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# Forestry England's aspirations for eDNA

Dr Andrew Stringer

# Closer than you think...

**We look after more than 1,500 forests and woods**

99% of people live within an hour's drive of one of our forests

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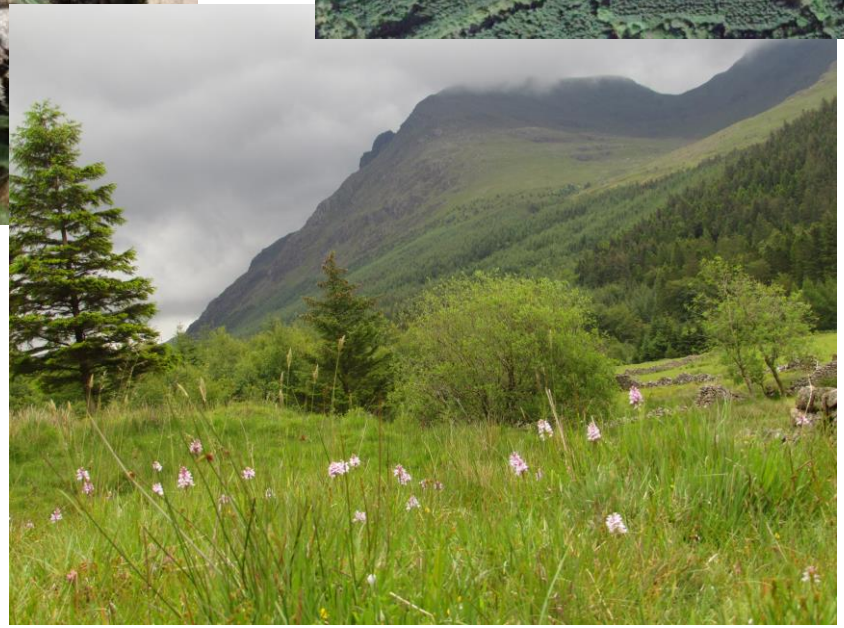
# Biodiversity plan focus areas:

- Protected species, sites, and watercourses



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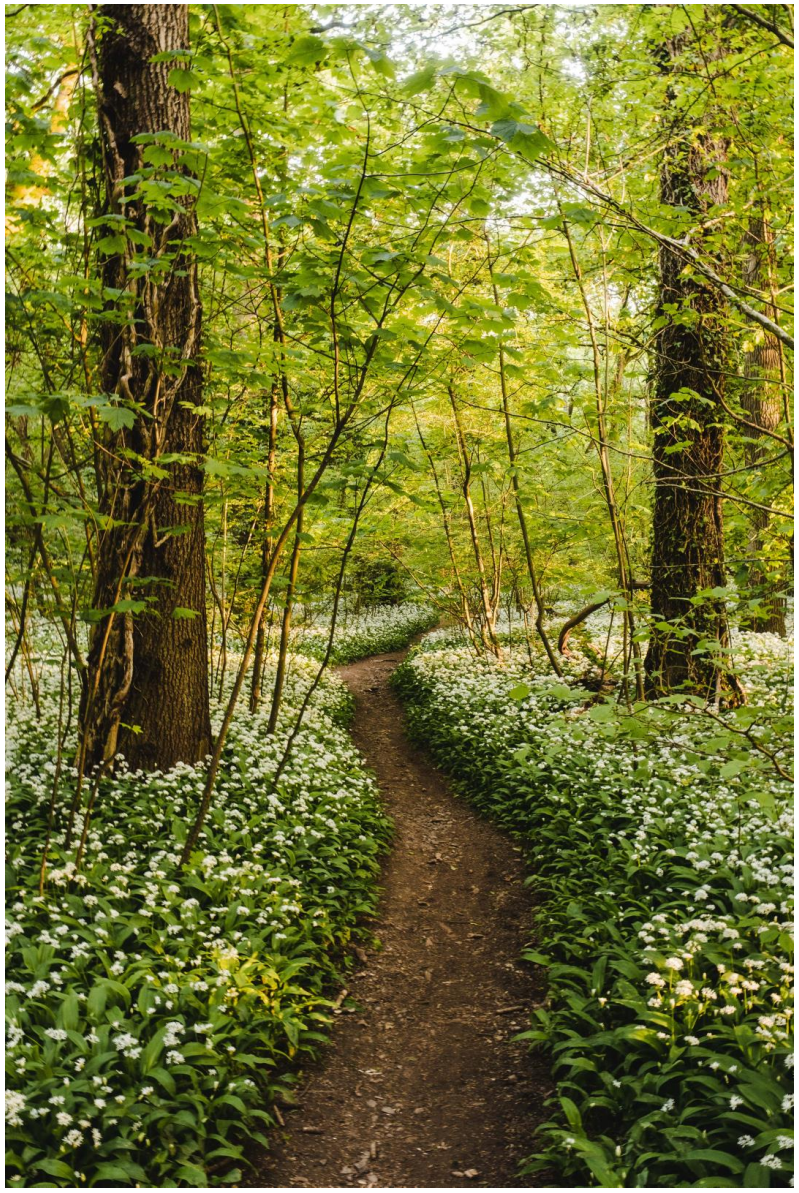
# Biodiversity plan focus areas:

- **Protected species, sites, and watercourses**
- **Ancient woodlands**

In 2007 we committed to restoring all 42,814 ha of our Plantations on Ancient Woodland Sites (PAWS). The easily restored sites have all been achieved, with 9,979 ha (23%) restored to >80% native woodland.



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# Biodiversity plan focus areas:

- Protected species, sites, and watercourses
- Ancient woodlands
- Open and dynamic habitats

In 2013 we had 16.8% open habitats, and the 2013 strategy committed us to 21.1% by 2060. Currently at 18.9% (5052 ha created).

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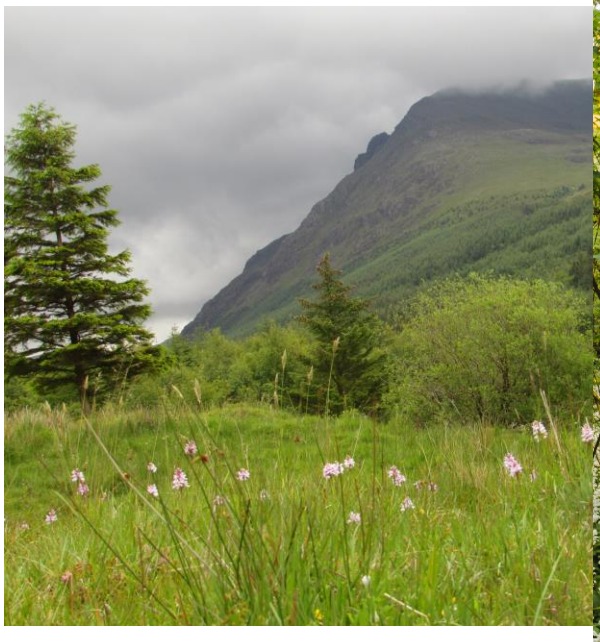
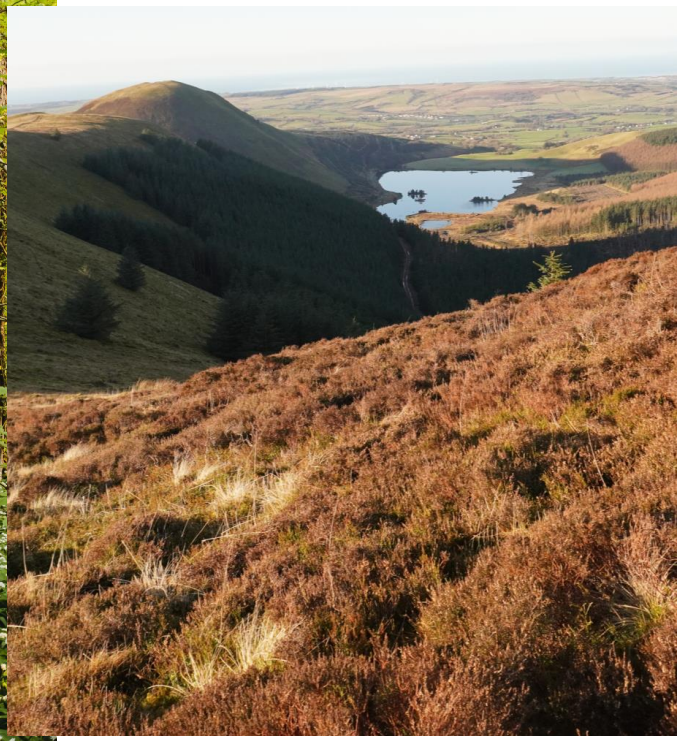
- 53% of the nation's forests are SSSIs, Open Habitats, Ancient Woodland, or Plantations on Ancient Woodland Sites





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## Biodiversity plan focus areas:

- Protected species, sites, and watercourses
- Ancient woodlands
- Creating networks of open and dynamic habitats
- Restoring Species

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# Ecosystem engineers

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# Ecosystem engineers

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# Ecosystem engineers

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# Ecosystem engineers

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## Biodiversity plan focus areas:

- **Protected species, sites, and watercourses**
- **Ancient woodlands**
- **Creating networks of open and dynamic habitats**
- **Restoring Species**
- **Forest Wilding -** *Places of innovation to rebuild biodiversity through restoring natural processes*

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- Protected species, sites, and watercourses (SSSI favourable %)
- Ancient woodlands (ha restored)
- Creating networks of open and dynamic habitats (ha)
- Restoring Species (# of projects)
- Forest Wilding (ha)

## You cannot manage what you do not measure

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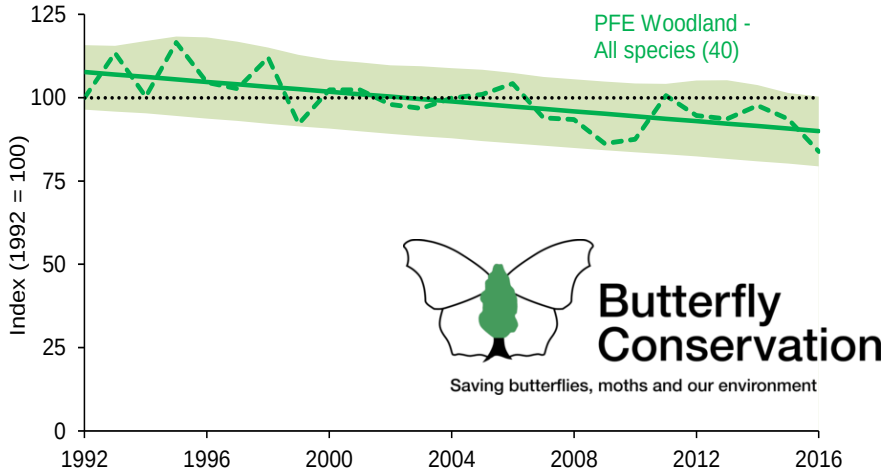
England butterfly population indicators for woodland sites (green line) and farmland sites (brown line).




- 18062 species have been found in the nation's forests, including 56% of priority species
- Literature backing for indicator species is weak – we can't rely on 40 butterflies (0.2% of all species recorded)…

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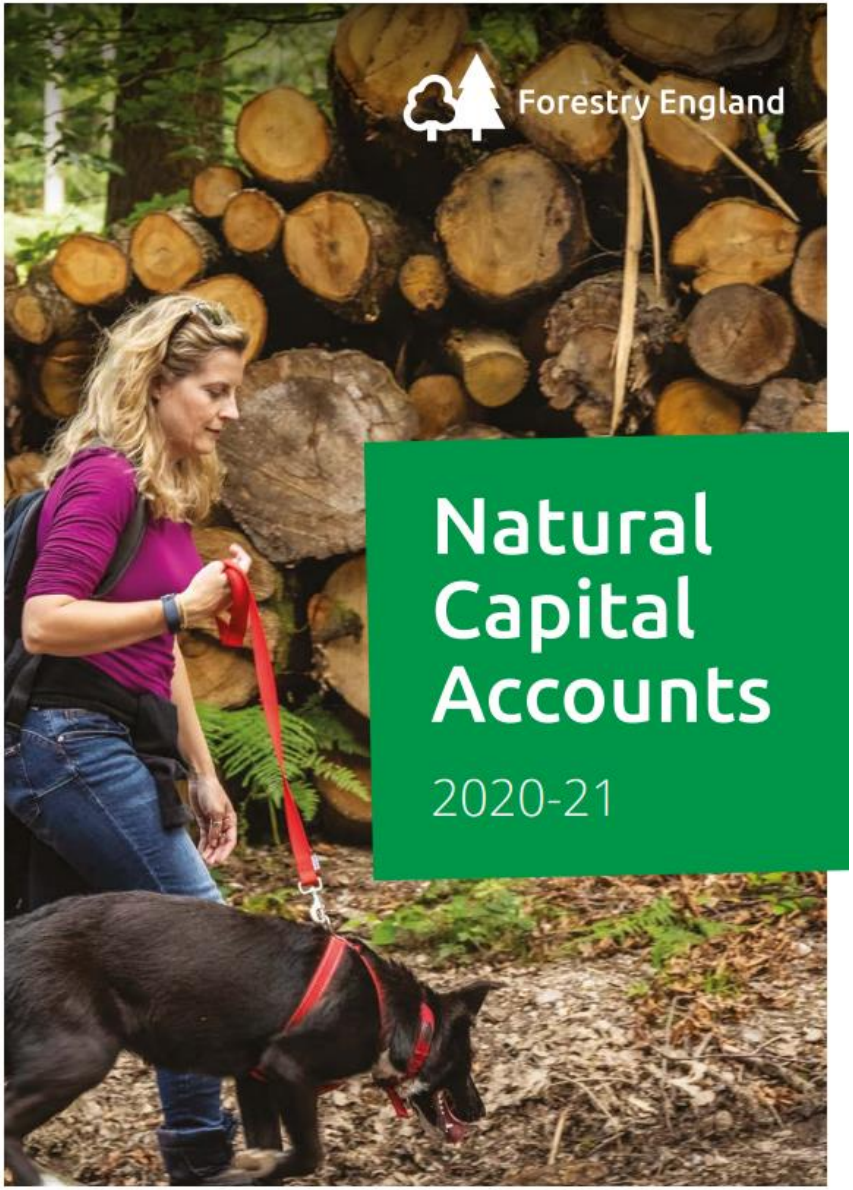

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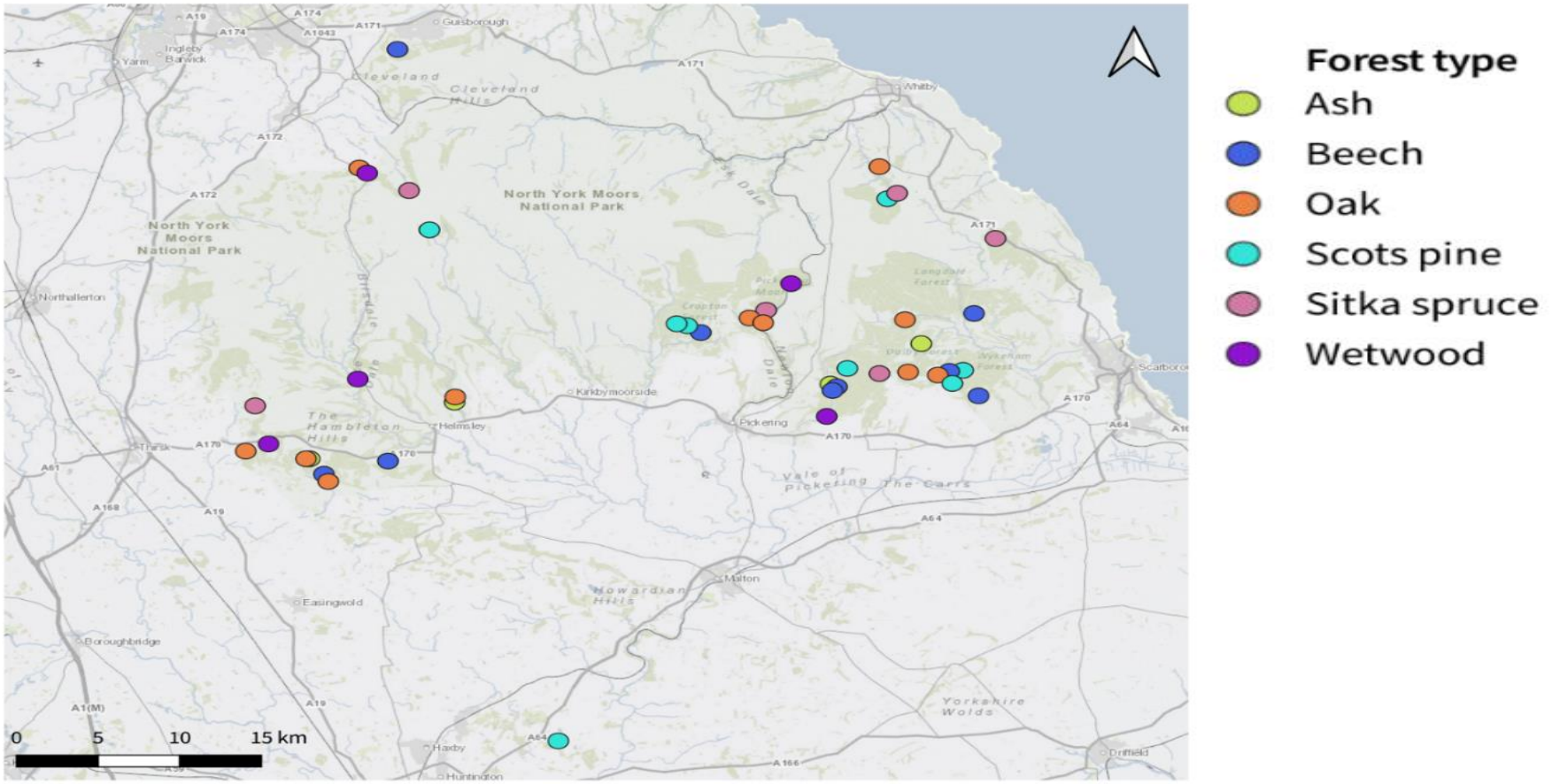
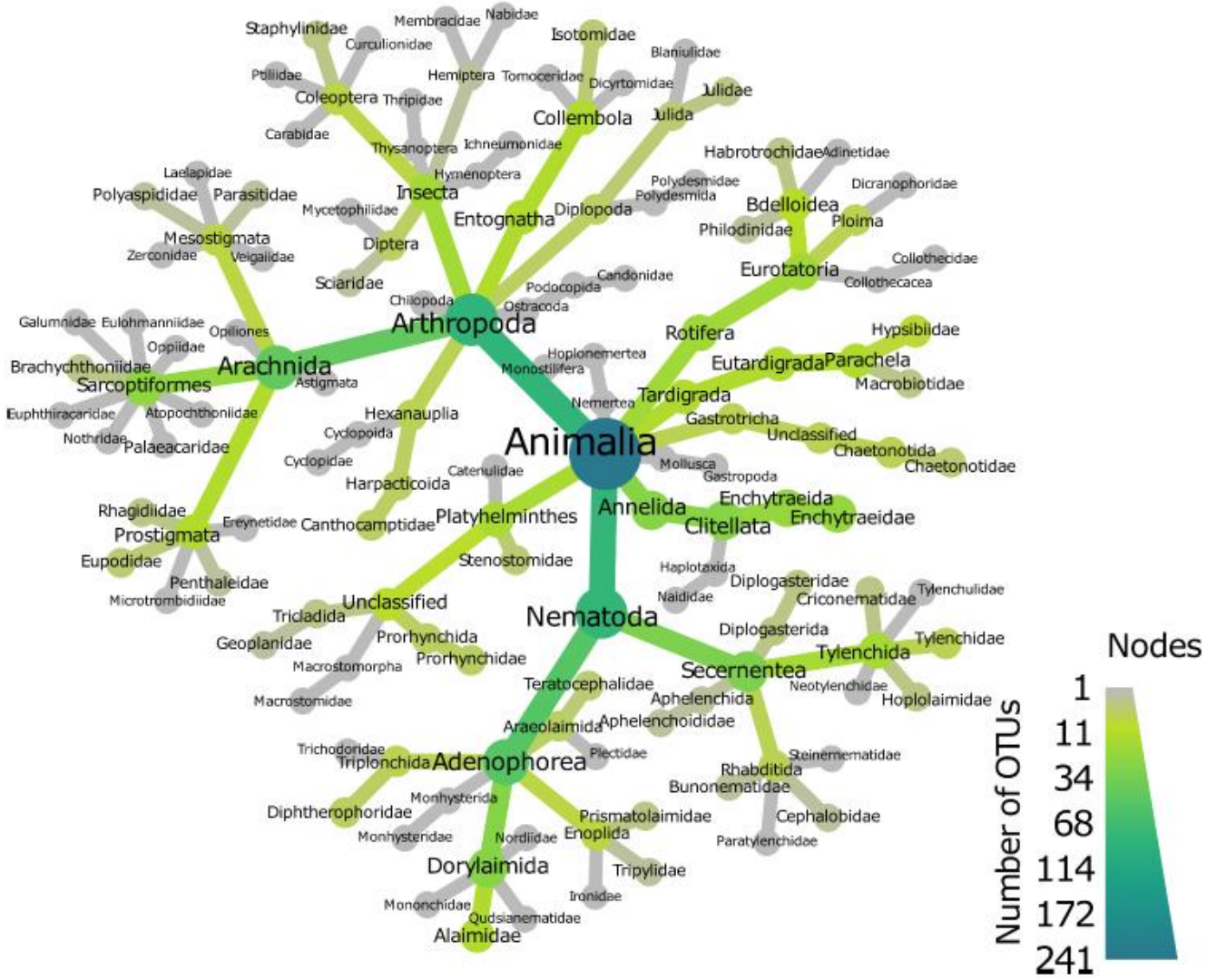
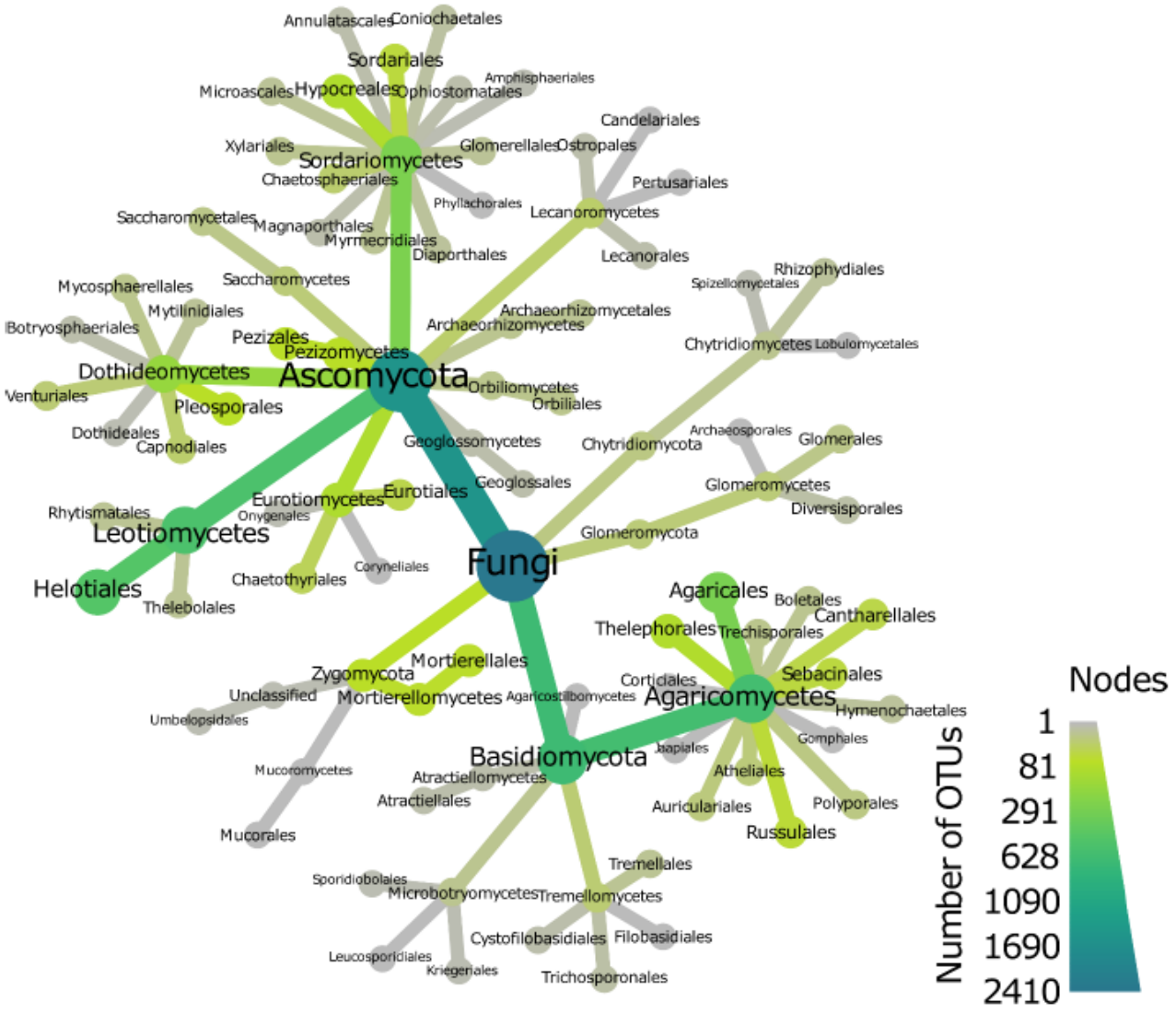
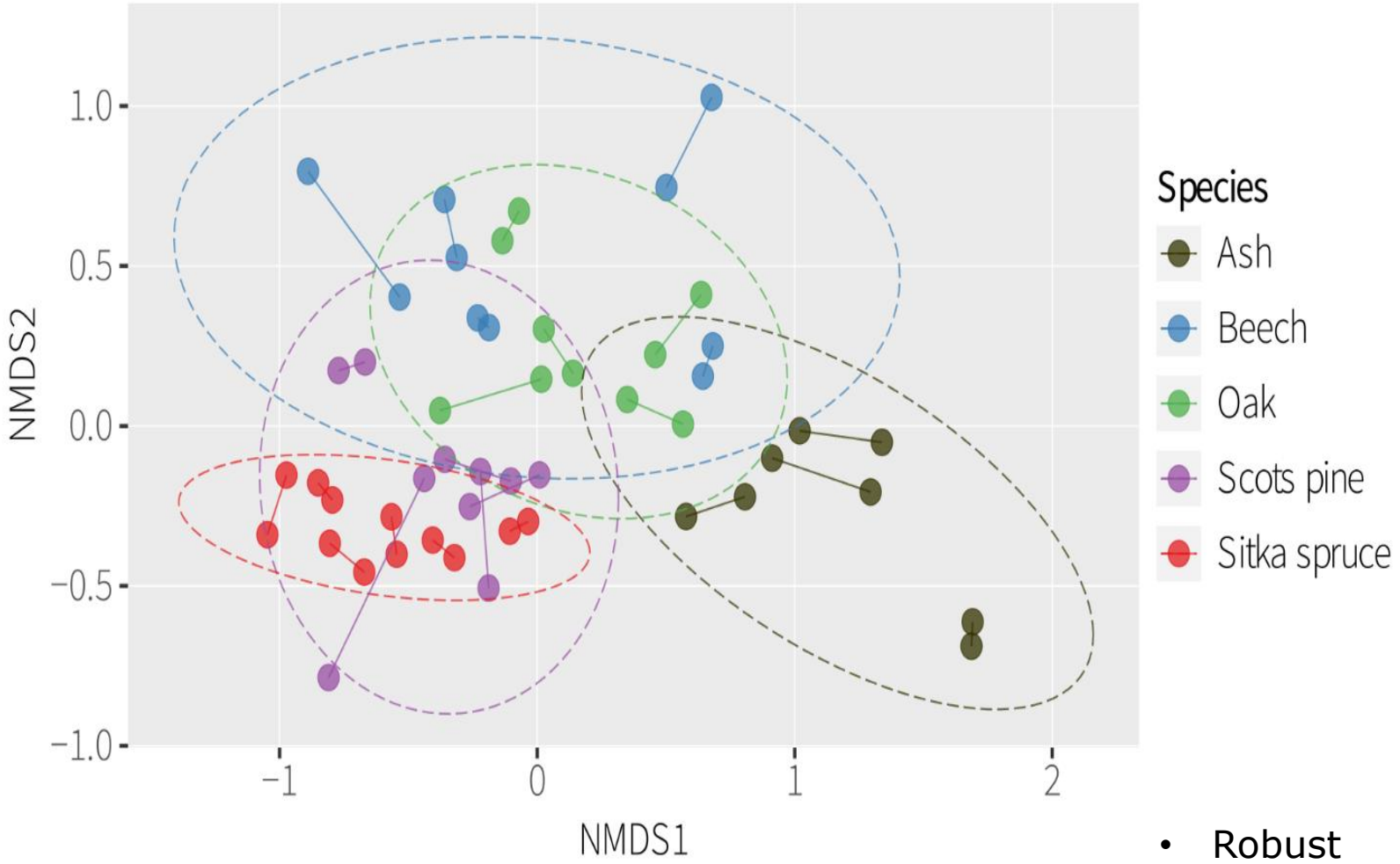
# Metabarcoding of soil environment DNA




- Soil samples collected and combined along two transects = two soil samples per sample site
- Fermentation layer where soil biodiversity expected to be high
- eDNA metabarcoding of invertebrates and fungi


Animalia
Arthropoda
Insecta
Entognatha
Arachnida
Sarcoptiformes
Astigmata
Mesostigmata
Diptera
Coleoptera
Hemiptera
Thysanoptera
Hymenoptera
Collembola
Diplopoda
Julida
Julidae
Isotomidae
Tomoceridae
Dicyrtomidae
Blaniulidae
Staphylinidae
Membracidae
Nabidae
Curculionidae
Ptiliidae
Thripidae
Carabidae
Ichneumonidae
Laelapidae
Polyaspididae
Parasitidae
Mycetophilidae
Zerconidae
Veigaiidae
Sciaridae
Chilopoda
Ostracoda
Podocopida
Candonidae
Galumnidae
Eulohmanniidae
Opiliones
Oppiidae
Brachychthoniidae
Euphthiracaridae
Atopochthoniidae
Nothridae
Palaeacaridae
Hexanauplia
Cyclopoida
Cyclopidae
Harpacticoida
Rhagidiidae
Prostigmata
Eupodidae
Penthaleidae
Microtrombidiidae
Ereynetidae
Canthocamptidae
Platyhelminthes
Catenulidae
Stenostomidae
Unclassified
Tricladida
Geoplanidae
Macrostomorpha
Macrostomidae
Prorhynchida
Prorhynchidae
Annelida
Clitellata
Enchytraeida
Enchytraeidae
Haplotaxida
Naididae
Nematoda
Teratocephalidae
Araeolaimida
Trichodoridae
Triplonchida
Adenophorea
Monhysterida
Diphtherophoridae
Monhysteridae
Dorylaimida
Mononchidae
Qudsianematidae
Alaimidae
Nordiidae
Enoplida
Prismatolaimidae
Tripylidae
Ironidae
Secernentea
Aphelenchida
Aphelenchoidididae
Plectidae
Rhabditida
Bunonematidae
Paratylenchidae
Cephalobidae
Steinernematidae
Diplogasteridae
Diplogasterida
Tylenchida
Neotylenchidae
Hoplolaimidae
Criconematidae
Tylenchulidae
Tylenchidae
Rotifera
Eutardigrada
Tardigrada
Gastrotricha
Habrotrochidae
Adinetidae
Bdelloidea
Philodinidae
Dicranophoridae
Ploima
Eurotatoria
Collothecidae
Collothecacea
Hypsibiidae
Parachela
Macrobiotidae
Unclassified
Chaetonotida
Chaetonotidae
Mollusca
Gastropoda
Polydesmidae
Polydesmida
Hoplonemertea
Monostilifera
Nemertea
Nodes
Number of OTUs
1
11
34
68
114
172
241


Annulatascales
Coniochaetales
Sordariales
Amphisphaeriales
Microascales
Hypocreales
Ophiostomatales
Candelariales
Xylariales
Glomerellales
Ostropales
Sordariomycetes
Chaetosphaeriales
Pertusariales
Phyllachorales
Lecanoromycetes
Saccharomycetales
Magnaporthales
Myrmecridiales
Diaporthales
Lecanorales
Rhizophydiales
Spizellomycetales
Mycosphaerellales
Saccharomycetes
Mytilinidiales
Archaeorhizomycetales
Botryosphaeriales
Archaeorhizomycetes
Pezizales
Chytridiomycetes
Lobulomycetales
Pezizomycetes
Dothideomycetes
Ascomycota
Orbiliomycetes
Venturiales
Orbiliales
Pleosporales
Dothideales
Capnodiales
Geoglossomycetes
Chytridiomycota
Archaeosporales
Glomerales
Geoglossales
Glomeromycetes
Eurotiomycetes
Eurotiales
Diversisporales
Rhytismatales
Onygenales
Glomeromycota
Leotiomycetes
Fungi
Coryneliales
Chaetothyriales
Helotiales
Thelebolales
Agaricales
Boletales
Cantharellales
Thelephorales
Trechisporales
Mortierellales
Sebacinales
Zygomycota
Corticiales
Unclassified
Mortierellomycetes
Agaricostilbomycetes
Agaricomycetes
Hymenochaetales
Umbelopsidales
Gomphales
Basidiomycota
Mucoromycetes
Atractiellomycetes
Atheliales
Atractiellales
Auriculariales
Polyporales
Mucorales
Russulales
Tremellales
Sporidiobolales
Microbotryomycetes
Tremellomycetes
Cystofilobasidiales
Filobasidiales
Leucosporidiales
Kriegeriales
Trichosporonales
Nodes
Number of OTUs
1
81
291
628
1090
1690
2410




- Robust
- Whole community
- Repeatable

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# What does the future look like?

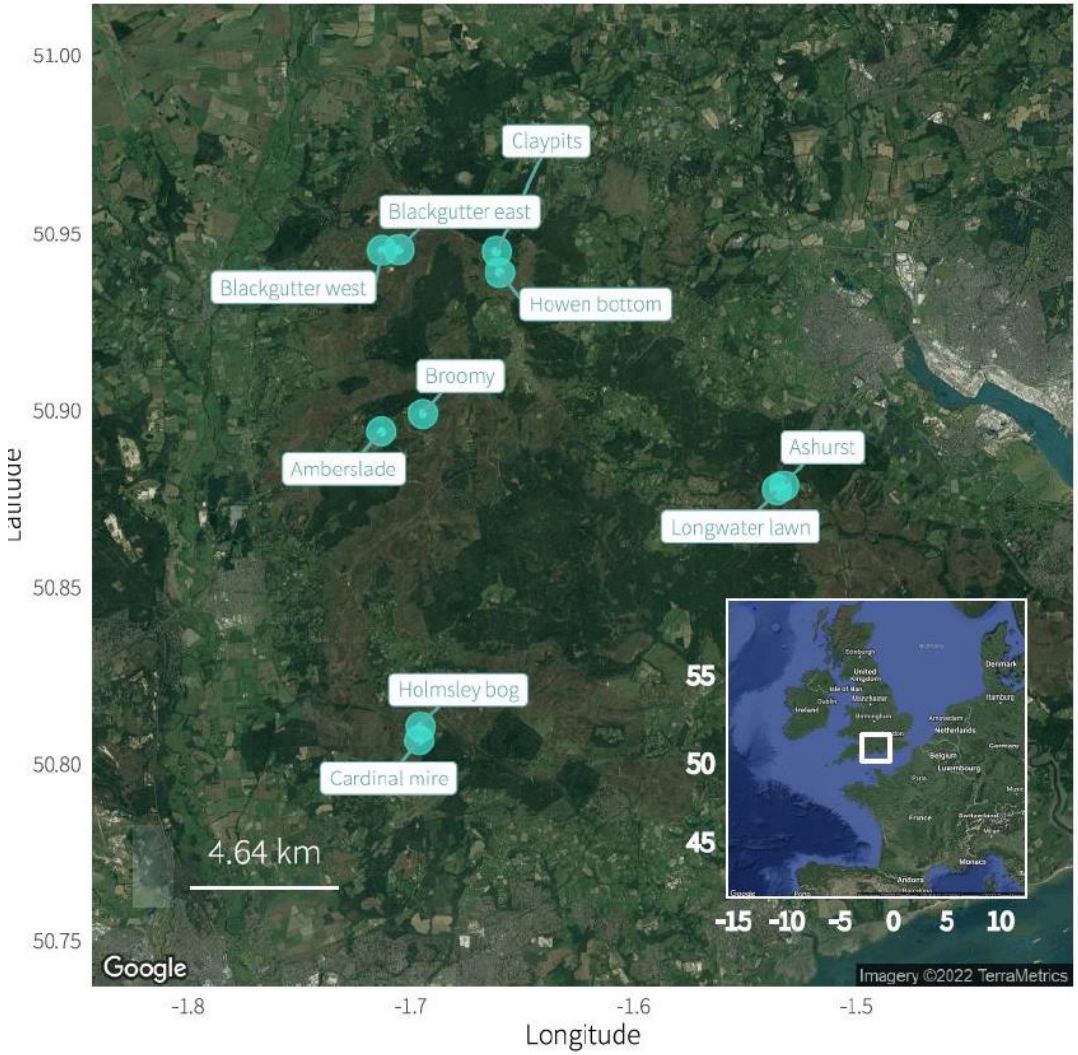
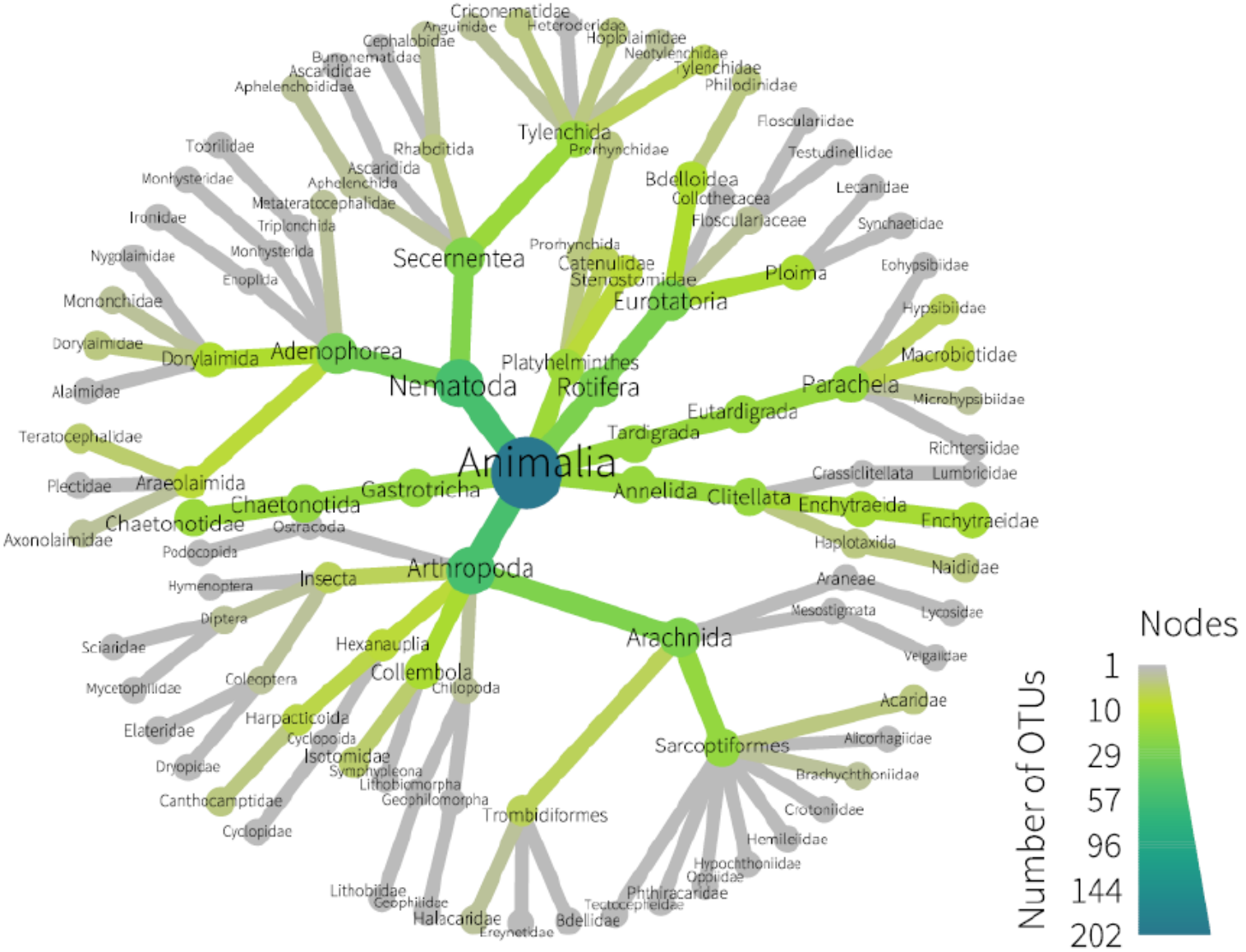


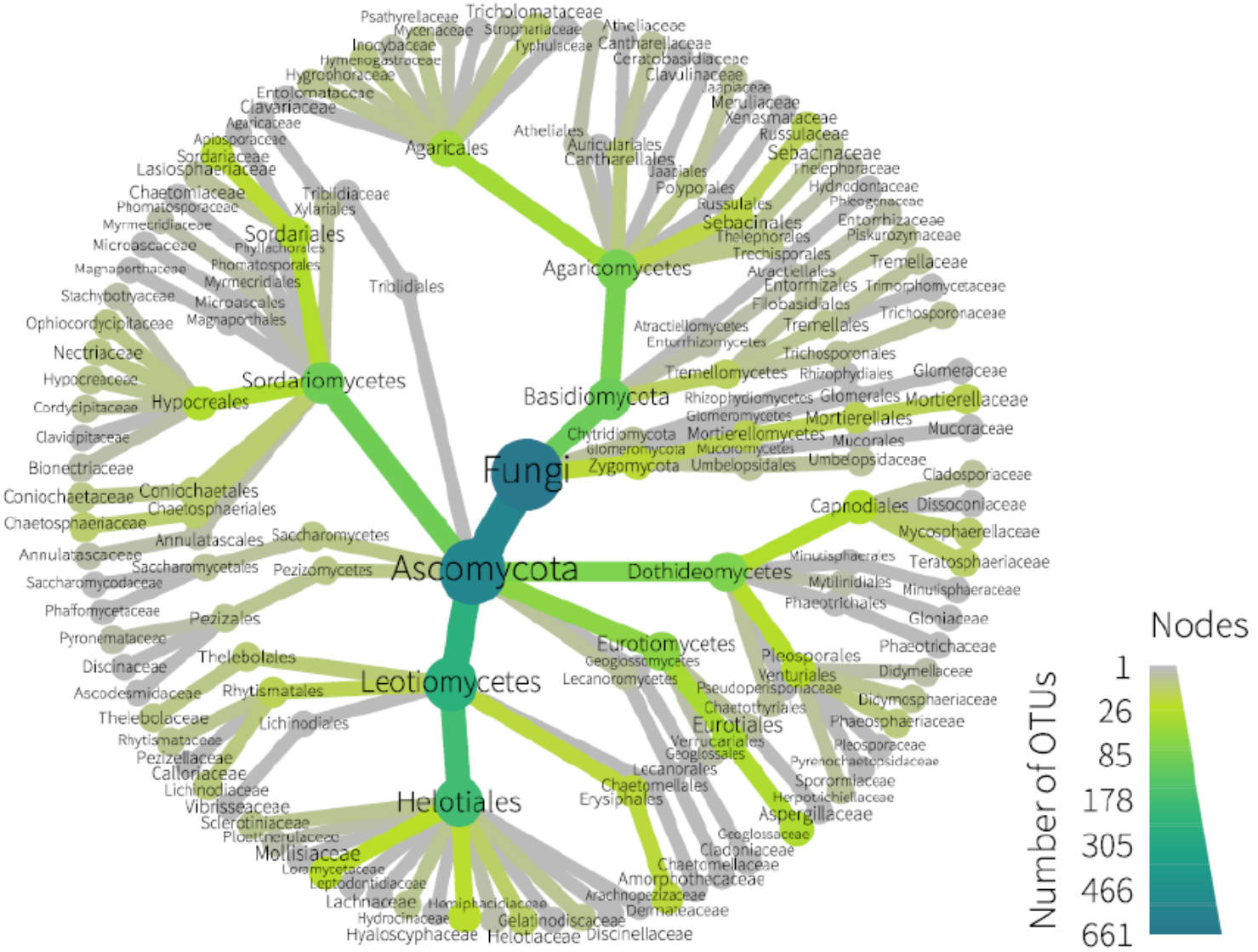

Figure 1. Soil sampling locations in the New Forest National Park, England

Five favourable, five unfavourable
Soil samples collected and combined along seven transects per site

Fermentation layer where soil biodiversity expected to be high

eDNA metabarcoding of invertebrates and fungi


Criconematidae
Anguinidae
Heteroderidae
Cephalobidae
Hoplolaimidae
Bunonematidae
Neotylenchidae
Ascarididae
Tylenchidae
Aphelenchoididae
Philodinidae
Tylenchida
Rhabditida
Prorhynchidae
Ascaridida
Bdelloidea
Aphelenchida
Collothecacea
Metateratocephalidae
Triplonchida
Monhysterida
Secernentea
Catenulidae
Stenostomidae
Ploima
Eurotatoria
Enoplida
Mononchidae
Dorylaimida
Adenophorea
Platyhelminthes
Nematoda
Rotifera
Alaimidae
Parachela
Eutardigrada
Tardigrada
Teratocephalidae
Animalia
Plectidae
Araeolaimida
Gastrotricha
Annelida
Clitellata
Chaetonotida
Enchytraeida
Chaetonotidae
Ostracoda
Axonolaimidae
Podocopida
Haplotaxida
Arthropoda
Naididae
Hymenoptera
Insecta
Araneae
Diptera
Mesostigmata
Lycosidae
Sciaridae
Hexanauplia
Arachnida
Collembola
Mycetophilidae
Coleoptera
Chilopoda
Acaridae
Harpacticoida
Elateridae
Cyclopoida
Sarcoptiformes
Isotomidae
Dryopidae
Symphypleona
Lithobiomorpha
Canthocamptidae
Geophilomorpha
Trombidiformes
Cyclopidae
Hemisarcoptidae
Lithobiidae
Phthiracaridae
Halacaridae
Bdellidae
Nodes
Number of OTUs
1
10
29
57
96
144
202


Fungi
Ascomycota
Basidiomycota
Agaricomycetes
Agaricales
Sordariomycetes
Sordariales
Hypocreales
Leotiomycetes
Helotiales
Eurotiomycetes
Eurotiales
Dothideomycetes
Capnodiales
Pezizomycetes
Pezizales
Saccharomycetes
Saccharomycetales
Annulatascales
Coniochaetales
Chaetosphaeriales
Triblidiales
Tribidiaceae
Xylariales
Phyllachorales
Phomatosporales
Myrmecridiales
Microascales
Magnaporthales
Nectriaceae
Hypocreaceae
Cordycipitaceae
Clavicipitaceae
Bionectriaceae
Coniochaetaceae
Chaetosphaeriaceae
Annulatascaceae
Saccharomycodaceae
Phaffomycetaceae
Pyronemataceae
Discinaceae
Ascodesmidaceae
Thelebolaceae
Rhytismataceae
Pezizellaceae
Calloriaceae
Lichinodiaceae
Vibrisseaceae
Sclerotiniaceae
Ploettnerulaceae
Mollisiaceae
Loramycetaceae
Leptodontidiaceae
Lachnaceae
Hyaloscyphaceae
Hydrocinaceae
Helotiaceae
Gelatinodiscaceae
Hemiphacidiaceae
Discinellaceae
Psathyrellaceae
Tricholomataceae
Mycenaceae
Strophariaceae
Inocybaceae
Typhulaceae
Hymenogastraceae
Hygrophoraceae
Entolomataceae
Clavariaceae
Agaricaceae
Apiosporaceae
Sordariaceae
Lasiosphaeriaceae
Chaetomiaceae
Phomatosporaceae
Myrmecridiaceae
Microascaceae
Magnaporthaceae
Stachybotryaceae
Ophiocordycipitaceae
Atheliales
Auriculariales
Cantharellales
Jaapiales
Polyporales
Russulales
Thelephorales
Trechisporales
Atractiellales
Entorrhizales
Filobasidiales
Atractiellomycetes
Entorrhizomycetes
Tremellomycetes
Tremellales
Trichosporonales
Rhizophydiales
Rhizophydiomycetes
Glomeromycetes
Glomerales
Mortierellomycetes
Mortierellales
Mucoromycetes
Mucorales
Umbelopsidales
Chytridiomycota
Glomeromycota
Zygomycota
Atheliaceae
Cantharellaceae
Ceratobasidiaceae
Clavulinaceae
Jaapiaceae
Meruliaceae
Xenasmataceae
Russulaceae
Sebacinaceae
Thelephoraceae
Hydnodontaceae
Phleogenaceae
Entorrhizaceae
Piskurozymaceae
Tremellaceae
Trimorphomycetaceae
Trichosporonaceae
Glomeraceae
Mortierellaceae
Mucoraceae
Umbelopsidaceae
Cladosporaceae
Dissoconiaceae
Mycosphaerellaceae
Teratosphaeriaceae
Minutisphaeriaceae
Gloniaceae
Phaeotrichaceae
Didymellaceae
Dicymosphaeriaceae
Phaeosphaeriaceae
Pleosporaceae
Pyrenochaetopsidaceae
Sporormiaceae
Herpotrichiellaceae
Aspergillaceae
Geoglossaceae
Cladoniaceae
Chaetomellaceae
Amorphothecaceae
Arachnopezizaceae
Dermateaceae
Mytilinidiales
Phaeotrichales
Pleosporales
Venturiales
Pseudoperisporiaceae
Chaetothyriales
Verrucariales
Geoglossales
Lecanorales
Chaetomellales
Erysiphales
Geoglossomycetes
Lecanoromycetes
Nodes
Number of OTUs
1
26
85
178
305
466
661

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| Site | Fungi spp |
|---|---|
| All sites | 654 |
| Holmsley bog | 144 |
| Amberslade | 296 |
| Broomy | 184 |
| Cardinal mire | 129 |
| Howen bottom | 113 |
| Claypits | 185 |
| Ashurst | 133 |
| Longwater lawn | 87 |
| Blackgutter east | 200 |
| Blackgutter west | 236 |

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| Site | Fungi spp |
|---|---|
| All sites | 654 |
| Holmsley bog | 22% |
| Amberslade | 45% |
| Broomy | 28% |
| Cardinal mire | 20% |
| Howen bottom | 17% |
| Claypits | 28% |
| Ashurst | 20% |
| Longwater lawn | 13% |
| Blackgutter east | 31% |
| Blackgutter west | 36% |

| Site | Ascomycota | Basidiomycota | Chytridiomycota | Glomeromycota | Zygomycota |
|---|---|---|---|---|---|
| All sites | 536 | 97 | 3 | 1 | 17 |

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| Site | Ascomycota | Basidiomycota | Chytridiomycota | Glomeromycota | Zygomycota |
|---|---|---|---|---|---|
| All sites | 536 | 97 | 3 | 1 | 17 |
| Holmsley bog | 23% | 12% | 33% | 0% | 35% |
| Amberslade | 47% | 31% | 67% | 100% | 53% |
| Broomy | 30% | 22% | 0% | 100% | 18% |
| Cardinal mire | 21% | 15% | 0% | 100% | 0% |
| Howen bottom | 19% | 6% | 0% | 0% | 18% |
| Claypits | 30% | 23% | 0% | 0% | 24% |
| Ashurst | 20% | 22% | 0% | 0% | 29% |
| Longwater lawn | 15% | 8% | 0% | 0% | 6% |
| Blackgutter east | 32% | 24% | 0% | 100% | 41% |
| Blackgutter west | 38% | 26% | 0% | 100% | 47% |

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| Site | Ascomycota | Basidiomycota | Chytridiomycota | Glomeromycota | Zygomycota |
|---|---|---|---|---|---|
| All sites | 536 | 97 | 3 | 1 | 17 |
| Holmsley bog | 23% | 12% | 33% | 0% | 35% |
| Amberslade | 47% | 31% | 67% | 100% | 53% |
| Broomy | 30% | 22% | 0% | 100% | 18% |
| Cardinal mire | 21% | 15% | 0% | 100% | 0% |
| Howen bottom | 19% | 6% | 0% | 0% | 18% |
| Claypits | 30% | 23% | 0% | 0% | 24% |
| Ashurst | 20% | 22% | 0% | 0% | 29% |
| Longwater lawn | 15% | 8% | 0% | 0% | 6% |
| Blackgutter east | 32% | 24% | 0% | 100% | 41% |
| Blackgutter west | 38% | 26% | 0% | 100% | 47% |

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| Site | Ascomycota | Basidiomycota | Chytridiomycota | Glomeromycota | Zygomycota | Combined index |
|---|---|---|---|---|---|---|
| All sites | 536 | 97 | 3 | 1 | 17 | |
| Holmsley bog | 23% | 12% | 33% | 0% | 35% | 0.34 |
| Amberslade | 47% | 31% | 67% | 100% | 53% | 1.00 |
| Broomy | 30% | 22% | 0% | 100% | 18% | 0.48 |
| Cardinal mire | 21% | 15% | 0% | 100% | 0% | 0.31 |
| Howen bottom | 19% | 6% | 0% | 0% | 18% | 0.10 |
| Claypits | 30% | 23% | 0% | 0% | 24% | 0.31 |
| Ashurst | 20% | 22% | 0% | 0% | 29% | 0.27 |
| Longwater lawn | 15% | 8% | 0% | 0% | 6% | 0.04 |
| Blackgutter east | 32% | 24% | 0% | 100% | 41% | 0.60 |
| Blackgutter west | 38% | 26% | 0% | 100% | 47% | 0.68 |

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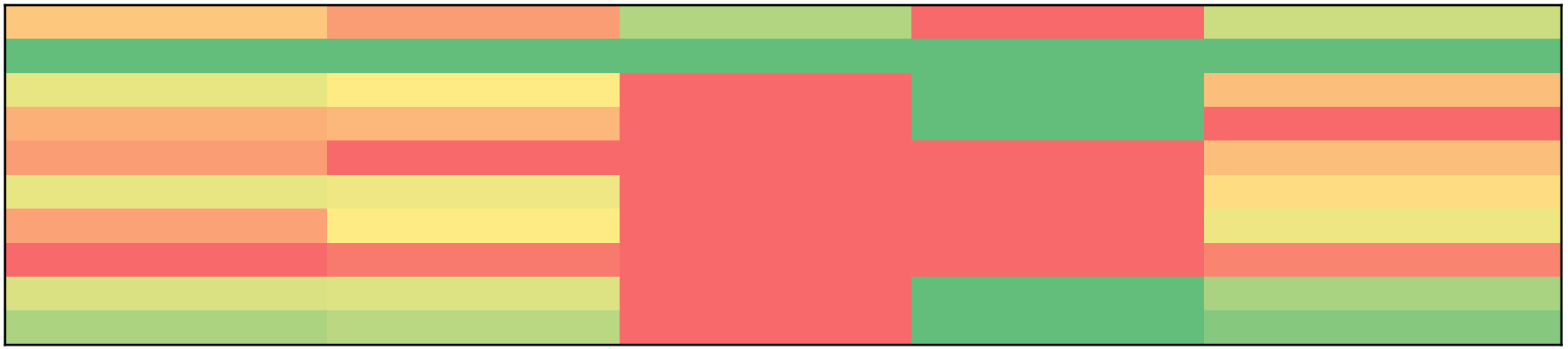
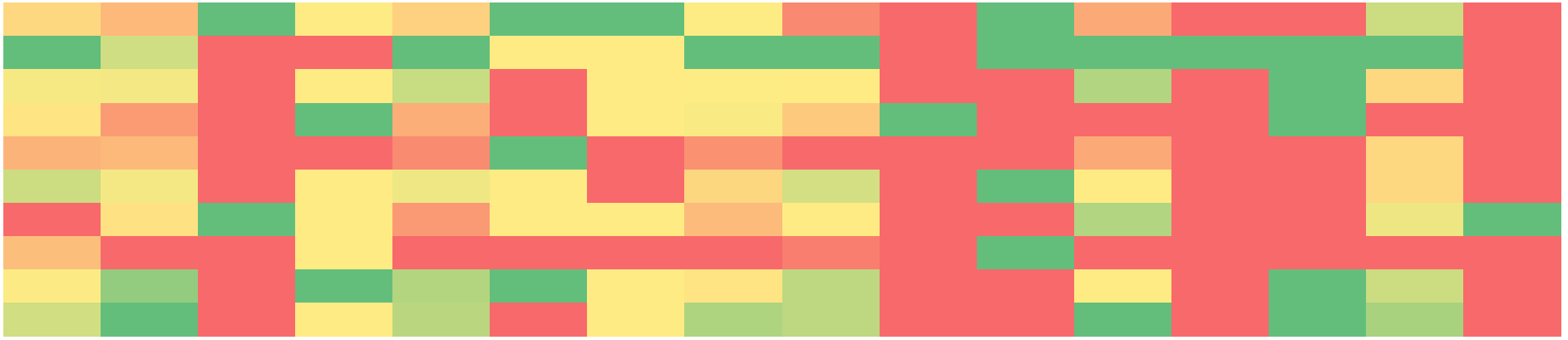
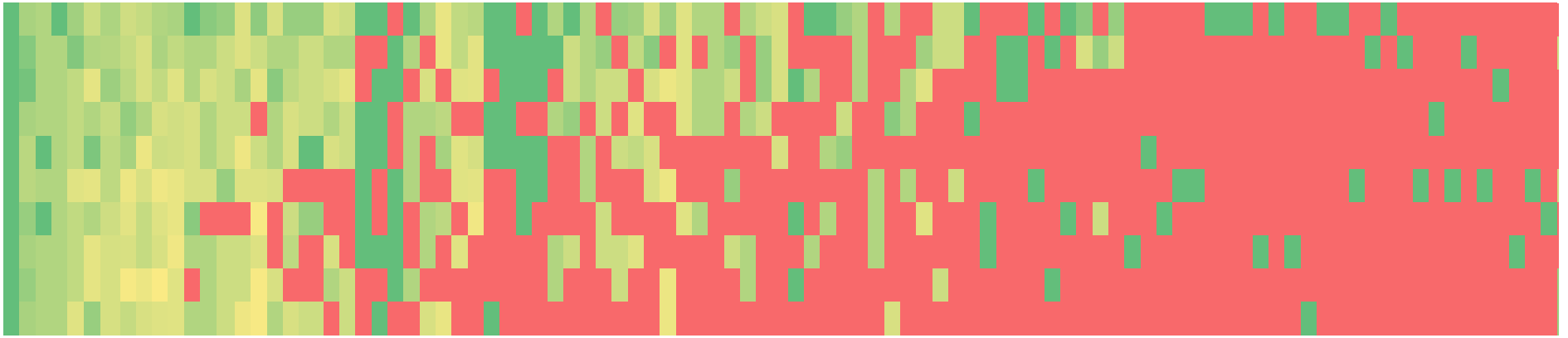
| Site | Ascomycota | Basidiomycota | Chytridiomycota | Glomeromycota | Zygomycota | Combined index |
|---|---|---|---|---|---|---|
| All sites | 536 | 97 | 3 | 1 | 17 | |
| Holmsley bog | | | | | | 0.34 |
| Amberslade | | | | | | 1.00 |
| Broomy | | | | | | 0.48 |
| Cardinal mire | | | | | | 0.31 |
| Howen bottom | | | | | | 0.10 |
| Claypits | | | | | | 0.31 |
| Ashurst | | | | | | 0.27 |
| Longwater lawn | | | | | | 0.04 |
| Blackgutter east | | | | | | 0.60 |
| Blackgutter west | | | | | | 0.68 |



Class (x16):



Family (x95):



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nature microbiology
Perspective
https://doi.org/10.1038/s41564-022-01228-3

# Defending Earth's terrestrial microbiome

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Colin Averill[1], Mark A. Anthony[1], Petr Baldrian[2], Felix Finkbeiner[1], Johan van den Hoogen[1], Toby Kiers[3], Petr Kohout[2], Eliane Hirt[1], Gabriel Reuben Smith[1] and Tom W. Crowther[1]

## Three priorities for monitoring:

- Increase scale and coverage of datasets
- Survey through time
- 'Third, and perhaps most urgently, we must work to share this information broadly, in fully open-access and transparent ways'