survey results may need to be taken in context with seasonal and annual weather cycles.

3.3 Results

After combining the data from the hay meadow soil pit survey transect and microhabitat searches, a total of 1,937 individual earthworms were recorded across the 13 survey sites where earthworm recording occurred. Of these specimens, 554 were identifiable to species level.

124 new earthworm species occurrence records were submitted to the National Earthworm Recording Scheme, where they were shared locally (via Greenspace Information for Greater London), nationally (via the National Biodiversity Network Atlas) and internationally (via the Global Biodiversity Information Facility).

A further 4 earthworm records were extracted from the National Earthworm Recording Scheme database from a previous survey at Gisburn Forest by Forest research in May 2021.

Details of the 13 survey sites and the respective number of records and species diversity is presented in Table 4. Species lists for all 13 survey sites are presented in **Table 5**.

Table 4: Summary of survey sites for the Forest of Bowland Earthworm Survey.

Site Name	Vice County	No. Records	No. Species
Botton Head	60 West Lancashire	15	9
Briercliffe Farm	59 South Lancashire	5	5
Cobble Hey	60 West Lancashire	8	6
Cockshots Farm	59 South Lancashire	30	11
Life 4 Life Community Meadow	60 West Lancashire	15	11
Hermitage Field Community Meadow	60 West Lancashire	11	7
Lower Lythe	60 West Lancashire	6	6
Gisburn Forest	64 Mid-west Yorkshire	12	5
Field Head Farm	64 Mid-west Yorkshire	6	5
Little Middop Farm	64 Mid-west Yorkshire	7	7
Midge Home	60 West Lancashire	5	4
The Inn at Whitewell	64 Mid-west Yorkshire	3	3
New Laithe	64 Mid-west Yorkshire	5	4
TOTAL		**128**	**20**

A number of rare species (see **Table 6**) were detected through the earthworm record and soil pit survey transects undertaken across the survey sites:

- *Aporrectodea icterica* was recorded at both the Hermitage Field Community Meadow and Life 4 Life Community Meadow sites. Nationally this deep bioturbating species is classified as rare. This species appears to be common and widespread across urban environments in London, particularly in grasslands (including amenity grassland), but records in the north of England and Scotland are very few and sparse.
- *Aporrectodea limicola* is a rare species that is thought to be a shallow bioturbator that has a preference for wet soils. The distribution in England appears to be restricted to the west and north. in England. This species was recorded at 5 of the 13 survey sites and was the third most recorded species within the soil pit survey transects (accounting for 15% of all adults recorded), indicating that the species appears to be thriving at these sites.
- *Dendrobaena hortensis* is a litter dwelling species with a restricted distribution that was recorded n Gisburn Forest. This was the first record of this species submitted to the National Earthworm Recording Scheme for Vice County 64 (Mid-west Yorkshire).

4 Conclusions

The Hay Meadow Soil Pit Survey Transects are generating a dataset that will provide information regarding earthworm assemblages associated with hay meadows at various stages of restoration. Further surveying and data collection will improve this data for analysis at a later date.

Compilation of 13 earthworm site species lists has highlighted that a number of rare earthworm species are present within the Forest of Bowland. This includes two species that are thought to be particularly rare in the north of England, and a third rare species that appears to be thriving within the environments where it was detected. The lists also highlighted two species (one rare and one uncommon) that had not been previously recorded with the vice county where they were detected.

Table 5: List of earthworm species recording across Forest of Bowland Earthworm Survey sites.

Site Name	Botton Head	Briercliffe Farm	Cobble Hey	Cockshots Farm	Life 4 Life Community Meadow	Hermitage Field Community Meadow	Lower Lythe	Gisburn Forest	Field Head Farm	Little Middop Farm	Midge Home	The Inn at Whitewell	New Laithe
Allolobophora chlorotica	x	x	x	x	x	x	x	x	x	x	x	x	x
Aporrectodea caliginosa	x	x	x	x	x	x	x	x	x	x		x	x
Aporrectodea icterica					x	x							
Aporrectodea limicola	x		x	x	x	x							
Aporrectodea longa	x	x	x	x	x				x				
Aporrectodea rosea	x	x		x		x	x	x	x	x			x
Bimastos eiseni								x					
Bimastos rubidus				x	x			x					
Dendrobaena attemsi								x					
Dendrobaena hortensis								x					
Dendrobaena octaedra								x					
Eisenia andrei/fetida agg.			x										
Eiseniella tetraedra	x	x		x	x						x		
Lumbricus castaneus	x			x	x							x	
Lumbricus festivus				x									
Lumbricus rubellus	x		x	x	x	x	x	x		x	x		
Lumbricus terrestris	x								x	x			x
Octolasion cyaneum					x	x	x			x			
Octolasion lacteum							x				x		
Satchellius mammalis				x	x					x			

Table 6: Summary of earthworm species recorded within this survey.

Species	Functional group (ecological category)	Distribution	Habitat specificity	Rarity
Allolobophora chlorotica	Shallow bioturbator (Epi-endogeic)	Widespread	Low	Very common
Aporrectodea caliginosa	Shallow bioturbator (Epi-endogeic) [2]	Widespread	Low	Very common
Aporrectodea icterica	Deep bioturbator (Hypo-endogeic)	Restricted	High	Rare
Aporrectodea limicola	Shallow bioturbator (Epi-endogeic) [3]	Restricted	High	Rare
Aporrectodea longa	Intense tunneler (Anecic) [2]	Widespread	Low	Common
Aporrectodea rosea	Shallow bioturbator (Epi-endogeic) [2]	Widespread	Low	Common
Bimastos eiseni [1]	Litter dweller (Epigeic) [3]	Widespread	Moderate	Common
Bimastos rubidus [1]	Litter dweller (Epigeic) [3]	Moderately widespread	Moderate	Uncommon
Dendrobaena attemsi	Litter dweller (Epigeic) [3]	Moderately widespread	Moderate	Uncommon
Dendrobaena hortensis	Litter dweller (Epigeic) [2]	Restricted	High	Rare
Dendrobaena octaedra	Litter dweller (Epigeic) [3]	Moderately widespread	Moderate	Uncommon
Eisenia andrei/fetida agg.	Litter dweller (Epigeic)	Moderately widespread	High	Uncommon
Eiseniella tetraedra	Litter dweller (Epigeic)	Widespread	Low	Common
Lumbricus castaneus	Litter dweller (Epigeic)	Widespread	Low	Common
Lumbricus festivus	Burrower (Epi-anecic) [3]	Moderately widespread	Moderate	Uncommon
Lumbricus rubellus	Litter dweller (Epigeic)	Widespread	Low	Common
Lumbricus terrestris	Burrower (Epi-anecic)	Widespread	Moderate	Common
Octolasion cyaneum	Deep bioturbator (Hypo-endogeic)	Widespread	Low	Common
Octolasion lacteum	Deep bioturbator (Hypo-endogeic) [2]	Moderately widespread	Moderate	Uncommon
Satchellius mammalis	Litter dweller (Epigeic)	Moderately widespread	Low	Uncommon

[1] Species is non-native in the UK. [2] Functional group estimated by author instead of using group established by Capowiez et al (2024). [3] Functional group estimated by author as not established in Capowiez et al (2024).

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