Wildlife Gardening Forum

Soil Biodiversity in the Garden

24 June 2015

Acknowledgements

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Programme

Hyperlinks take you to the relevant sections

- **‘Working with soil diversity: challenges and opportunities’** Dr Joanna Clark, British Society of Soil Science, & Director, Soil Research Centre, University of Reading.
- **‘Journey to the Centre of the Earth, the First few Inches’** Dr. Matthew Shepherd, Senior Specialist – Soil Biodiversity, Natural England
- **‘Mycorrhizal fungi and plants’** Dr. Martin I. Bidartondo, Imperial College/Royal Botanic Gardens Kew
- **‘How soil biology helps food production and reduces reliance on artificial inputs’** Caroline Coursie, Conservation Adviser. Tewkesbury Town Council
- **‘Earthworms – what we know and what they do for you’** Emma Sherlock, Natural History Museum
- **‘Springtails in the garden’** Dr. Peter Shaw, Roehampton University
- **‘Soil nesting bees’** Dr. Michael Archer. President Bees, Wasps & Ants Recording Society
- **Meet the scientists in the Museum’s Wildlife Garden**
  - Pond life: Adrian Rundle, Learning Curator.
  - Earthworms: Emma Sherlock, Senior Curator of Free-living worms and Porifera.
  - Terrestrial insects: Duncan Sivell, Curator of Diptera and Wildlife Garden Scientific Advisory Group.
  - Orchid Observers: Kath Castillo, Botanist.
  - Moths: Alessandro Giusti, Curator of Lepidoptera.

We are grateful to the British Society of Soil Science for their support for this conference

WORKING WITH SOIL DIVERSITY

Dr Joanna Clark
Director, Soil Research Centre
British Society of Soil Science

Soil Biodiversity in the Garden, Wildlife Gardening Forum Conference, June 2015

2015

International
Year of Soils

Food and Agriculture Organization
of the United Nations

Healthy soils are the basis for healthy **food production**.

Soils are the **foundation for vegetation** which is cultivated or managed for feed, fibre, fuel and medicinal products.

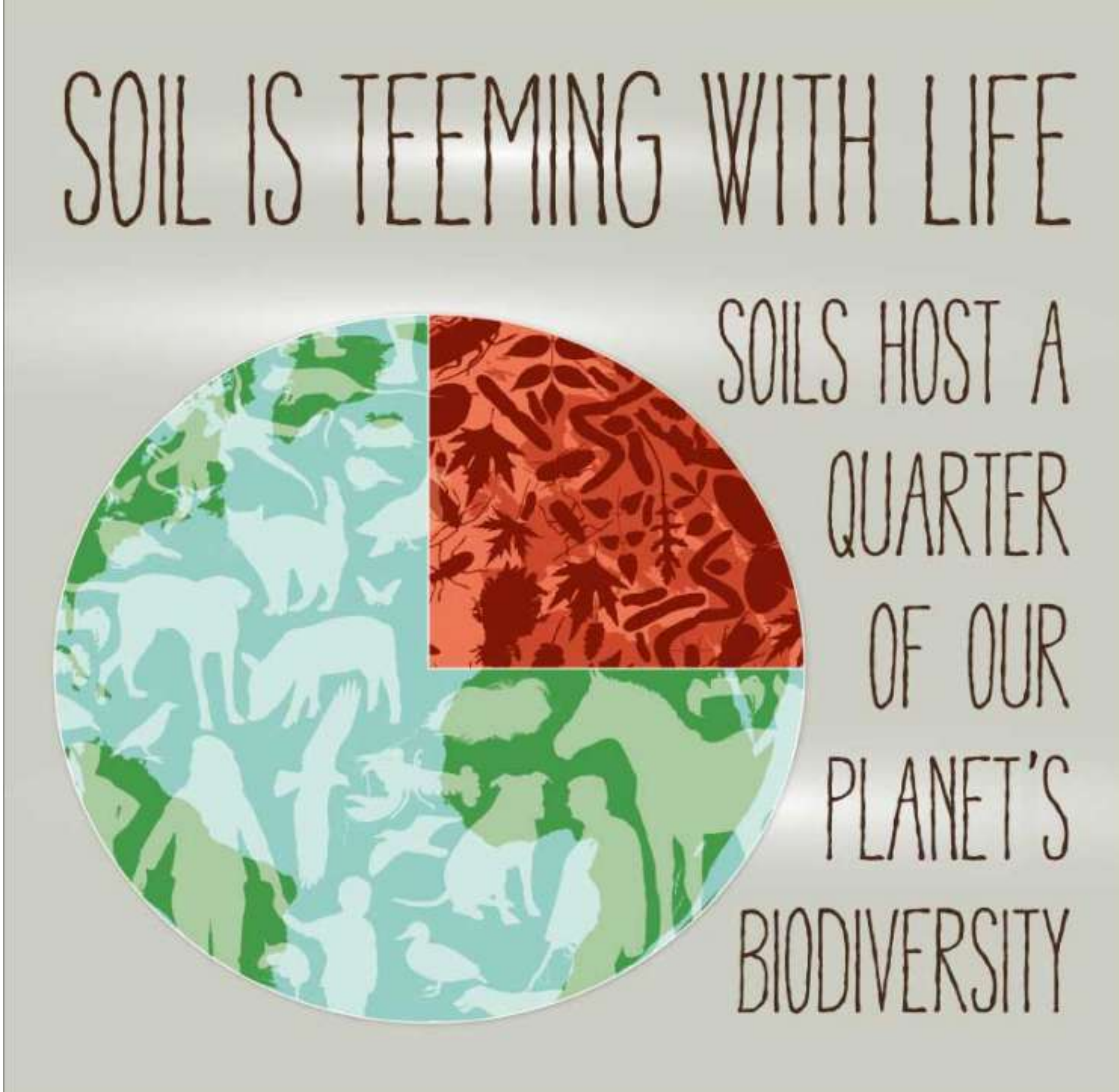
Soils support our planet's **biodiversity** and they host a quarter of the total.

Soils help to combat and adapt to **climate change** by playing a key role in the carbon cycle.

Soils **store and filter water**, improving our resilience to floods and droughts.

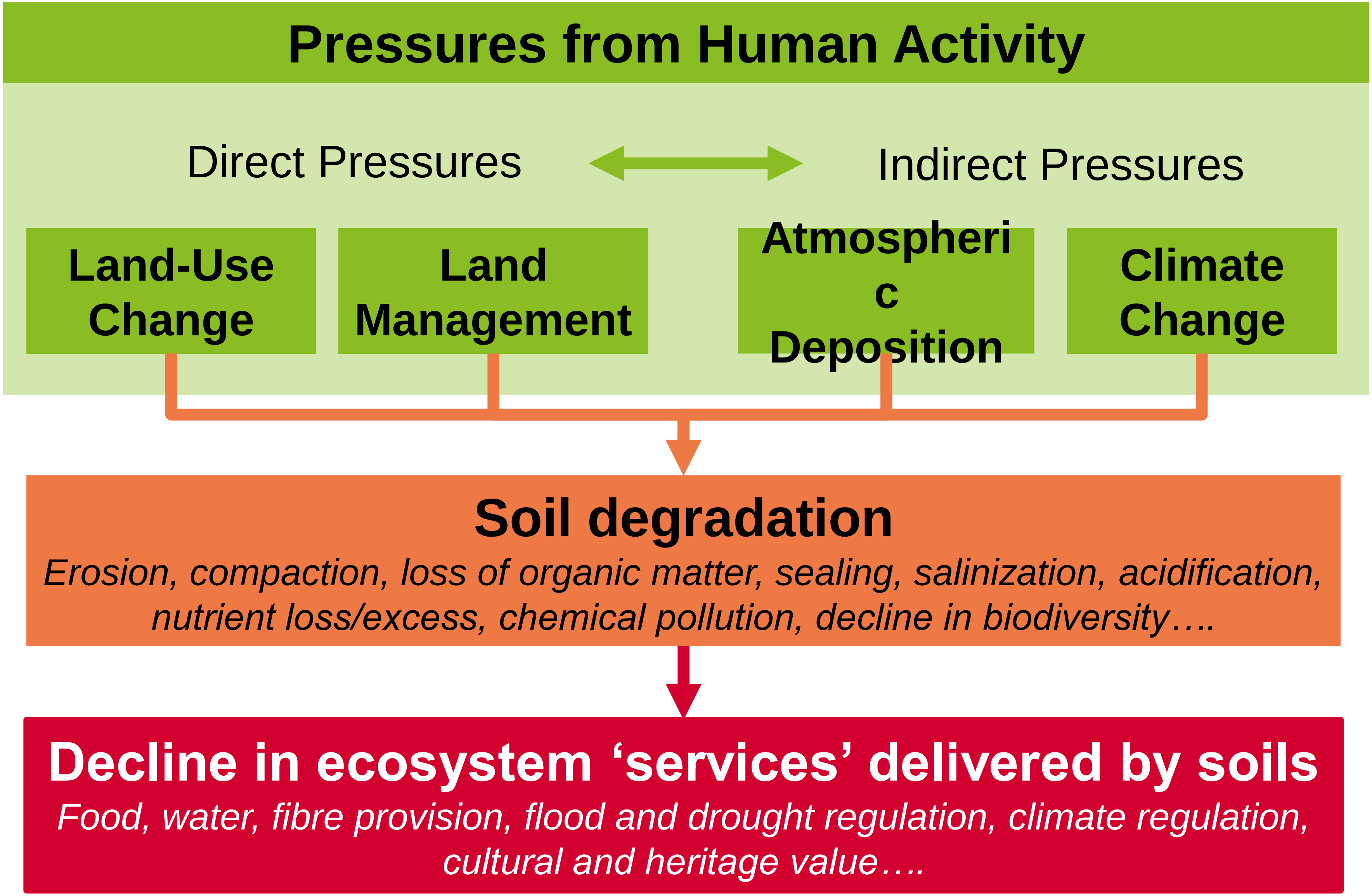
Soil is a **non-renewable resource**; its preservation is essential for food security and our sustainable future.


HEALTHY SOIL IS THE KEY TO FOOD SECURITY AND NUTRITION FOR ALL
95%
OF OUR FOOD
COMES FROM OUR SOIL


SOIL IS TEEMING WITH LIFE
SOILS HOST A QUARTER OF OUR PLANET'S BIODIVERSITY


Food and Agriculture Organization
of the United Nations
2015
International
Year of Soils
THERE ARE MORE ORGANISMS IN ONE TABLESPOON OF HEALTHY SOIL...
...THAN THERE ARE PEOPLE ON EARTH


OUR SOILS ARE IN GREAT DANGER
11 HA OF SOILS ARE SEALED UNDER EXPANDING CITIES EVERY HOUR IN EUROPE


Pressures from Human Activity
Direct Pressures
Indirect Pressures
Land-Use Change
Land Management
Atmospheric Deposition
Climate Change
Soil degradation
Erosion, compaction, loss of organic matter, sealing, salinization, acidification, nutrient loss/excess, chemical pollution, decline in biodiversity….
Decline in ecosystem 'services' delivered by soils
Food, water, fibre provision, flood and drought regulation, climate regulation, cultural and heritage value….

Land Use Change

What do we gain?

What do our soils gain?

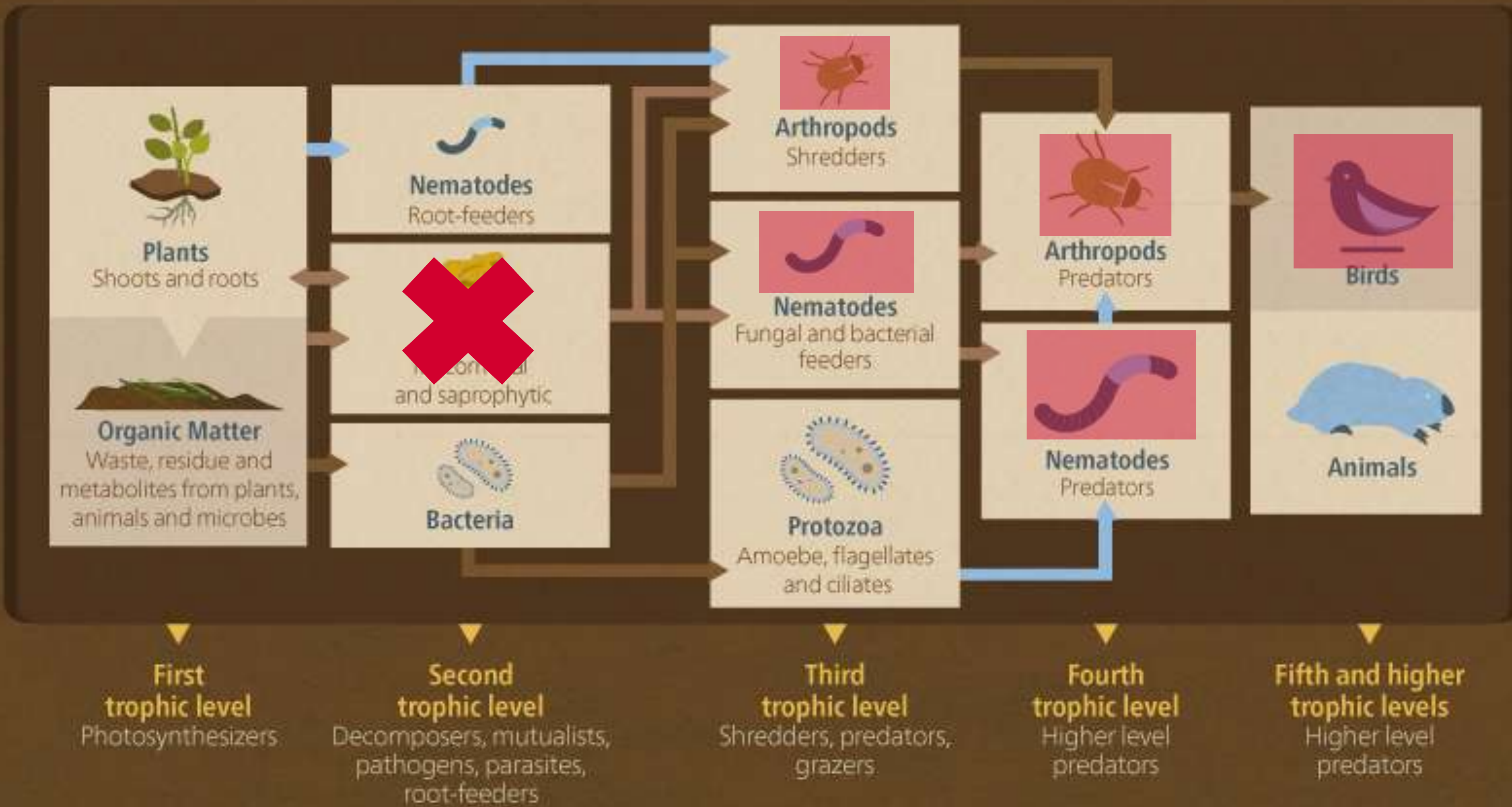
What do we loose?

What do our soils loose?

Images: wwf.org

THE SOIL FOOD WEB

When these diverse soil organisms interact with one another and with the plants and animals in the ecosystem, they form a complex web of ecological activity.



www.fao.org/soils-2015

Soils are not equal, soils are diverse

Upland Climate: Cool & Wet

Poor drainage Good drainage

Peat

Peaty podzol

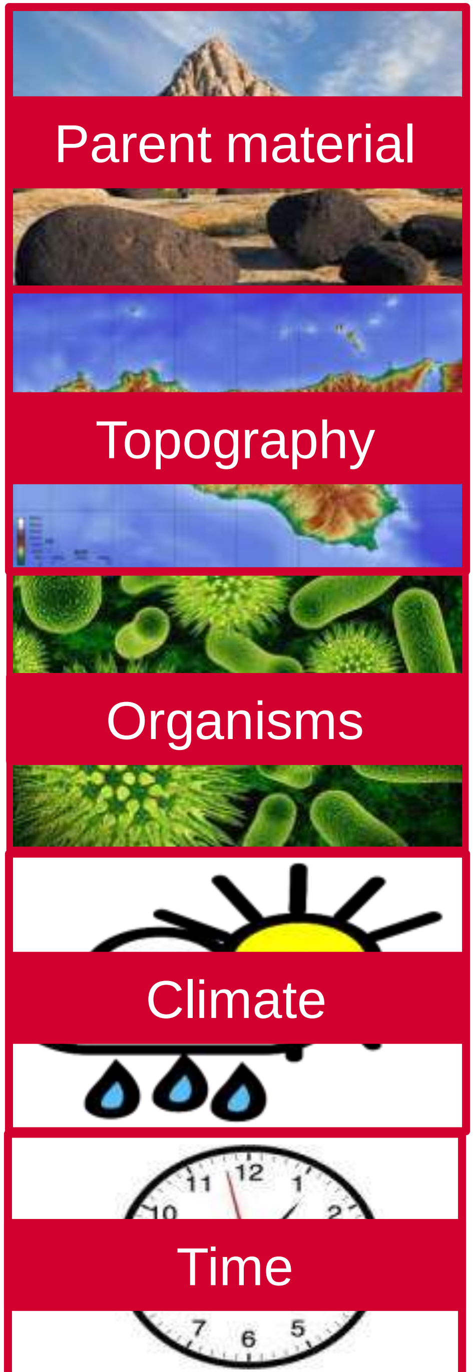
Lowland Climate: Warm & Dry

Poor drainage Good drainage

Gley

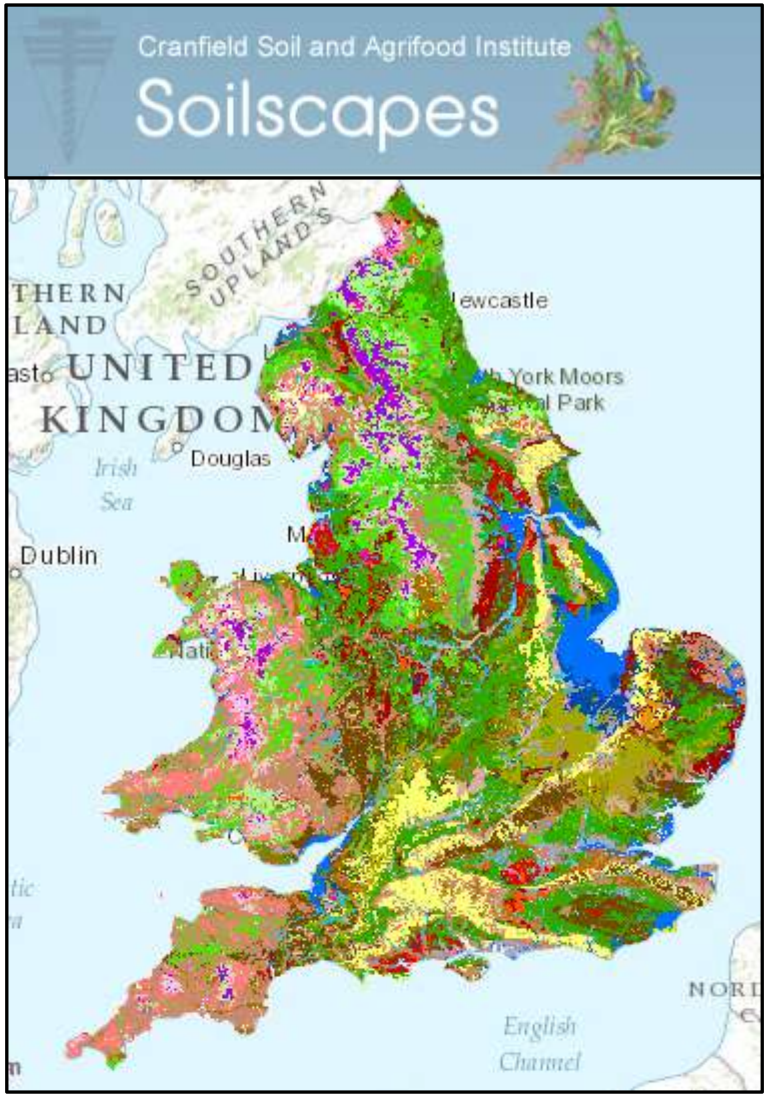
Brown Earth

Images: www.macaulay.ac.uk/host



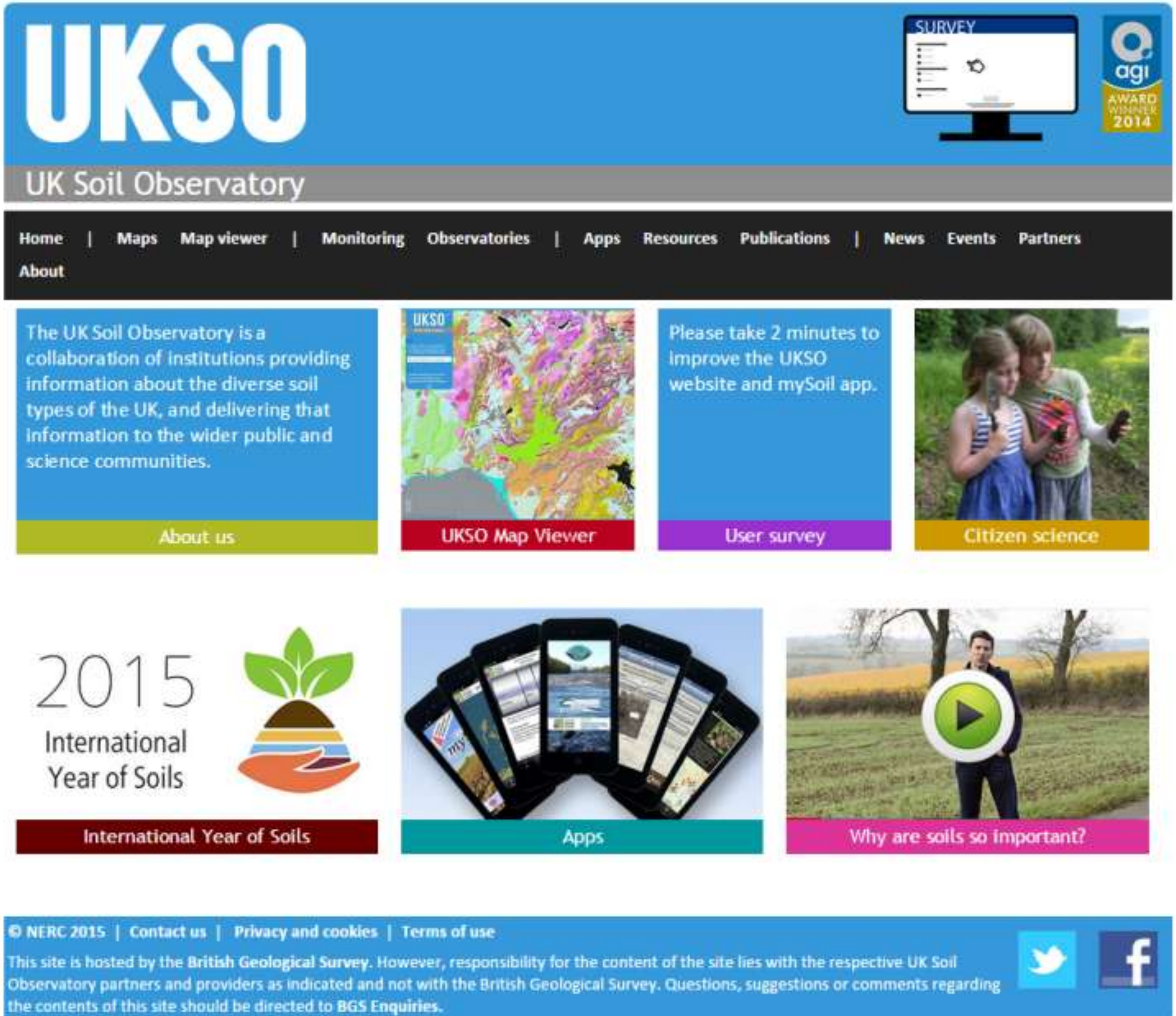
Soil Forming Factors

Diversity in soil forming factors leads to diversity of soils



752 Soil Series mapped in England and Wales

Grouped into 27 soil types in Soilscapes (e.g. brown earth etc.)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International
Year of Soils
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www.ukso.org

“A healthy life is not possible without healthy soils”

Ban Ki-moon, UN Secretary-General
5 December 2014, World Soil Day

www.un.org

Conclusion: Work with natural soil diversity to protect and sustain healthy soils

2015 International Year of Soils

Journey to the Centre of the Earth – The First Few Inches

Matthew Shepherd
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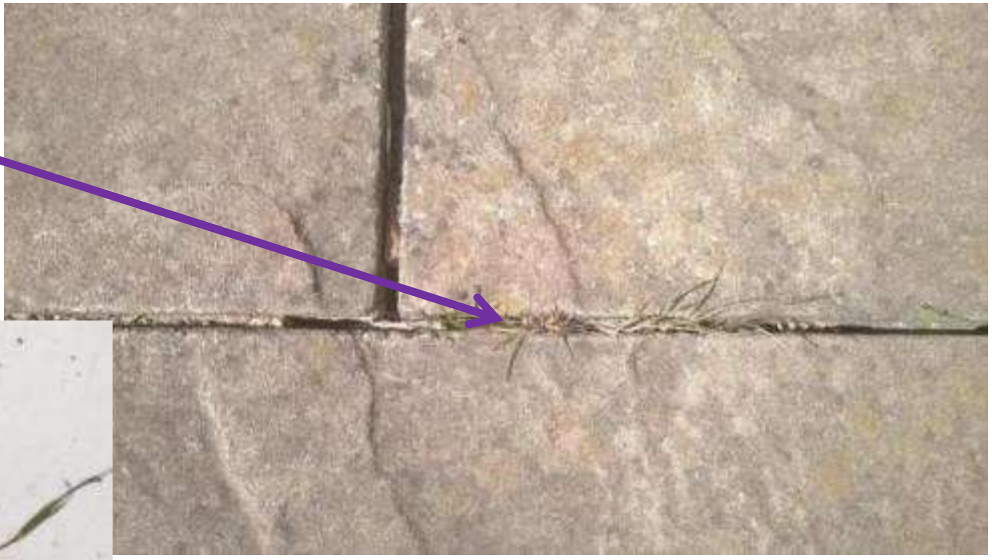
Natural England
matthew.j.shepherd@naturalengland.org.uk

NATURAL ENGLAND

Amazing garden biodiversity!

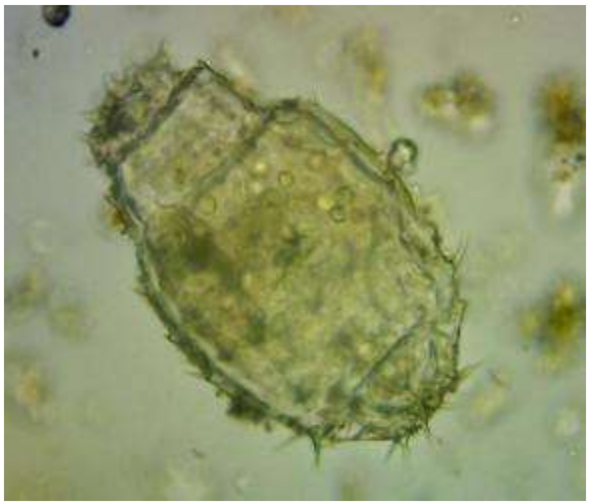
It is amazing how biodiverse a garden is. Take this tuft of grass growing between paving slabs.



Steve dug it out to have a look what was in it – his wife was pleased because she thought he was weeding the patio!

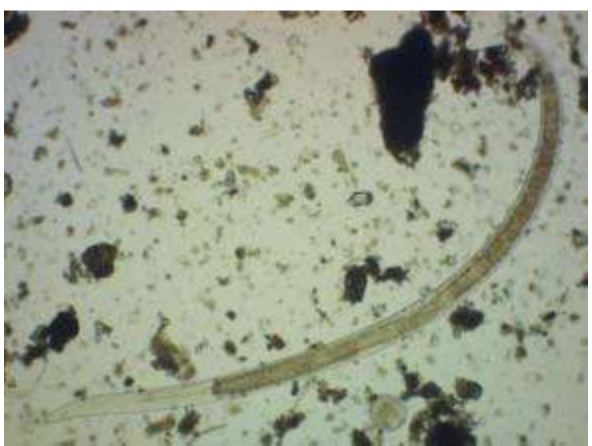
Colpoda sp. a ciliated protozoa which swims through soil water

A fungal spore, just beginning to geminate



A rotifer “tun” – a form the animal takes when it becomes completely dried out,

A rehydrated rotifer – constantly moving, looping like a leech, and filtering water with its crown of cilia.



Nematode dauer larva – a slow moving form resistant to drying

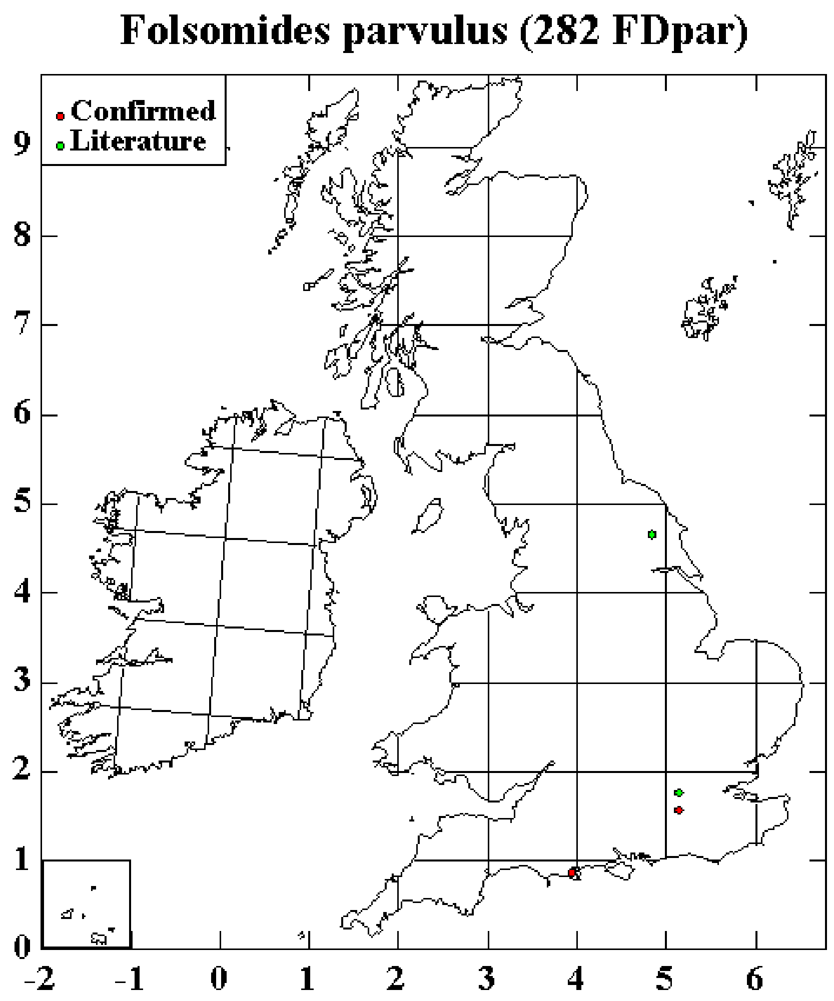
Amazing garden biodiversity!

...and a Springtail called *Folsomides parvulus*.

Amazing garden biodiversity!

"*Folsomides parvulus* is a rare species with a very distinctive body shape … There is one slide in the NHML collection bearing the Hartland Moor specimen), and individuals collected by Peter Shaw from a chalk quarry on Box Hill in Surrey were confirmed as this species by Steve Hopkin. The other literature records are from a chalk quarry in Yorkshire (Parr, 1978) and (oddly) manure in the rose garden at Kew Gardens (Lawrence, 1967).

"*Folsomides* sp. are well-known for their ability to withstand extreme dryness and can survive for long periods in a cryptobiotic state… once dessicated could survive relatively high temperatures as well as cooling to -180C. This probably explains the tendency of this genus to turn up in the hot, thin soil ...."



Amazing garden biodiversity!

It also makes them well adapted to a parched life between the paving slabs outside my kitchen door! So after finding this whole wonderful community in that tuft, I went and carefully stuffed it back in the crack, much to the annoyance of my wife!

Amazing garden biodiversity!

NATURAL ENGLAND

So soil life is…

- Accessible!
- Fascinating!
- Identifiable!
- All over your garden!


These are some of the common groups of organisms you may find in your soil
bacteria
protozoa
fungi
flatworms
oribatid mites
molluscs
potworms
springtails
predatory mites
pauropods
proturans

How soil begins…

‘Soil’ includes a wide variety of habitats and can be defined as ‘what plants grow in’ or ‘what accumulates when there’s nothing to clear it away’. Soils can start to form as lichens growing on rocks or other surfaces begin to break down the mineral material, and you’ll find soil life here too. Like our paving slab fauna, and the lichen itself, these don’t mind drying out.

More honorary soil…

Moss *Brachythecium ruabulum*

Mosses are also early colonisers of bare rock and other substrates, and the organic matter and moister environment they provide support a different fauna – these from a tuft of moss on my garden path. Both the mites and moss piglets still need to cope with dry spells.

A wrinkly oribatid *Scutovertex* sp.

A moss piglet or water bear (Eutardigrade)

Compost = soil fuel

A compost heap is buzzing with soil life, all adapted for rapid decomposition of this abundant resource, or for eating the decomposers… Predatory mites and tiny fungivore mites occur as well as compost worms and big springtails

Dendrodrilus rubidus – an earthworm common in compost heaps, along with the Eisenia tiger worms. All adapted to life in a biog pikles of rotting vegetation

Pot worms (enchytraiedae): tiny relatives of earthworms abundant in organic rich or acid environments

Ereynetes sp. – The network patterns on the back of this tiny fungivore look like an angry spiderman!

Orchesella cincta – one of our largest springtails

A dinychid turtle mite, hunting nematodes

Big ‘litter’

Banksinoma sp – note the large anal shields on this mite which let out a high fibre diet of rotting wood!

The litter that accumulates on the soil’s surface isn’t just leaves – it includes all manner of dead material – even trees. A tough diet means that many creatures here grow slowly, and live a long life, and therefore need to be well defended. Here are a few of the creatures that turn up in rotting wood.

Kalaphorura burmeisteri is a blind springtail that looks like the michelin man – with poison glands!

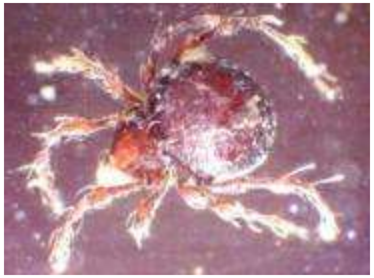
Centre:box mites live long and defend themselves by folding up into an impregnable “pip”

The front “feeler” legs of this *Linopodes* mite are incredibly long.

Blaniulus guttatus – a small millipede dotted with red poisonous glands..

Little litter

Smaller litter, such as leaves, is more readily digested, and this supports a dynamic habitat of grazers and decomposers, and their predators.



Damaeid mites have long spidery legs, but move slowly through the litter as fungivores

Veigaiia sp – this is a predatory litter mite, equipped with huge pincers for mouthparts.

Dicyrtomina saundersi is a common golbular springtail with colourful maroon and green patterns.

Pogonognathellus longicornis – our largest springtail, can be ID’ed by its antennae which curl up when blown upon

Pseudo scorpions like this *Allochernes wideri* prowl the litter and grab passing springtails for lunch.

Chamobates sp. like many oribatid mites, can tuck their legs away under side “wings”.

The soil surface!

Other ‘soil’ creatures run around on the soil’s surface. Part the grass in your garden and you may spot some of these characters:

Smooth soil surfaces, plant stems and paving slabs allow *Anystid* mites to pick up speed – the fastest animals in the world, for their size!

Sminthurinus aureus comes in black as well as yellow!

Lumbricus rubellus a common surface earthworm that rarely burrows.

Lepidocyrtus cyaneus is one of our commonest springtails. They dash around the soil surface like tiny drops of quicksilver.

Isotoma viridis is another common grassland springtail – larger and green!

Pergamasus sp. A large predatory mite

Deeper in the soil

The soil itself is a fractal cave system of pores, dripping with water, swarming with bacteria, branched by fungi, and with creatures crawling through the pores, or making new ones. These animals would be typical within the first 8cm of soil.

Stenaphorua denisi has tail spines for protection or anchorage?

Oppiid mites are tiny and hugely diverse – the 'small brown job' of soil biology!

Oribatid mites in the soil tend to be neater – note the smaller wings on this *Scheloribatid*

Tiny *Sphaeridia pumilis* is named after its rounded bottom

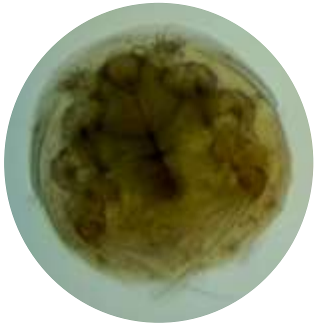
"Endogeic" means inside the earth – and these worms, such as *Octolasion cyaneum* here, are pale and pasty.

Alliphis mites live free in the soil, but seem to travel with beetles

The inky depths

As you go deeper into the soil, the pores get smaller, and so do the creatures that live in them. There are also fewer creatures as you go down the soil profile because most of the energy supply goes into the topsoil. However, among the tiny crevices below 15cm you will a few of these tiny creatures. Bucking the trend deep burrowing earthworms can dig burrows 2m into the subsoil, increasing drainage and aeration.

Lumbricus terrestris – the common Lob Worm, can pass on its burrows to other worms after it dies.



Tiny *Scutacarid* mites have round shells and brush-like hind legs, and look a bit like miniaturised horseshoe crabs.

Rhagidiid mites are found at the surface too, but some wriggle very deep indeed and they are among the most common mites found in caves

Tarsonemid mites are weirdly shaped, and males use huge back legs to carry females around before mating. They're also found in plant galls.

Chamobates sp. like many oribatid mites, can tuck their legs away under side "wings".

But all this fascinating life isn't just there for decoration! Soil needs life to work

- Soil life:
  - Builds soil structure – crumbs and channels
  - Makes humus to store water and nutrients
  - Recycles nutrients at plant roots
  - Controls pests using predators and microbes

Without the soil life to decompose the plant litter, rebuild the soil aggregates, create new pores, renew the humus and prey on soil pests, the soil starts to degrade.

Nutrients can remain bound up in organic matter, trapped in anaerobic compacted soils, humus levels dwindle, accelerated by soil disturbance, making the soils poorer at holding water and nutrients.

Less biomass of soil life means fewer predators, which makes life easier for sudden outbreaks of pests.

But soil needs plants too – principally as a source of fuel:

- Soil life dwindles without plants
  - Photosynthates
  - Root exudates
  - Litter
  - Compost
  - Dung
- No fuel = no work = soil problems

In conclusion: soil life is almost entirely the gardener's friend, but needs fuel, from plants (or compost etc.) to survive. Putting more organic matter into the soil will result in a larger biomass of soil life working for you.

Wildlife gardening for soil life?

- Maintain a variety of (micro) habitats
- Don’t be too tidy!
- Take an interest…

But if you want to encourage a high diversity of soil life in your wildlife garden, what should you do?

- Maintain a variety of microhabitats’ – just like life aboveground – you get different species living in different places in different ways. Leaving some areas undisturbed will encourage long-lived organisms, while sudden appearances of fresh organic matter will attract a different group.
- Don’t be too tidy! Piles of rotting vegetation, logs, clippings – even dung – will encourage a new a diverse flora.
- And take an interest! You can get a microscope for about £10 on the internet; go and dig up a bit of soil and have a look at it.

Soil life needs you!

- Surprising easy to get into…
  - Cheap microscopes (£10 from e-bay!)
  - Online help & resources
  - FSC field guides
- You are the next experts!
- Recording and monitoring - your data will help
- New world to be discovered!
- Join our Soil Biodiversity UK Facebook group here:

Mycorrhizal fungi and plants

Martin Bidartondo, Imperial College & Kew Gardens

Fungi, and mycorrhizal fungi in particular, have something of a public relations problem. Many people are more familiar with fungi as agents of disease than with their far more common roles in recycling nutrients and helping plant growth, the word mycorrhiza is both difficult to pronounce and write, and mycorrhizal fungi live hidden in the soil away from even the more curious eyes.

In fact, many gardeners only come across mycorrhizal fungi through products on sale at garden centres and online. I often receive calls and emails from people who are trying to grow some particular plant or tree about whether to add mycorrhizal fungi to their soil and which product is best. I do not have a good answer to those questions, unfortunately, because I am a bit sceptical about many of these products from reading their fine print where they rarely indicate which species of fungi they contain, from where, in what form or how much.

If they do provide any of this information, they often seem likely to be mismatched to most plant species, or simply be weedy mycorrhizal fungi that may or not promote plant growth in the typically nutrient-rich conditions of most garden soils - soils that probably already harbour many weedy mycorrhizal fungi. No harm in trying, though, and you never know, you might get lucky!

So, let us turn now to a ‘crash course’ on the biology and ecology of mycorrhizal fungi and then highlight some of the projects currently going on.

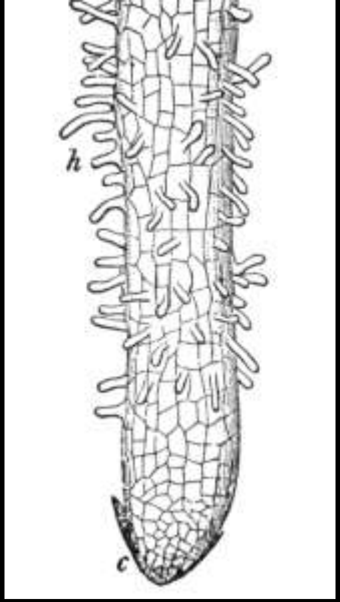
We can think of plants as an energy source, something like a power drill that needs a set of attachments in order to perform various tasks. For plants, those "attachments" are mycorrhizal fungi that colonize roots, grow into the smallest crevices and pores of soil, and mine them for the mineral nutrients and water that plants require to grow. In return, the fungi get direct access to carbohydrates produced by plants. The roots of plants are capable of forming root hairs to explore soil, but they are no match for fungal filaments. Root hairs are short, thick, cannot branch or fuse. The filaments (aka hyphae) of fungi can grow as long as resources and the environment allow, they are much thinner, and they can branch and fuse to form networks.

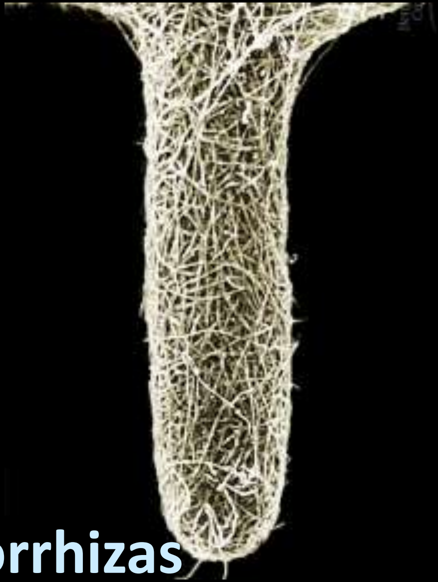
A single gram of soil can contain over thirty metres of mycorrhizal fungi! Most plants are better off turning off their stout root hairs and paying nimble fungi for the hard work of mining.

Early in the evolution of plants on land some 500 million years ago, the services of fungi were necessary for plant success, and they continue to be so for the vast majority of plants today. Mycorrhizas are an ancient intimate symbiosis between plants and fungi that is typically mutualistic - both plants and fungi benefit from growing into each other.

There are two major types of mycorrhizas today.

- Arbuscular mycorrhizas (aka endomycorrhizas, VAM or AM) are the most common in herbaceous plants, shrubs and some trees, they are specialized for P uptake and thus are dominant in systems where P available for plant growth is limited such as grasslands and tropical forests.
- Ectomycorrhizas are restricted to trees like pine, spruce, beech and oak, they are specialized for N uptake and thus dominate systems where N availability is low such as boreal and temperate forests.
- In addition, two plant families have evolved their own individual mycorrhizal types - the heathers that grow in the extraordinarily low-nutrient heathlands, and the orchids whose young seedlings grow completely underground and, suprisingly, entirely supported by fungal carbohydrates (mycorrhizas functioning in reverse!).





Arbuscular mycorrhizas

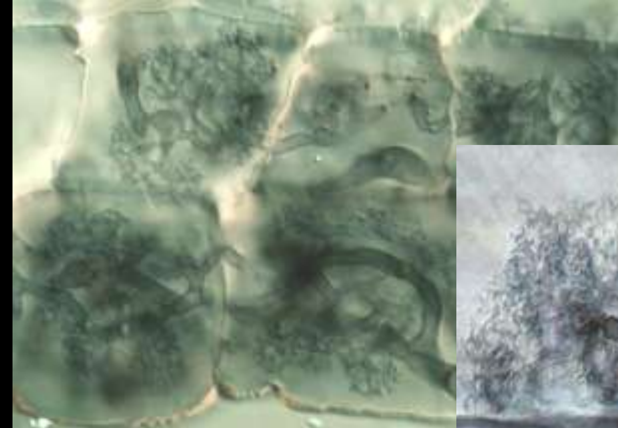
Ectomycorrhizas

Arbuscular mycorrhizas:

ca. 80% of plant families

+ Glomeromycota fungi

P uptake



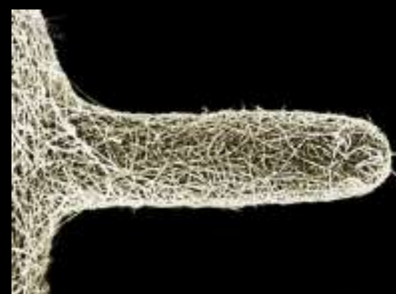
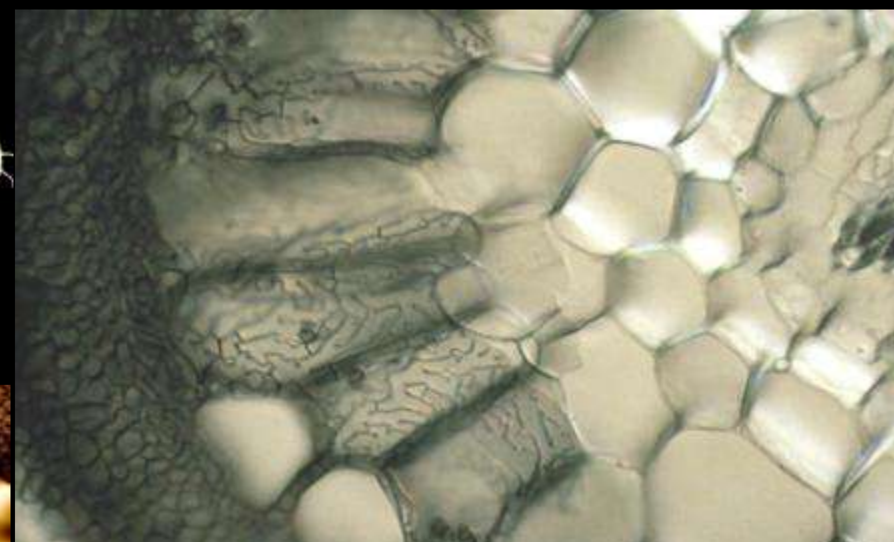
Ectomycorrhizas:

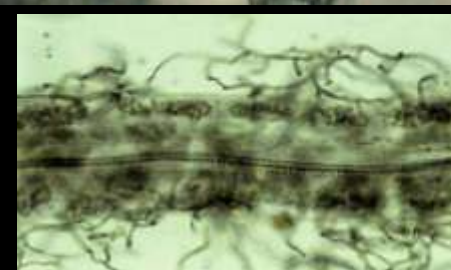
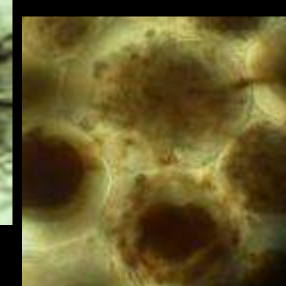
ca. 3% of plant families

+ some Basidiomycota

and few Ascomycota

N uptake

Ericoid mycorrhizas: heathers + few Ascomycota

Orchid mycorrhizas: orchids + few Basidiomycota & Ascomycota

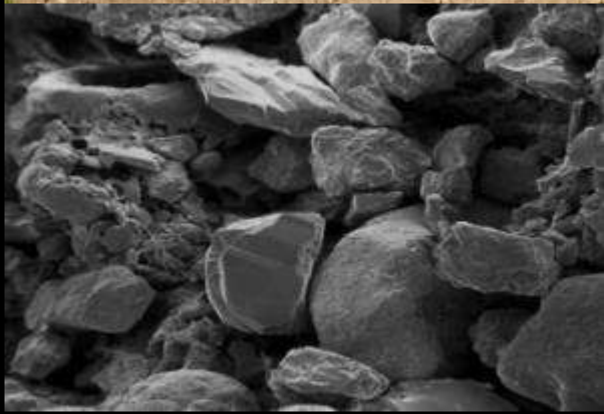
Mycorrhizas

are ancient plant-fungal symbioses,

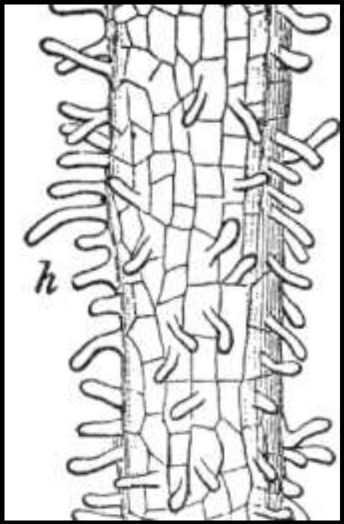
typically mutualistic and obligate,

based on trading photosynthate for soil minerals,

involving the majority of plants and a minority of fungi.



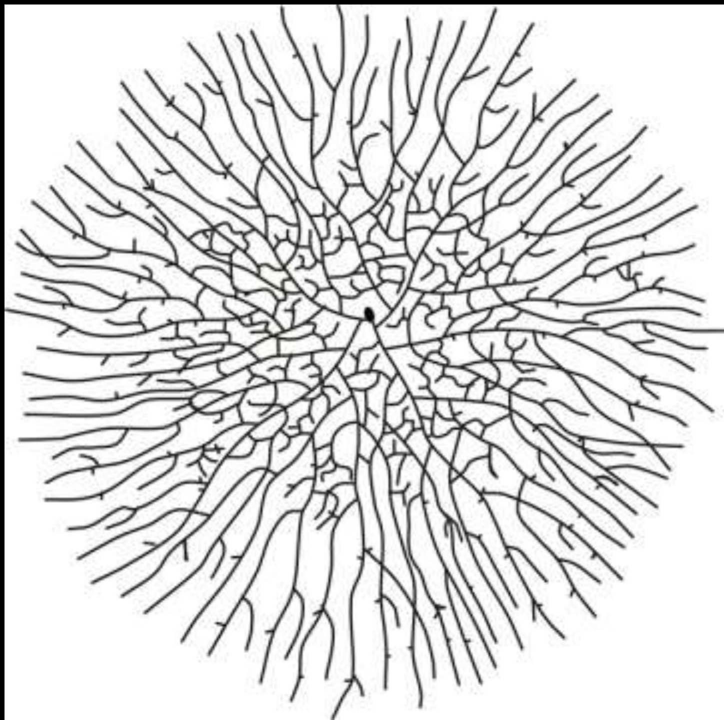
Plants *vs*. fungi:



Root hairs 10-20 micron diameter
< 1.5 cm length
unbranched
nonfusing

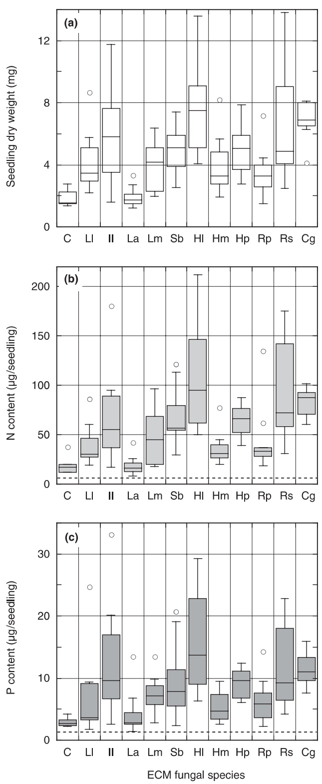
Filaments > 2 micron diameter
indeterminate length
branching
fusing

Up to 35 m of fungi per g of soil.



Ecologists have known for some decades that different species of mycorrhizal fungi have very different effects on plant growth. It matters which species of fungi, which species of plant, and which environmental conditions are present. Some of the clearest demonstrations of this have been elegant experiments by Kazuhide Nara in Mount Fuji.

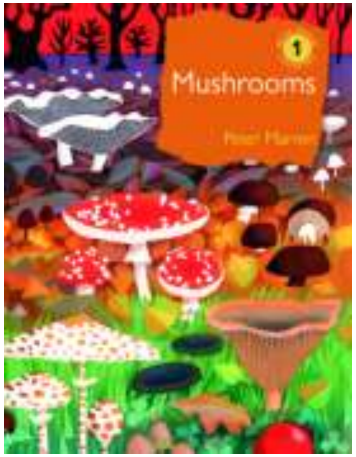
We also know that some mycorrhizal fungi are under huge pressure from commercial harvesting for human consumption - these include the expensive and still uncultivable chanterelles, porcini and truffles, that must be gathered from natural forests.

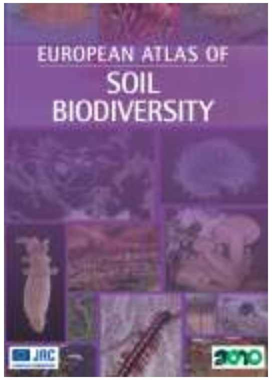


£20/kg

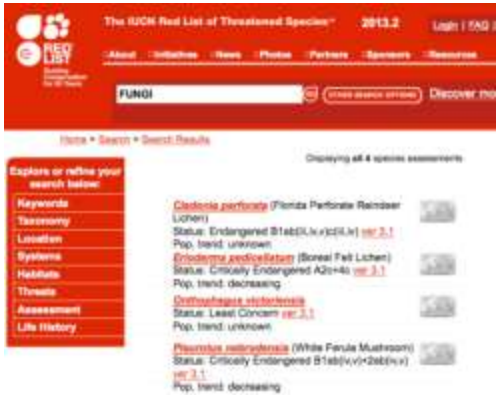
Nonetheless, fungi are essentially ignored by conservation policy, as pointed out by Peter Marren in his 2012 book 'Mushrooms'.

"We have only a very imperfect idea of the distribution and status of fungi. Hence, it is difficult to assess which species are genuinely rare or declining, and which are merely poorly recorded or simply do not fruit very often. Certain countries, most notably the Netherlands, have made creditable stabs at producing Red Lists. Elsewhere, the evidence is patchy."





Contains no maps for fungi…



>21,000 species red-listed by IUCN. Three are fungi…

Ecologists, such as Erik Lilleskov and Jeri Parrent, have called for efforts to build global datasets and predictive models for fungi before it is too late in the face of rapid global change. We are in the midst of the largest ever uncontrolled experiment - every day we are all taking vast amounts of C and N from the atmosphere and lithosphere, and dumping them into the biosphere.

"Although it is tempting to throw up our hands given the complexity of the challenge, we believe that the attempt should be made to build global data sets and predictive models, recognizing that this will be an iterative process. The price of not acting now will be a lost opportunity to define baseline species distribution data in the face of rapid global change."

Erik Lilleskov & Jeri Parrent 2007

Because plants trade much of their C for N from mycorrhizal fungi, and most C is in plants and soil, the effects of pollution on plant-fungal symbiosis deserve close attention.

ATMOSPHERE

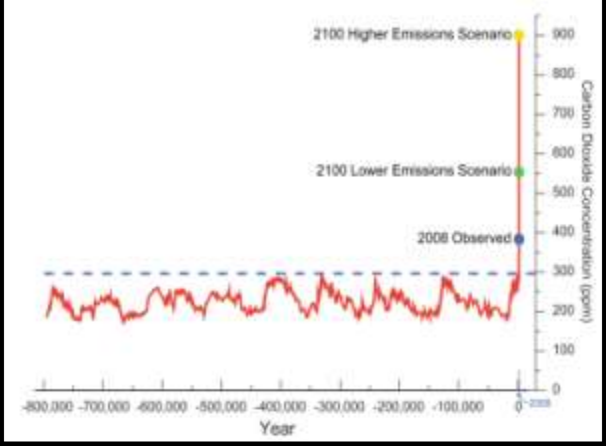
N from air

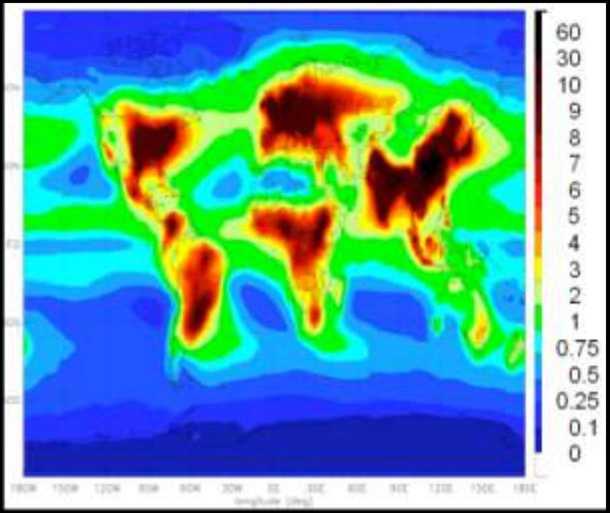
BIOSPHERE

N from fossil fuels

CO_2 from fossil fuels

LITHOSPHERE





Historical levels: CO_2 *ca*. 300 ppmv
N deposition *ca*. 0 kg/ha/yr

Current levels: **CO_2 to 390 ppmv**
N deposition *ca*. 0 to 50 kg/ha/yr

Plants trade 20% of their C to get 75% of N from fungi.

High and increasing pollution globally.

What is happening below ground ?

We are carrying out detailed large-scale molecular analysis of mycorrhizas in Europe's dominant forests (e.g. pine, spruce, beech, oak) in collaboration with one of the world's most extensive and intensive monitoring networks.

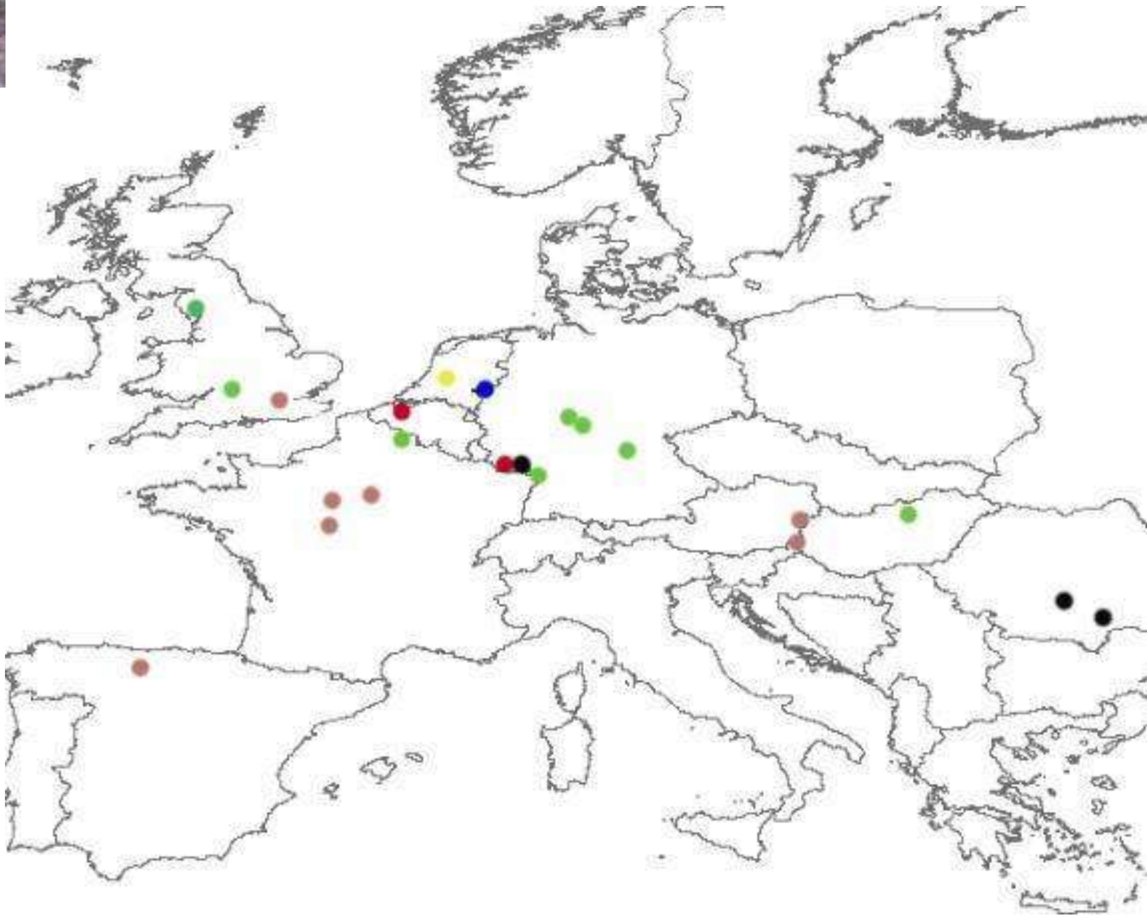
http://icp-forests.net

Large-scale analysis of mycorrhizal fungi belowground is finally feasible now, and the promise of predictive power regarding diversity, distribution, function and change is now within reach.

22 oak monitoring plots

2,112 soil cores

6,336 mycorrhizas

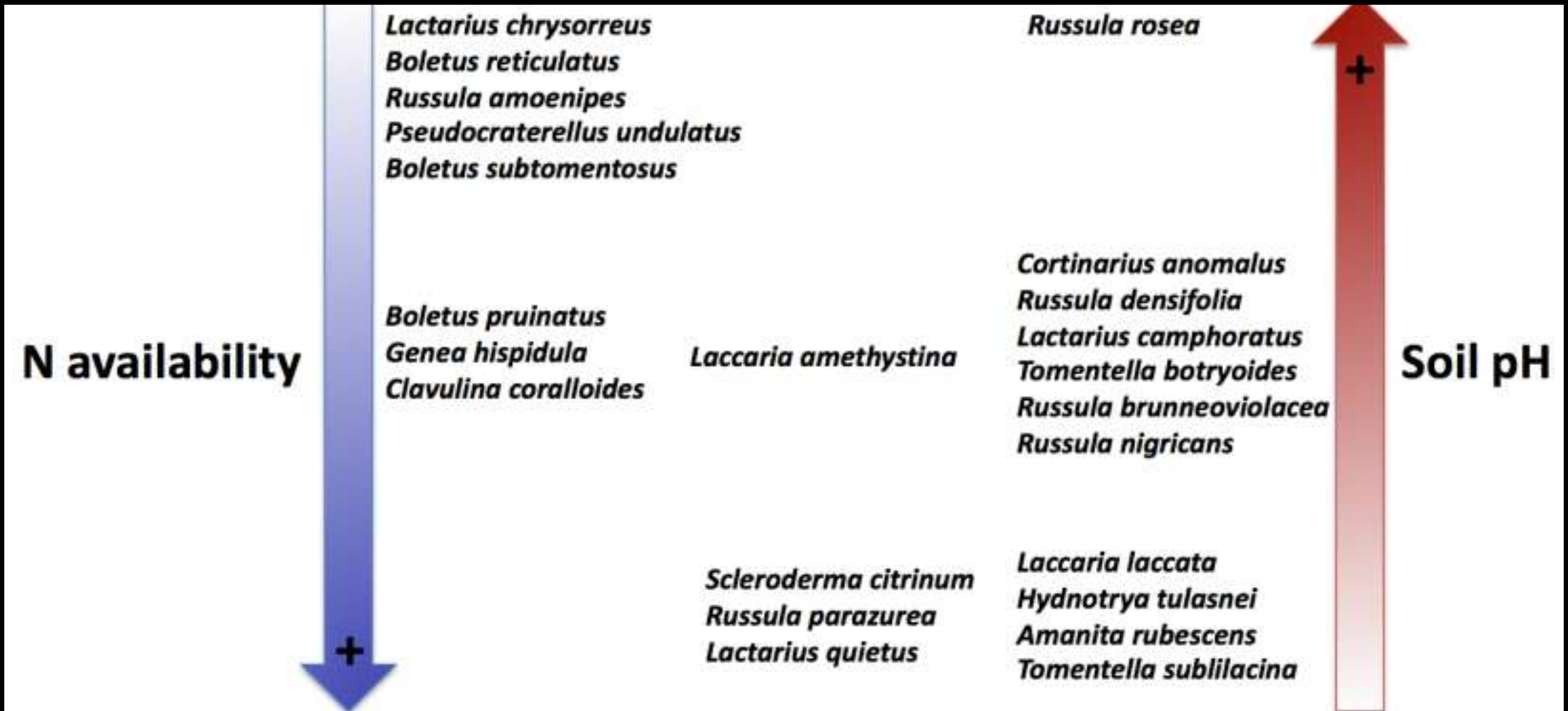


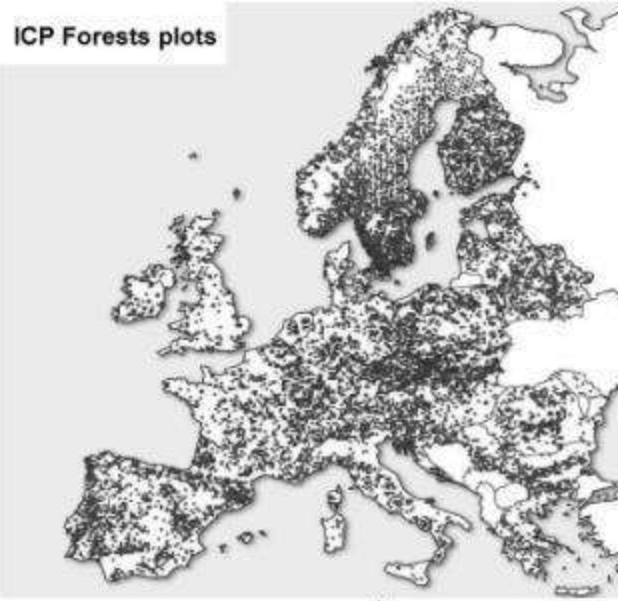
We are working hard to implement standardized sampling for DNA sequence-based data on fungal geographic distribution from long-term plots that are intensively monitored for environmental data. So far, we are finding that N pollution is negatively affecting the richness and evenness of mycorrhizas across Europe.

N pollution, soil pH & root density explain changes in mycorrhizal richness, evenness and functional types. Two **N critical loads** for mycorrhizal richness and evenness:

9.5 – 13.5 kg N/ha/yr: moderate changes.

>17 kg N/ha/yr: drastic changes.

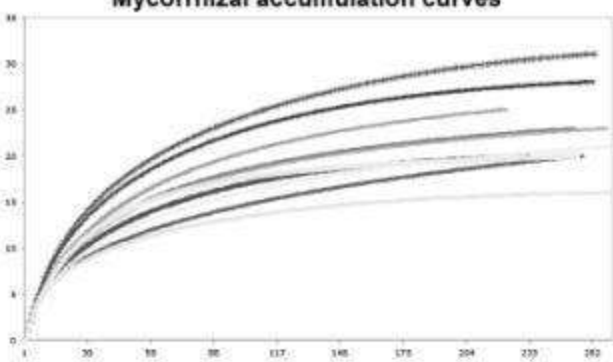




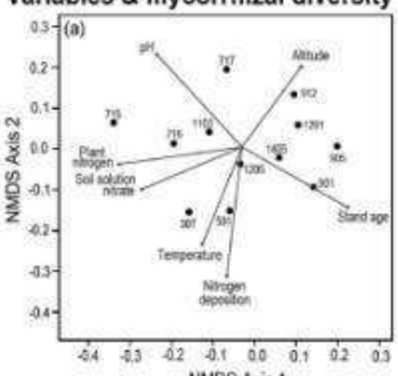
ICP Forests level II plots
√ = plot already sampled

Typical level II plot map

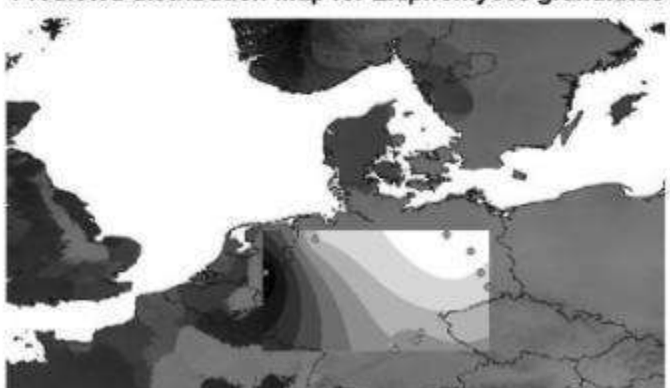
Mycorrhizal accumulation curves



Ordination of environmental variables & mycorrhizal diversity



Predicted distribution map for *Elaphomyces granulatus*



"Standardized sampling

for DNA sequence-based data

on fungal geographic distribution

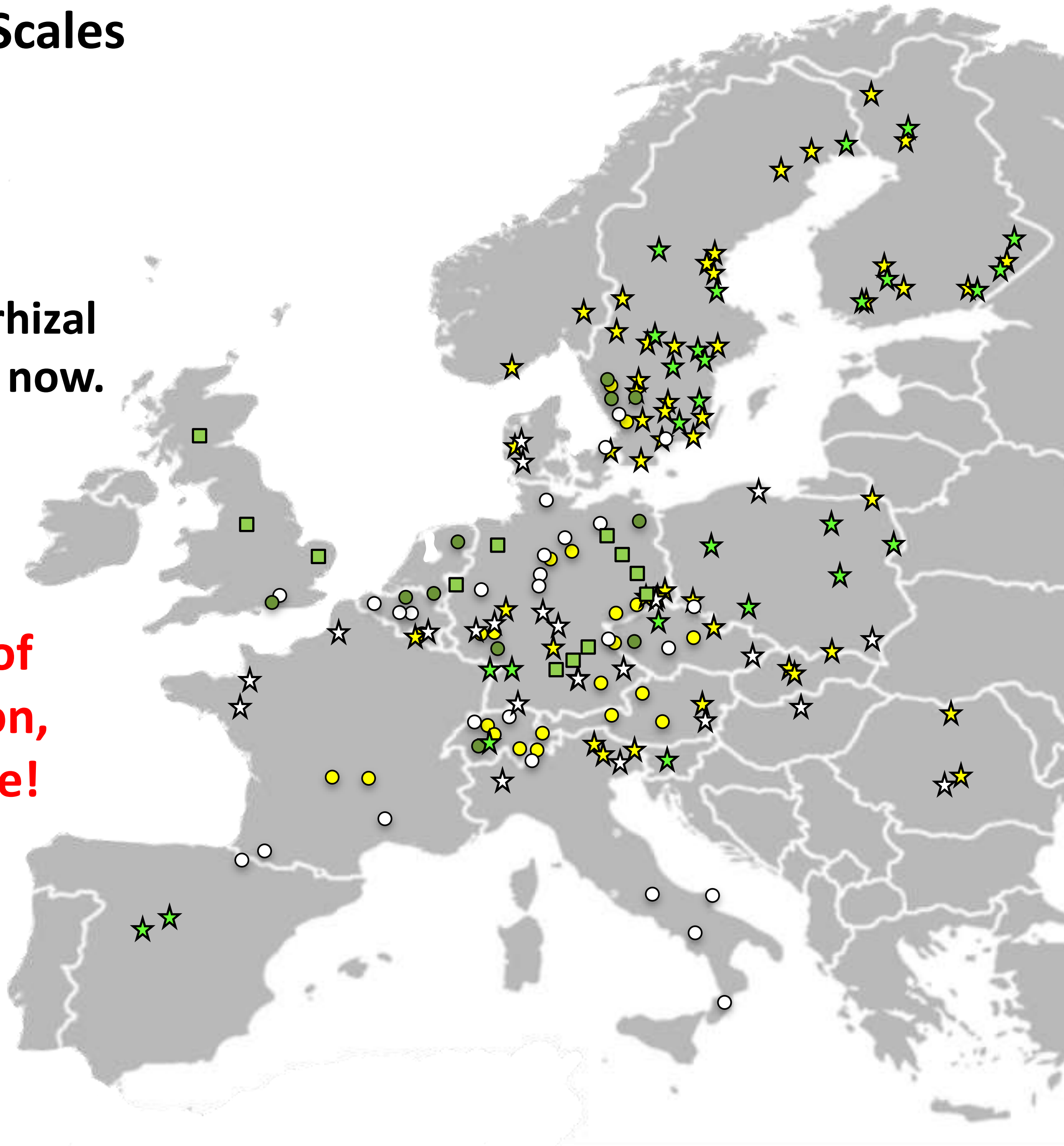
from long-term plots

that are intensively monitored

for environmental data."

Suz, Fischer, Bidartondo. 2014. **Molecular Ecology**.
Suz, Mueller, Bidartondo. 2014. **Annals Forest Science.**
Tse-Laurence, Bidartondo. 2011. **iForest.**
Cox, Lilleskov, Bidartondo. 2010. **Ecology Letters.**
Peay, Bidartondo, Arnold. 2010. **New Phytologist.**
Cox, Rautio, Bidartondo, Vesterdal. 2010. **Annals Forest Science.**

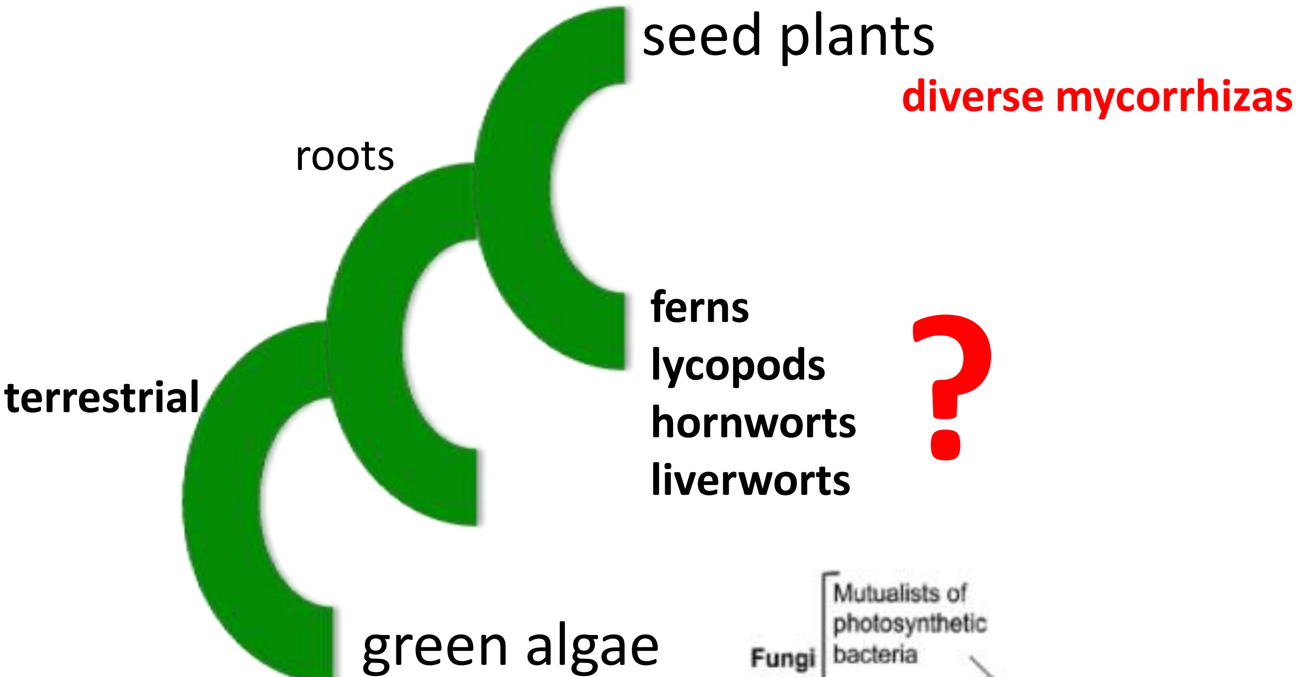
Mycorrhizas at Large Scales
2013-2016

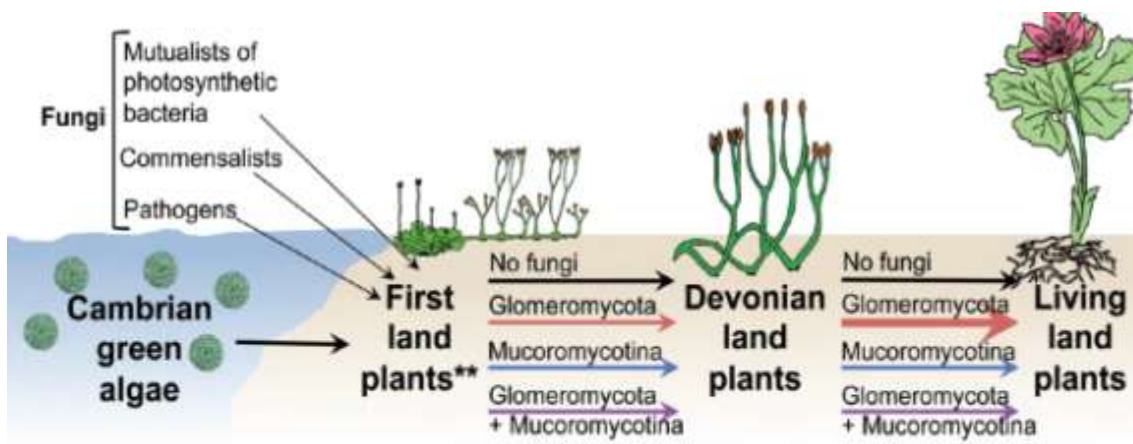


Large-scale forest mycorrhizal assessments are feasible now.

Predictive models of diversity, distribution, function and change!

Only with that knowledge can we design robust experiments to understand mechanisms and test management techniques for global change at different scales, from Europe's vast forests to our own wildlife gardens.





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2011. **Biology Letters** 7: 574-7.

Natural Environment Research Council, ICP Forests, EU Marie Curie, Bentham-Moxon Trust, Forest Research & British Mycological Society.

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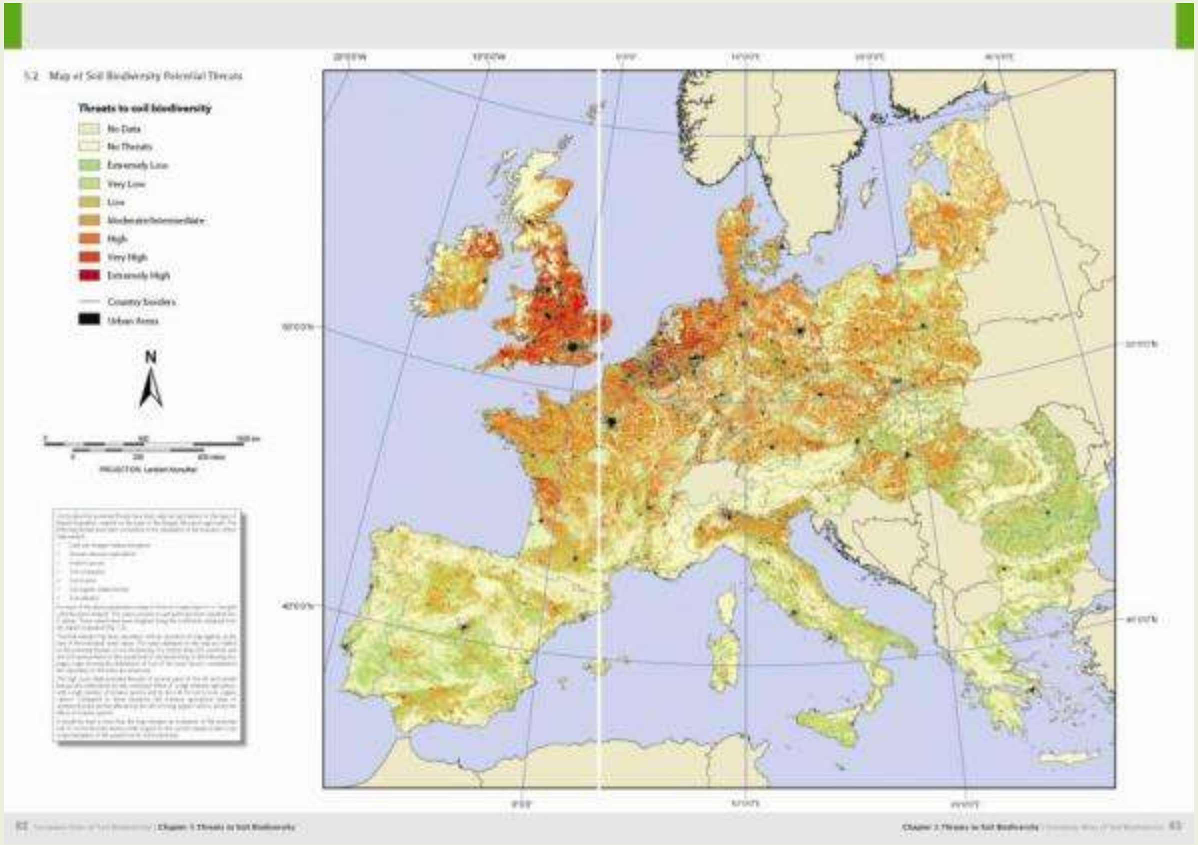
How soil biology helps food production and reduces reliance on artificial inputs

Caroline Coursie, Conservation Adviser
Tewkesbury Town Council

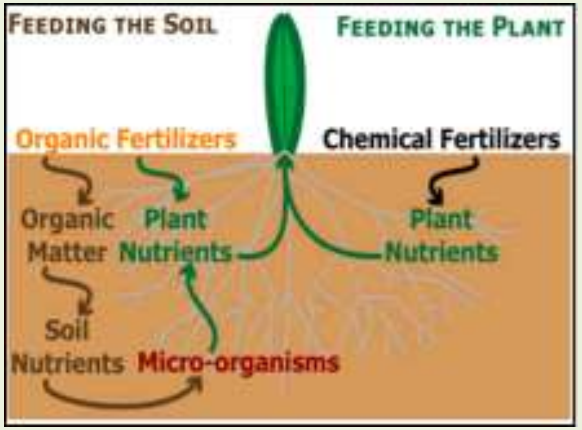
Threatened soil biodiversity

On a recent map of depicting the level of threat to soil biodiversity in Europe, it is very evident that soil biodiversity is generally very threatened which means that the resilience of our food production systems, our wildlife and ultimately our food security are also all under threat !



Soil as a Habitat

Structure + Chemistry + Biology



A fully functioning soil will have good soil structure, a balanced chemistry and thriving populations of soil biodiversity. A healthy soil will innately have good supplies of nutrients and be able to supply all the necessary nutrients for plant growth. A thriving soil biodiversity will control pests and diseases. Energy derived from sunshine should be driving the soil ecosystem.

I generally prefer to avoid bare soil (unless managing specifically for e.g. ground nesting bees). A bare soil is prone to leaching, is not capturing sunshine and has no plants photosynthesising. Photosynthesis is the process where plants capture energy from the sun and convert it into carbohydrates, proteins, lipids and other compounds which are essential for plants. A healthy soil can store nutrients and prevent them contaminating water bodies, it can also bind pesticides and de-nature them. Systems which rely on artificial inputs such as pesticides and fertilisers invariably end up with problems and we see this reflected currently with our farmers trapped in farming systems dominated by artificial inputs , contaminating watercourses, accompanied by often poor soil health and commodity prices our food production systems are in trouble.

Structure

Compaction = No air/anaerobic conditions, fungi crushed, excess alcohols kill plant root cells, diseased plants, poor yields , nutrient leaching

Soil compaction is a widespread problem and many farmers, growers and allotment holders don’t even know they have it! Processes such as rotavating or ploughing, especially when the soil is wet, can lead to hard layers (pans) at different depths which then results in anaerobic conditions and encourages anaerobic bacteria, poor rooting, waterlogging, plants which are more susceptible to disease and less able to compete against weeds, poor yields, nutrient leaching, problems with slugs etc!

Heavy power fuelled cultivations eat up fuel and many of soil creatures can’t get out of the way fast enough. The solution is work with the soil and nature.

Rotavating

Rotovating / digging (ploughing)

= bacterial dominance (good for annuals)

But:

= Loss of soil structure

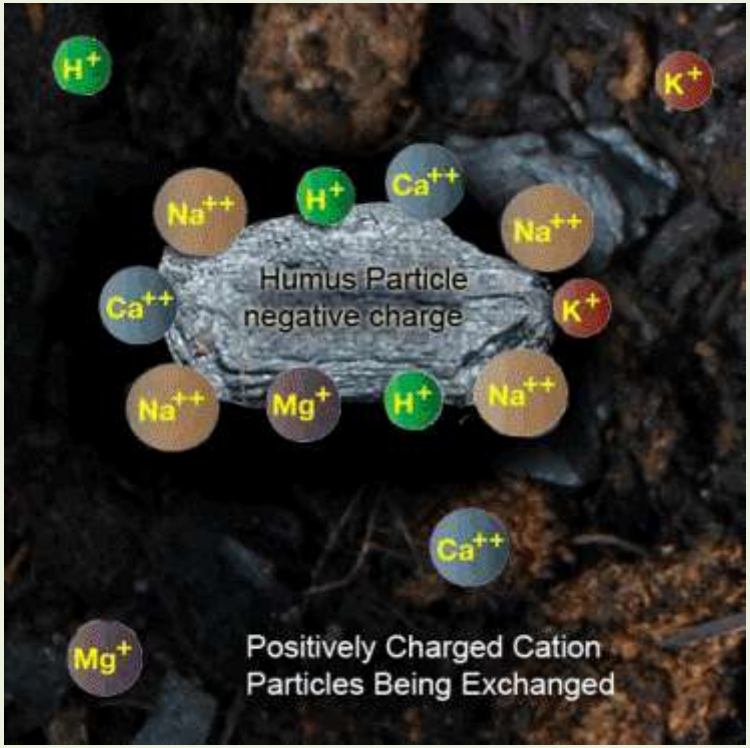
= Loss of soil biota/ damaged food web

= Increased reliance on artificial inputs

= Loss of fungi

= Energy wasted

Cation Exchange Capacity (CEC)



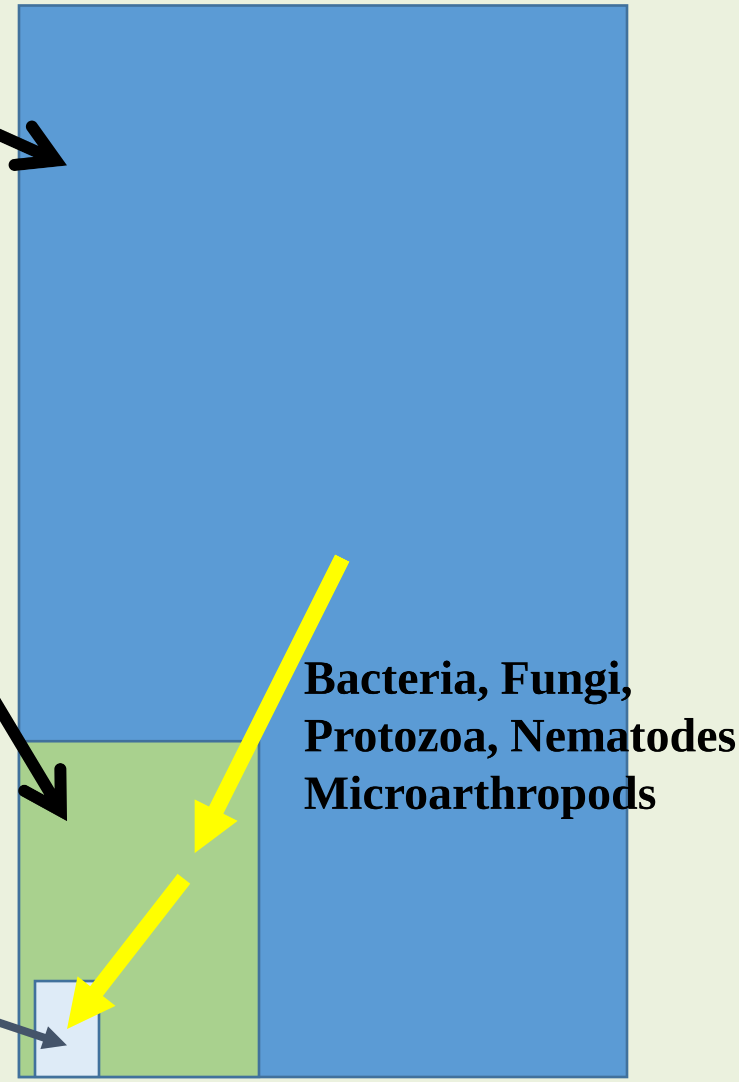
You've heard the song "I feel the earth move under my feet "? A healthy soil is full of energy. If you tune yourself in, your soil will tell you what it needs. Different soil types have different levels of electrical activity. Clays and high organic matter soils have what's called a Cation Exchange Capacity. During processes such as weathering and biological activity, the negative charge on the clays and organic matter result in exchange processes with the soil solution. For example Hydrogen ions (H+) may be exchanged for Calcium (Ca++). Most of this activity happens on the surface of clay. Soils which have more sand in them, have much lower electrostatic charge and will rely much more on management of organic matter to prevent nutrient loss and reach full yield potential. This is one of the mechanisms by which nutrients become available so it is worth looking after.

Nutrient Pools in Soil

Total – everything

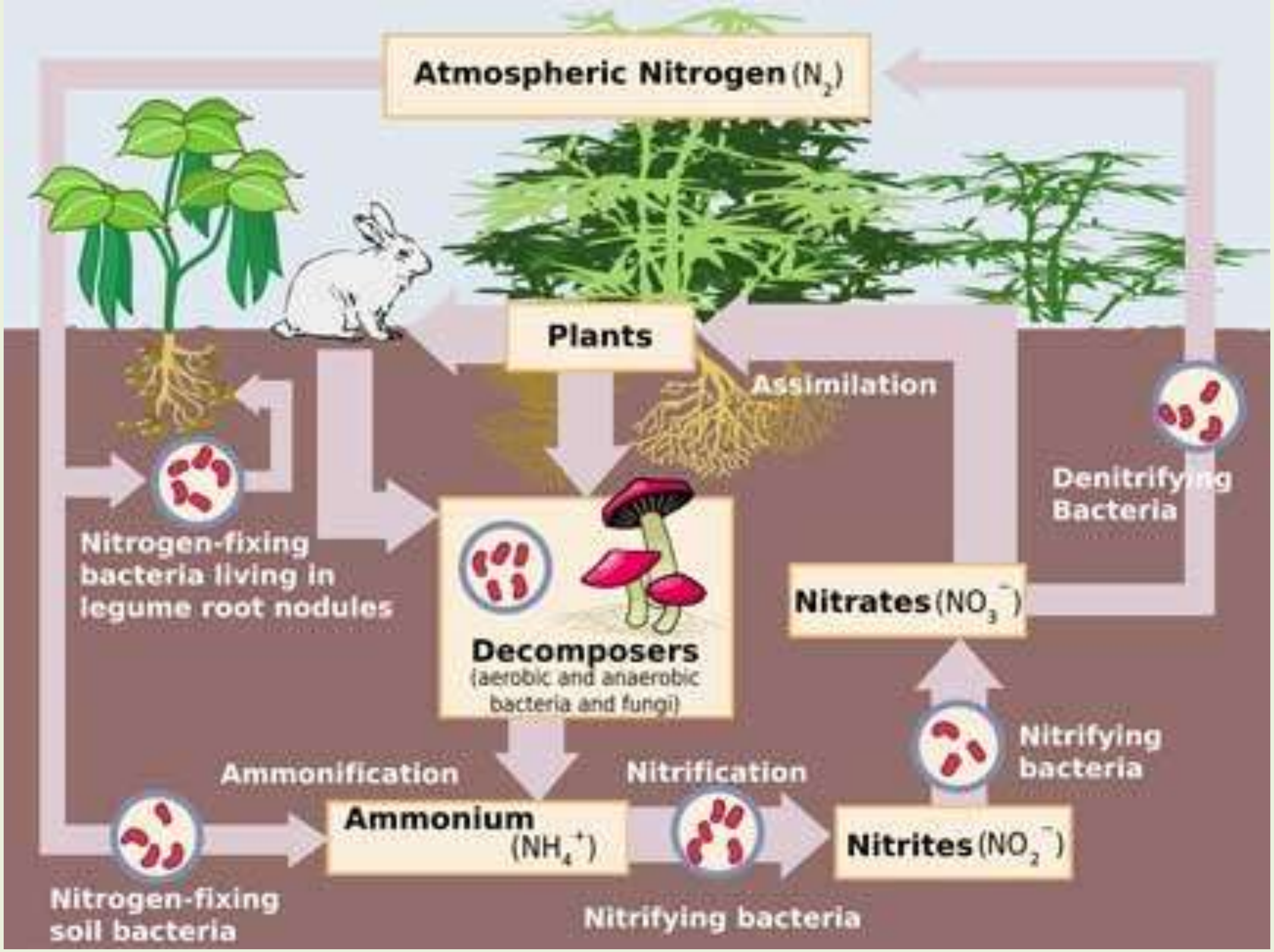
Exchangeable - easily pulled off surfaces; easy to make soluble

Soluble – dissolved in soil solution; potentially available to plants



Only a tiny amount of all the nutrients in the soil is needed to produce crops. We can all probably remember studying the soil food web at school? it's being brought back to life again by people such as Dr Elaine Ingham, an American microbiologist (whose web site and u-Tube videos are worth a visit). A biologically active soil with diverse predator prey systems is required for these nutrients to become available and remove reliance on artificial inputs.

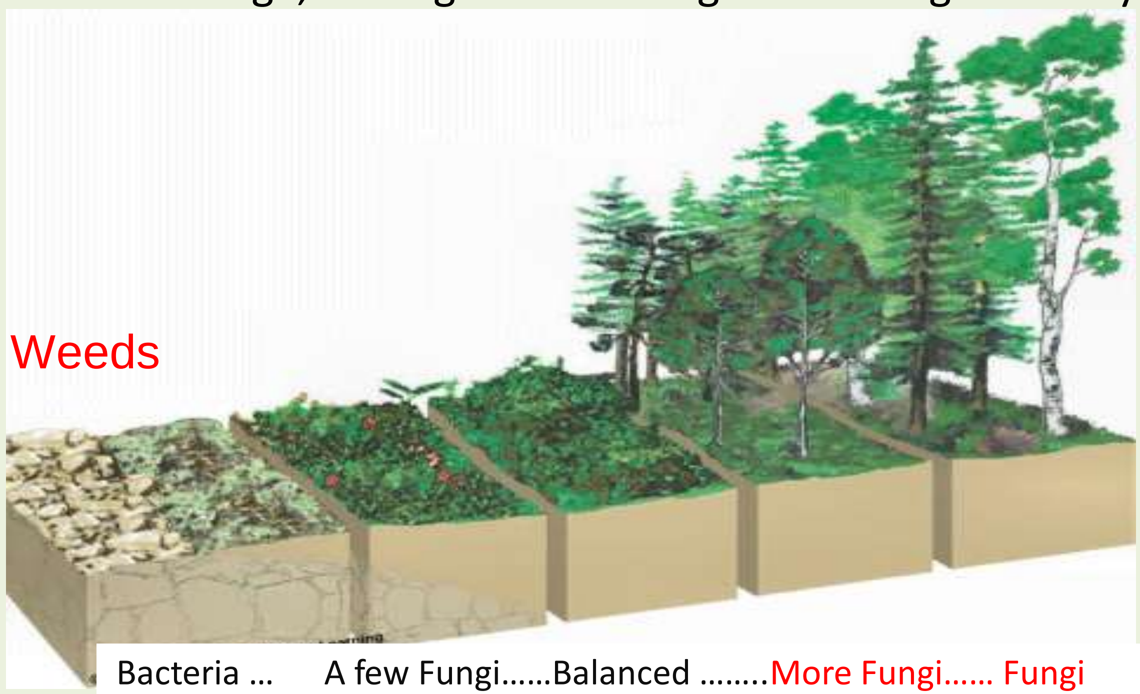
Plants cannot absorb N from the air (as N2)
N is needed for proteins and enzymes.
N transported from older to younger leaves
Nitrogen fixing bacteria turn into plant usable form



In a healthy soil, soil biology will...

- Suppress Disease = reduced pesticides
- Retain Nutrients = stop run-off, leaching
- Make nutrients available = reduce artificial fertilizer = flavor and nutrition
- Decompose toxins
- Build Soil Structure = reduce water use, increase water holding capacity, increase rooting depth
- Rhizosphere = plant roots and surrounding soil. Under the influence of the plant. This area is very energy rich and supports soil microbial populations 100s of times greater than soil only s few millimetres away.

If you leave a soil to do its own thing untouched by human activity it is likely to go through a succession process of what we might see first as ‘weeds’ (the right plant in the wrong place?!), then it may get grazed by herbivores, they may get eaten, there is plant and animal decomposition, and ultimately scrub and forest will develop. As this process happens the soil moves from becoming bacterial dominated (e.g. where it is *asked to produce annual crops) to* becoming more fungal dominated (e.g. the rich organic soils of primary forest). By adding manures and composts we are attempting to redress the balance and encourage, amongst other things more fungal activity.



Bacteria …   A few Fungi……Balanced ……..More Fungi…… Fungi

Bacteria:	10 µg	100 µg	500	600 µg	500 µg	700 µg
Fungi:	0 µg	10 µg	250	600 µg	800 µg	7000 µg

Soil Foodweb Inc

Photosynthesis
Leaves to Roots -

50% of energy into roots is released as:

- **Simple Sugars**
- **Proteins**
- **Carbohydrates**

Sunlight is converted through plants photosynthesising into energy which is released through and by the roots into simple sugars, proteins and carbohydrates, like the ingredients you might mix in the kitchen to make cakes!

Continuing this metaphor, the complex environment in the roots and soils means that different parts of the root systems produce different kinds of cakes which support different populations of soil biology.

Soil biology = Free fertiliser

Soil bacteria and fungi = small bags of fertiliser

Nematodes and protozoa = are fertiliser spreaders

Bacterial Slime = bacteria exudates : slime attaches to surfaces , makes soil alkaline ,encourages N fixing bacteria , traps pathogens. Higher pH soils

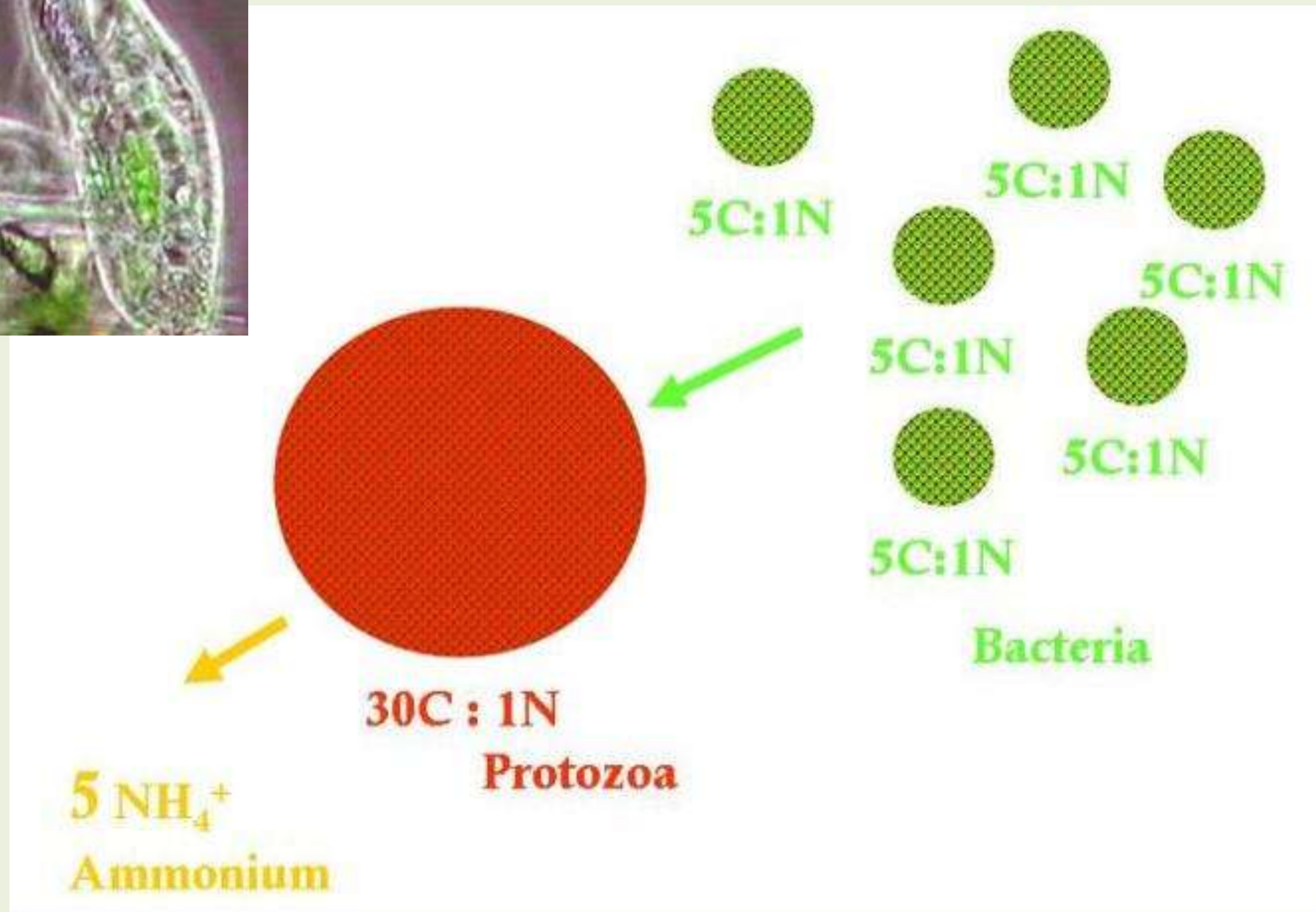
Fungal dominated soils are more acid (N remains in ammonium form)

Mycorrhizal fungi form symbiotic relationship with roots providing physical protection and nutrient delivery

If you lose/suppress the bacteria, fungi, nematodes and protozoa activity e.g. Through artificial inputs, Ph, OM) = Earthworms, as major shredders move out

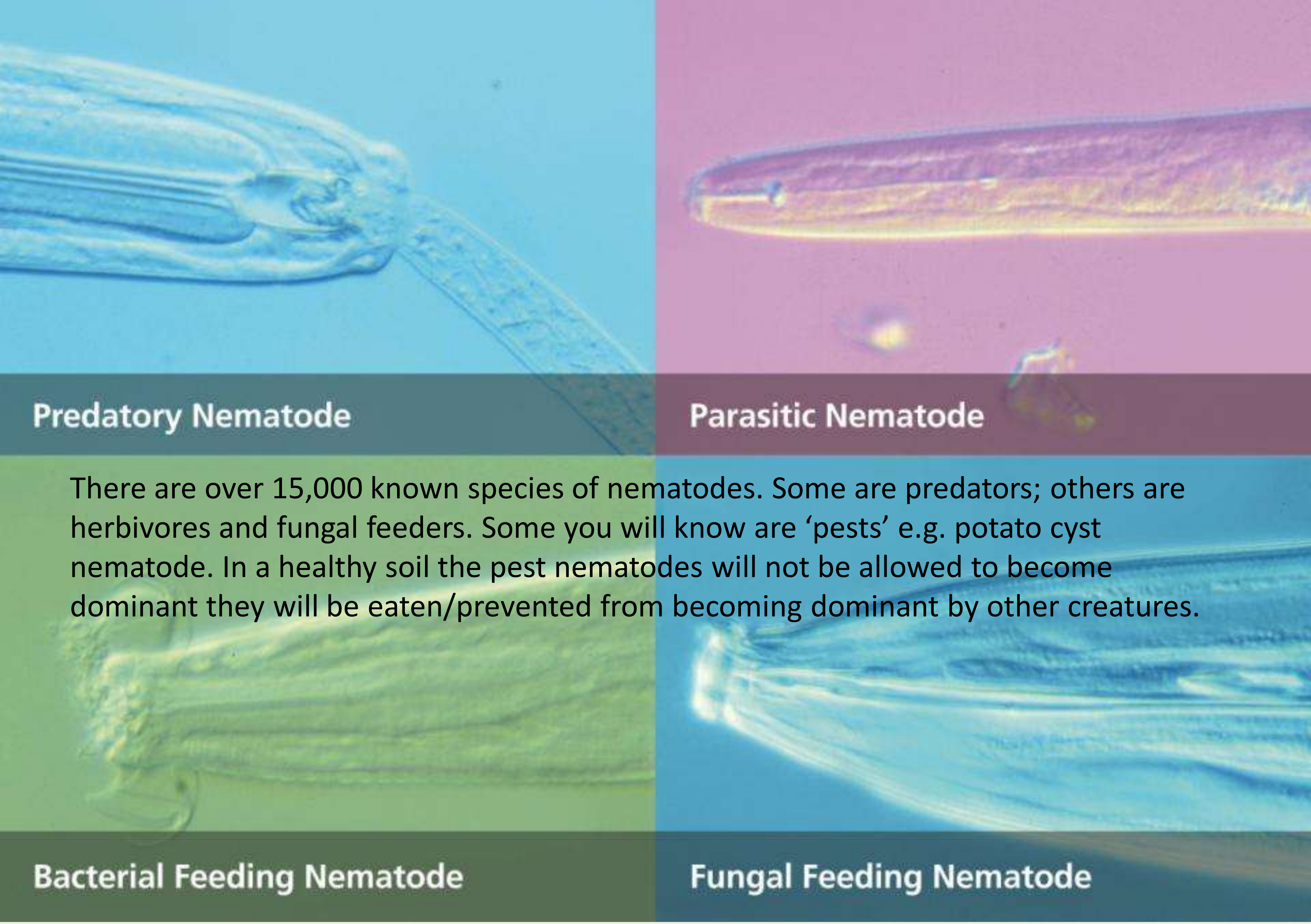
(Nihorimbere et al 2010, Lowenfels et al 2010)

A protozoan eats tens of thousands of bacteria in a day. As it eats, it excretes excess nitrogen resulting in ‘free’ nitrogen for plant growth



Ammonia Nitrogen - an inorganic, dissolved form of nitrogen that can be found in water, but in the presence of oxygen will convert to nitrate (NO3-)

(Kloepper et al., 1978).



There are over 15,000 known species of nematodes. Some are predators; others are herbivores and fungal feeders. Some you will know are ‘pests’ e.g. potato cyst nematode. In a healthy soil the pest nematodes will not be allowed to become dominant they will be eaten/prevented from becoming dominant by other creatures.

Source: Soil Food Web Inc ©

Plants are not defenceless.

In nature, plant disease is the exception because the conditions that are optimized for the plant growth may not be favourable for pathogens (Paulitz et al., 2001).

Only about 2% of the known fungal species are able to colonize plants and cause disease (Buchanan et al., 2000).

Plant-associated bacteria can reduce the activity of pathogenic microorganisms through microbial antagonisms and by activating the plant to better defend itself = induced systemic resistance (ISR)

Insect pests

- Pests are often the result of the soil food web / general biodiversity imbalance accompanied by problems in soil structure, soil chemistry and artificial inputs such as fungicides.
- Observe relationships which are present. You can buy a USB microscope for £10 online. This can be connected to your lap top and the
- Artificial Fertilisers, modern varieties, loss of biodiversity etc. encourage pests such as aphids (surges of nitrogen) and resistance
- Encourage beneficial biology which can range from predatory protozoa and nematodes to ladybirds and their larvae to birds such as sparrows which eat aphids
- If you must treat slugs consider applying predatory nematodes and if you really must apply a pesticide read up about ferrous phosphate which is sometimes cleared by organic bodies.
- Avoid off the shelf insecticides. These often contain neonicotinoid. These are not good! They compromise your soil biology and our pollinators.

Use cover crop mixes (often called green manures)

Cover Crops = No Bare Soil

Composting

- Adds a diversity of soil animals
- More diversity = better pathogens, competition
- In cold conditions it makes a better habitat for worms beetles millipedes etc
- Hot composting provides a usable product faster which will have fewer weeds. Not something I have mastered yet on my allotment, whilst I have farmers who are doing this on a large scale!
- Inoculants: such as mycorrhizal fungi can be obtained from soil which is known to support them. For example I may make a solution from soil supporting a mature hedge in which to dip new hedge plants before planting
- Compost 'teas' are another form of inoculants which an increasing number of farmers are experimenting with (e.g. visit the Soil Association website and their Field Labs
- Vermicompost: can range from the by-products of wormeries in the back garden to commercial scale systems using earthworms to convert slurry to 'natural' fertiliser
- Mulching : different mulches have different properties e.g. grass cuttings are bacterial and liked by many annuals
- Mulches excel when used in conjunction with compost

Lab tests

There are lots of ways you can monitor how biologically active your soil is including sending off samples for analyses. Commercial growers may seek to achieve balanced ratios of for example active fungi: active bacteria e.g. A ratio of less than 1 for growing tomatoes. Trees and soft fruits may prefer more fungal dominated soils so the grower may be aiming for an active fungi: active bacteria of much greater than 1.

Active Fungi (AF) /Total Fungi (TF)
Active Bacteria (AB) /Total Bacteria (TB)

AF/AB and TF/TB < 1 : = Bacterial dominated soils :
Annuals and vegetables prefer bacterially dominated soils

AF/AB and TF/TB = 1 : = balanced ratio . Arable crops, salads, cucumbers and tomatoes

AF/AB and TF/TB > 1 : = Fungal dominated soils.
Suited to crops that will prefer a more fungal environment – most woody plants and soft fruit including trees, shrubs and soft fruit like strawberries and blueberries.

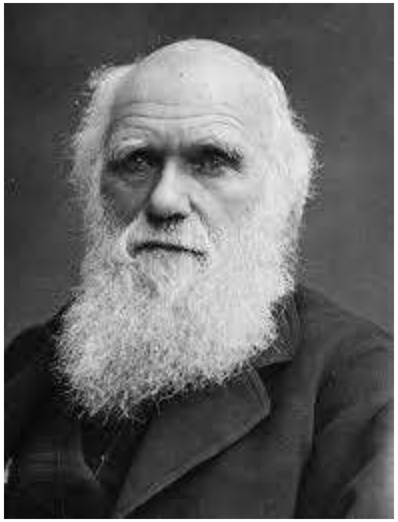
Earthworm Society of Britain
DIG INTO THE WORLD OF EARTHWORMS

NATURAL HISTORY MUSEUM

Earthworms – ‘what we know and what they do for you’

Earthworms are essential animals for the health of our natural environments. Some of Science's greats such as Aristotle and Darwin were very aware of the significance of these humble creatures.

Aristotle called them "*The Intestines of the Earth*" and "*Natures Plough*"



Darwin dedicated much of the last years of his life to them. In fact in his lifetime his bestselling book was his works on earthworms.

- *"It may be doubted whether there are many other animals which have played so important a part in the history of the world, as these lowly organised creatures"*

“*Ecosystem Engineers*”

In recent years they have been classed with the new phrase “ecosystem engineers” by Lavelle et al, a great term I think for what they are doing, but considering their importance and ease of collection and identification they have been largely overlooked.

Worms:

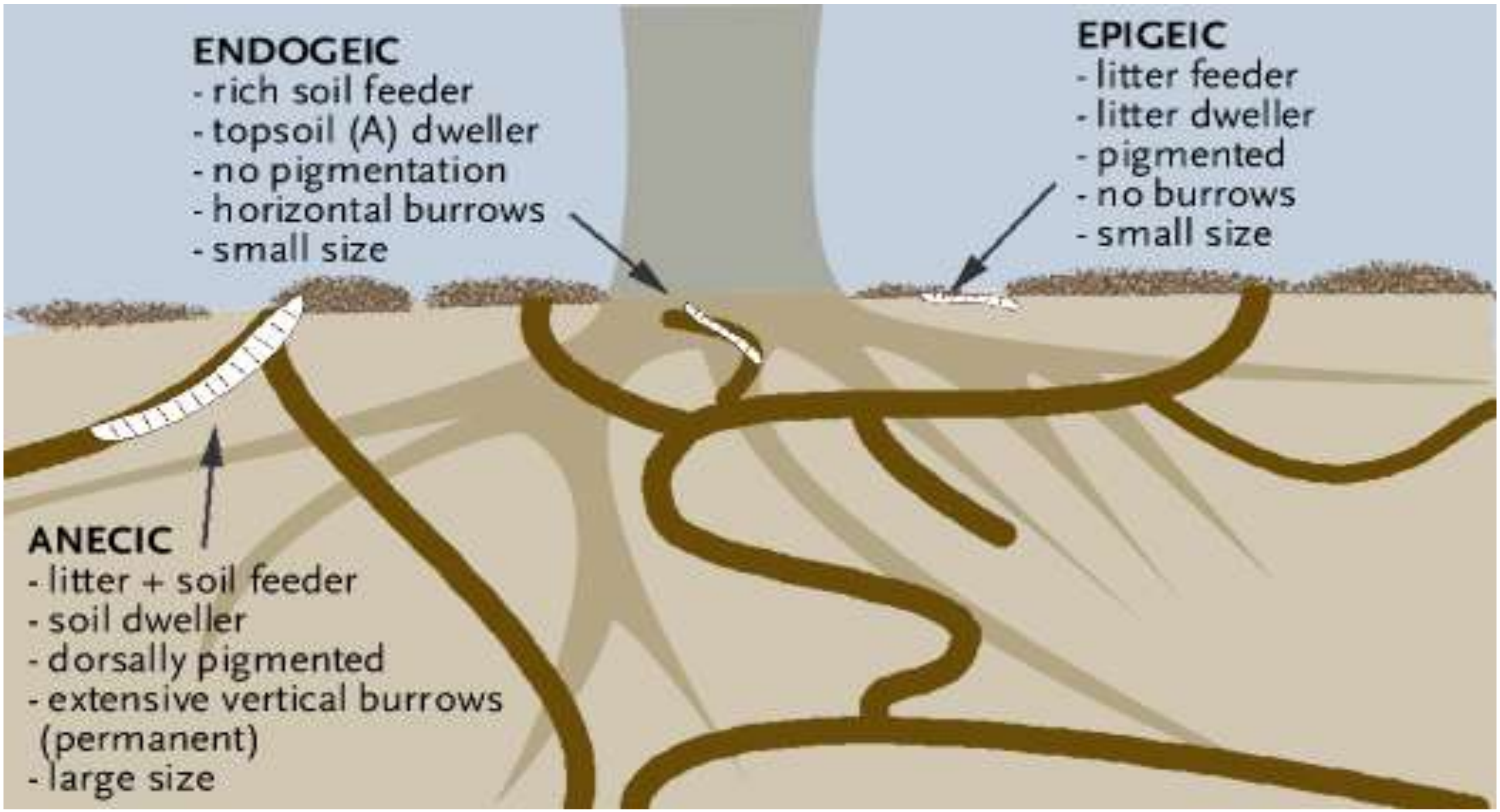
- Aerate the soil
- Break down dead organic matter
- Break down minerals in the soil
- Convert nutrients in the soil to a form the plants can uptake more readily
- Vital food source for the ecosystem
- Could tell us more about the soils and ecosystems they are found in

An average garden has around 440 earthworms per cubic metre

A ploughed field has on average less than 290 worms per cubic metre.

Darwin’s figure was an average of 53,767 per acre

Ecological Groups:
Different words do different jobs



www.nrri.umn.edu/.../ecology_groups.html

Composting

"Replacing plant compost with vermicompost resulted in a 36% greater crop yield"

Nancarrow and Taylor

UK worm species

There are 27 worm species in the UK.

Eisenia fetida **(Tiger Worm)**

- Found in compost heaps and in organic rich areas
- Deep red in colour and stripey
- Used in worm farms
- A detritivore- feeds on dead plant material

Lumbricus terrestris **(Night Crawler or Lob Worm)**

- The largest worm in the UK (up to 30cm long)
- A deep burrowing worm (anecic) that comes to the surface at night or in heavy rain
- Deep red on its front end

Aporrectodea longa
(Black-headed Worm)
- Anecic
- Grasslands and gardens
- This picture shows how a worm can regenerate its tail.

Allolobophora chlorotica
- This worm can be greenish in colour
- It has 3 little suckers on the underside of its saddle
- This worm lives below the surface of the soil and rarely comes out.
- It is also known as the stubby worm as is short (up to 8cm) and quite wide

Aporrectodea rosea

- Small pink worm
- often with characteristic flared TP
- Soil feeder
- Found in most habitats

Aporrectodea caliginosa

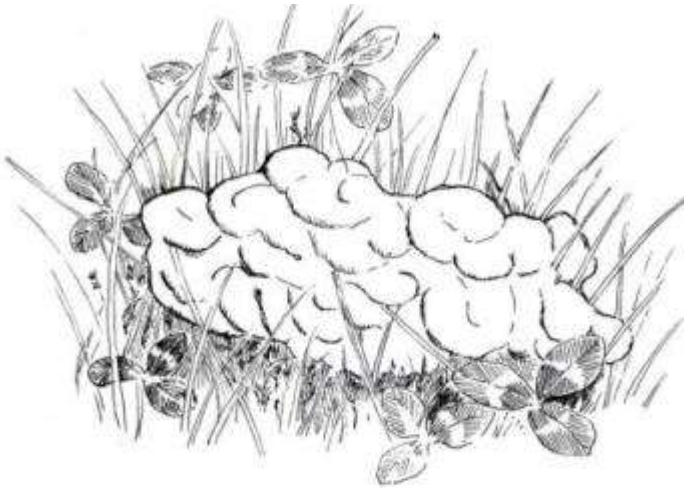
- This worm is usually grey in colour
- It lives below the surface of the soil
- It converts the minerals in the soil to a form that plants can use

Dendrobaena octaedra

- Small red headed worm up to 6cm in length
- Detritivore – lives in the leaf litter and surface layers of the soil, consuming dead organic material.

Signs of worms

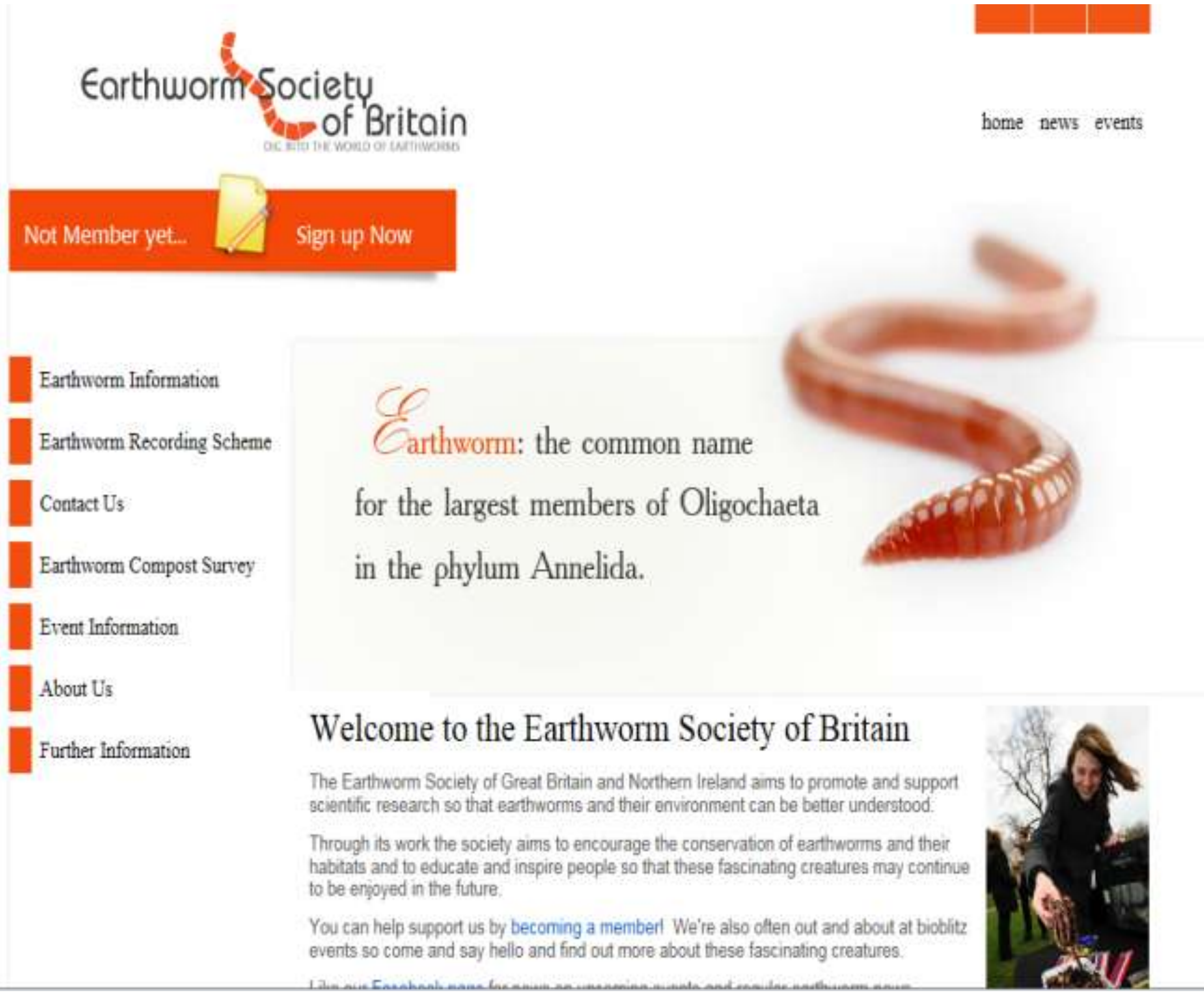
Casts



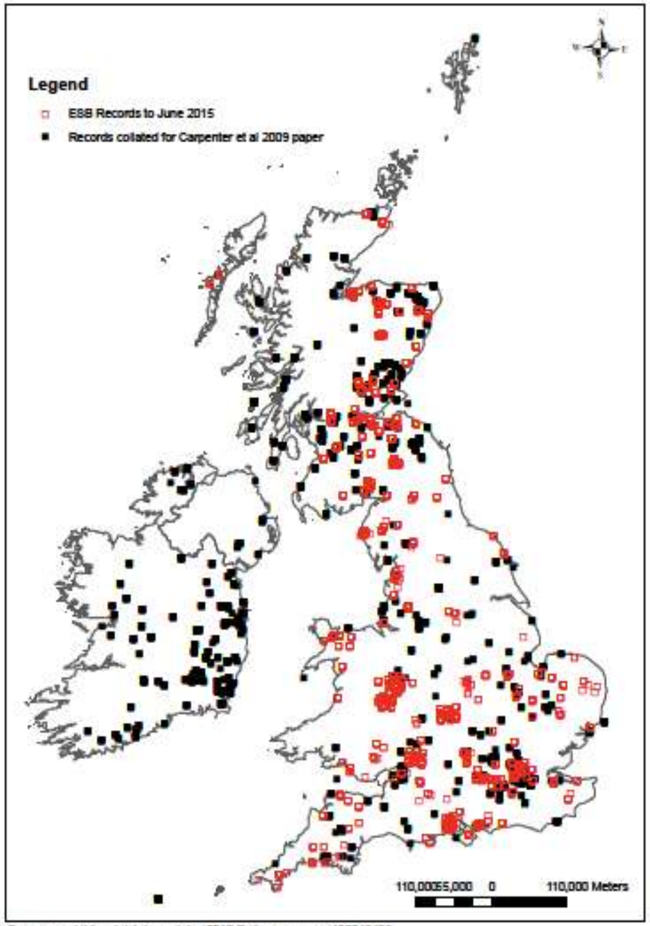
Middens

Twigs and dead leaves pulled together to cover the burrow entrance to anecic worm burrows

Want to find out more? Join the Earthworm Society of Britain.



Earthworms are massively under-recorded and under-loved in the UK. Compare the map on the left of just one woodlouse species (the Common Pygmy Woodlouse) to this map of all earthworm records (all 27 species) to date. The black before the establishment of the Earthworm Society in 2009, the red after.



FSC Key

They are easy to identify with the new aidgap key and there are plenty of courses being run by the ESB each year. So this map should be solid colour!

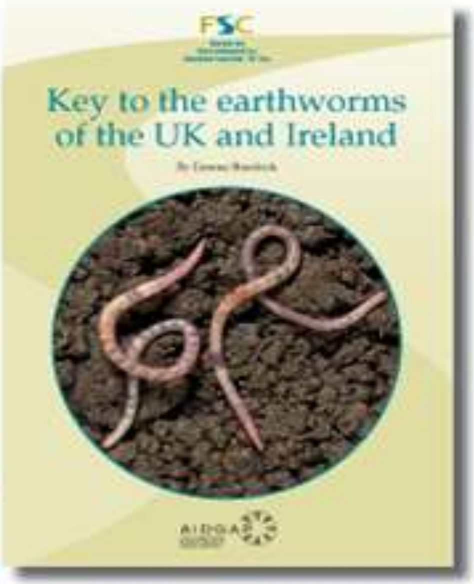
Earthworms

■ Code: OP150 ■ Author(s): Sherlock ■ Date: ■ Price : £7.50

Illustrated in colour throughout, this groundbreaking new AIDGAP guide should enable users to identify all 27 species of earthwoms found living freely in the UK and Ireland. Extensively tested and refined in identification workshops, a special feature of this book is a fully illustrated guide to the main external features used in the key; experience has shown that these are often a significant barrier in earthworm identification. Detailed species accounts are also included.

AIDGAP produces simple and clearly written identification keys, aimed at non-specialist users from age 16+

The FSC is one of the UK's leading publishers of identification guides, ranging from easy to use fold-out charts through intermediate level AIDGAP guides, to specialist books such as the Synopses of the British Fauna and RES Handbooks



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Survey work

Soil Biology & Biochemistry 41 (2009) 1857–1865

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Soil Biology & Biochemistry

journal homepage: www.elsevier.com/locate/soilbio

ELSEVIER

A six year study of earthworm (Lumbricidae) populations in pasture woodland in southern England shows their responses to soil temperature and soil moisture

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Climate responses
Soil conditions
Non-parametric regression

ABSTRACT

There are very few studies on the effects of temporal changes in soil properties on ecosystem engineers in UK soils. This study addresses this lack by presenting earthworm diversity data from a six-year seasonality study comprising 72 monthly samples from the litter and soil of pasture woodland in the New Forest, southern England. These data were analysed in the context of soil moisture and soil temperature, key factors affecting earthworm abundance, and factors likely to be strongly affected by future climate change. The data for the whole period were analysed using non-parametric regression and an additive model used to separate within-year and between-year effects. Seasonal patterns are present for all the common species, generally with a maximum in March and a minimum in September. A majority of the five commonest species show a strong decline in abundance during the two extremely dry periods (2002–2003 and 2006). In sharp contrast, the same species showed a relative increase during the very wet summer and autumn of 2007. There was, however, no significant overall trend in either the climate

Also look out for a new guide to the leeches, nemateans and flatworms to be found in your gardens and if you want to test it when a prototype comes out - let us know!

Trocheata subviridis, the leech you are most likely to find in gardens

The unseen world of springtails in gardens

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London

Springtails or **Collembola,** are numerically among the dominant arthropods on land, probably second behind acari, ahead of ants.

Any soil, any moss bank, any waters edge, any fresh water surface, almost any tree bark will have Collembola.

Collembola are mainly detritivores – fungivores, though a few will nibble young leaf tissue. They promote decomposition and are food items linking microbes to predatory arthropods.

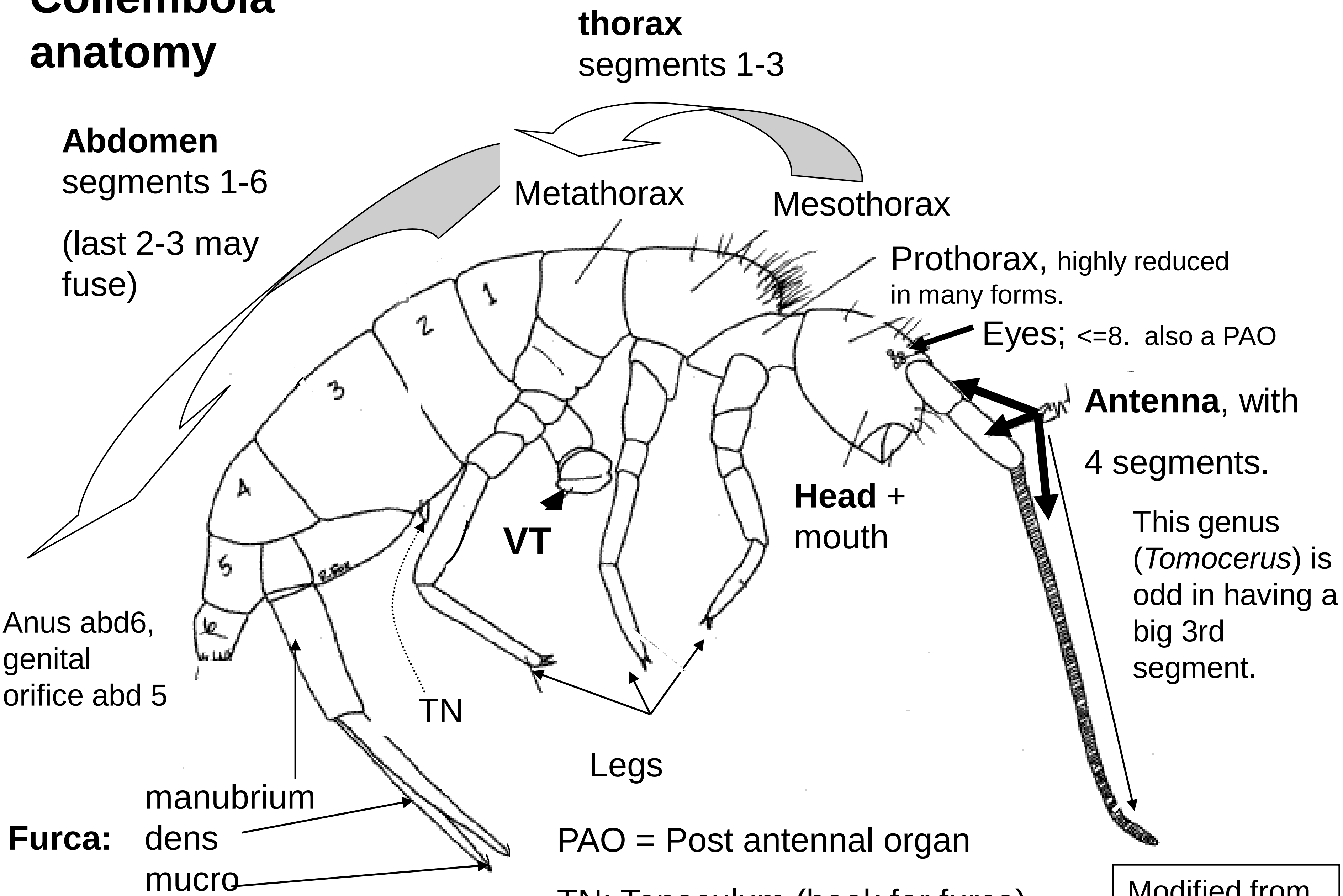
Collembola among the oldest (evolutionarily) and least changed of all terrestrial arthropod groups.

They are traditionally classed as wingless insects, but molecular classification puts them closer to crustacea.

Many (not all) Collembola have a "spring in the tail" – a unique escape mechanism involving a jumping organ (the **furca**), which latches into a hook (the **tenaculum**), storing energy until released as a jump.

The diagnostic feature is harder to see - the ventral tube or collophore, which gave the group its name (Collembola = sticky peg).

Collembola anatomy



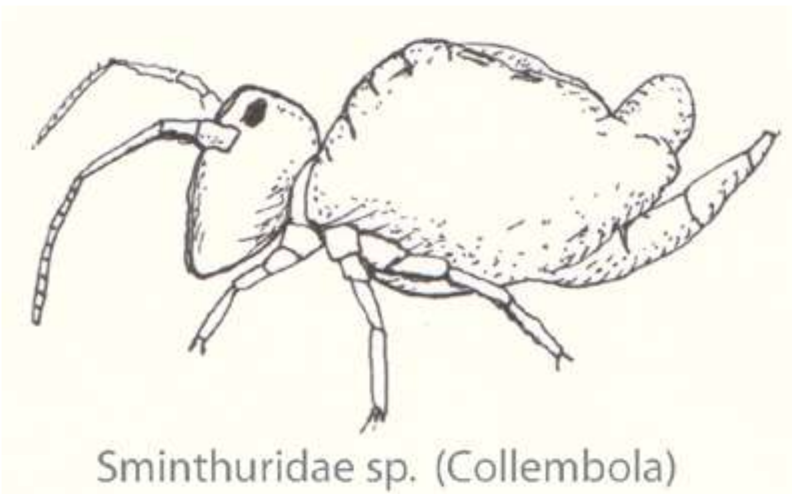
PAO = Post antennal organ

TN: Tenaculum (hook for furca)

VT: Ventral tube or collophore

Modified from an original by R Fox

The symphylopleona (sminthurids) follow this basic plan but have fused body segments and look very weird. They do have the furca and ventral tube.



Are they human pathogens? No!

Bizarrely there are a few cases in the wilder medical literature attributing human parasitoses to springtails.

Twaddle, they're imagining it. (I found one paper about skin collembola that referred to their pupae!) These are 'delusory parasitoses'.

I was once asked to survey a client's skin for Collembola (until the university insurers heard the phrase "collect medical samples from a psychiatric patient")

The original figure that spawned the mind-virus: a springtail-like shape in one flake of skin. This is an artefact of preparation and a good example of pareidolia (seeing what you want to!).

So any diagnosis that attributes to Collembola symptoms such as fatigue, joint swelling, fibromyalgia, hair loss, hard nodules under the skin, organisms biting, moving & scratching under the skin is gold standard, unmitigated, paranoia-inducing lies!

In your gardens there are certain to be Collembola, outnumbering all the true insects (+/- ants).

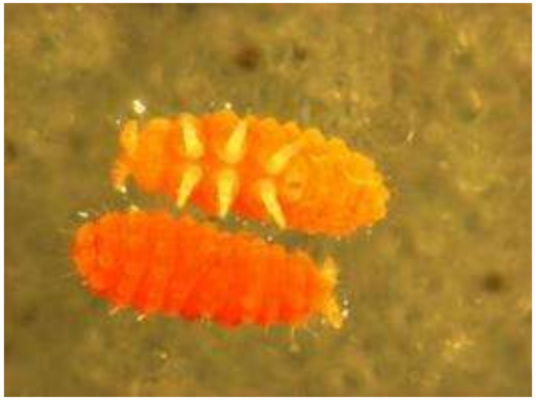
Books say 20,000/m^2 - 60,000/m^2, but my experience suggests 10,000-30,000.

Despite this most people never see them, as they are both small and cryptic.

A swarm of *Hypogastrura*

The commonest place to see Collembola is when one disturbs damp decaying leaf mould, then have a look with a hand lens. Small grey animals can be seen running around, then suddenly vanishing (as they jump).

Some pretty (but rare) UK Collembola.



Bilobella braunerae

Orchesella flavescens – prettiest UK species?

Of the c. 390 species of Collembola in the UK, only a few can be ID'd with a hand lens. Most need a microscope, sorry.

This is the easiest Collembolan to ID, also among the largest and the commonest: *Orchesella cincta*, the "black belted springtail" – the solid black abd3 is always visible.

Another group of common, large Collembola are shiny grey and about 5mm long, with long antennae. These are the Tomocerids, all big and with an unusually elongated antenna 3.

If the antenna curl into a complete loop when blown on, it's the UK's biggest springtail, formerly *Tomocerus longicornis*, but now called *Pogonognthellus longicornis*, a giant at 6mm long!

Pogonognathellus longicornis

Not quite as big but even commoner, *Tomocerus minor* with non-curling antennae.

Pogonognthellus longicornis next to *Megalothorax minimus* © Steve Hopkin

Entomobryas

Up every tree, every wall, if you see a Collembolan with a stripy dorsal pattern it's Entomobrya, but you'll need a key to get the species.

E. nivalis

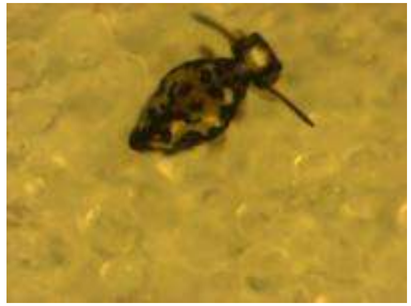
E. intermedia

E. multifasciata

E. albocincta

The UK is undergoing invasions by waves of alien immigrants. (Not the Daily Mail editorial, but a widespread entomological observation.)

Katiannidae
New to science
Heligan gardens 2009



Katiannidae
New to science
Bodmin 2012

Sminthurides bifidus (?)
New to UK
Somerset 2012

Calvatomina superba (?)
New to UK
Sheffield 2009

Leaf surface dancers

Surface dwelling 'Lucerne fleas' or 'sminthurids' (correctly the Symphypleona) run around on most leaves, and have complex mating dances.

Sminthurus viridis,
the true 'Lucerne flea'

Deuterosminthurus
mating dance

Sminthurinus trinotatus

Do Collembola matter?

Their biomass is tiny compared to mass of soil, typically around 0.5 g m^{-2}. but species richness is substantial (c.10-20 species m^{-2}).

Amien MacFadyen when asked whether such a tiny mass of soil animals actually mattered, pointed out that the mass of oil in an engine is minimal, but try making an engine work without oil!

+

=

Beyond being flippant, what he meant was that soil decay processes go vastly faster when animals are present. Collembola have been shown to speed decay of organic matter, though they are not normally the dominant drivers.

An excellent analogy for the action of soil invertebrates on leaf litter decay is burning a stack of magazines on a bonfire (try it one day!). They are almost impossible to burn, until poked with a stick when they flare up.

As a gardener, what can I do for my Collembola?

Actually most of the time they get on with their lives and we get on with ours without much interaction. It is almost impossible to create a springtail-free habitat (apart from baked dry surfaces), and normal gardening composting should give you good populations of many common species. They hardly ever cause horticultural damage – we're trying to publish about the 1st commercial outbreak since WW2!

You won't need telling that insecticides are not good for Collembola. There is a real dearth of literature of the effects of residual neonicotinoids on Collembola but good reason to expect bad effects.

Habitat diversity for Collembola

One good thing that you can do in a garden is to create a diversity of habitats.

Recent work by Stephanie Bird (at the RHS P4B plots) has clearly shown that the Collembola in grassland were consistently different to flower beds just metres away, different again to nearby wild habitats.

Obviously most gardens will already have lawns and flower beds, but the principle is wider: try to maintain a mosaic of many soil/vegetation combinations and you will have a more diverse fauna.

Also think of suspended soils: accumulations of leaf litter or big old moss/lichen mats up trees (or on roofs). These are very slow to develop and have some unusual Collembola that seem to be rare.

Mainly Mining Garden Solitary Bees

Are gardens good for mining bees?

Michael Archer

Vespid Studies

Solitary bees are common in gardens. 30 species were found in a large garden in York, 45 species in a Leicester suburban garden and from a study of 12 gardens 145 species (range 14-118). From about 228 solitary bees recorded nationally, 183 (c.80%) are mining bees or bees dependent on nesting mining bees (cleptoparasites).

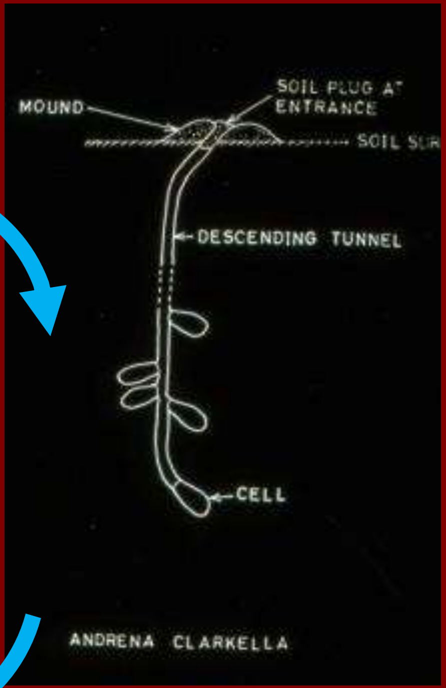
A *Nomada* cleptoparasite

Lifecycle of *Andrena clarkella*

Nests in sandy thinly vegetated soils on the level in sunny situations.

After hatching, the larva quickly eats the provisions and matures into a resting stage until the following spring when it pupates and emerges as an adult.

The adults emerge in early spring and mate



The female mines a single vertical burrow with branches in which the earth cells are built.

Each cell is provisioned with a pollen-nectar ball on which an egg is laid.

An earth cell

Gardens provide many habitats with resources for mining bees

- Flowers, herbs, shrubs and trees
- Lawns
- Paths
- Walls
- Rockery
- Compost heaps
- Dead wood

So are gardens good for mining bees: some analysis

- **Percentage of aerial nesting solitary bee species nationally** (AF) = 17.9%

- **York Victorian Cemetery**: 10 aerial nesters, 15 subterranean nesters AF = 40.0%
- ie rather few mining bees

- **Leicester garden**: 27 year study with a Malaise trap.
  - Species taken 1-7 years – 3 aerial nesters, 11 subterranean nesters

  AF = 21.4% - near national value
  - Species taken 8-27 years – 9 aerial nesters, 11 subterranean nesters

  AF = 45.0% - very high value

- **12 Garden Study**
  - Found in 1-4 gardens: 11 aerial nesters, 60 subterranean nesters

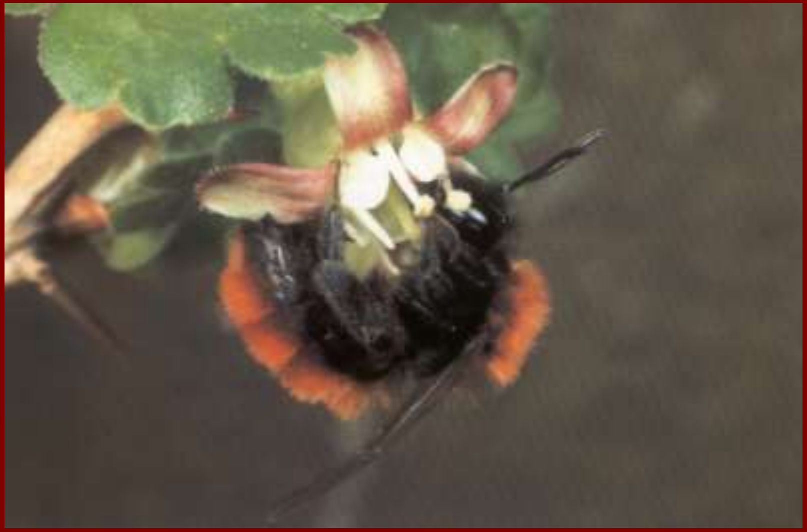
  AF = 15.4%, near national value
  - Found in 5-11 gardens: 12 aerial nesters, 21 subterranean nesters

  AF = 36.4% – rather high value.

Is the relative lack of mining solitary bees due to the frequent disturbance of the soil and the lack of bare or sparsely vegetated soil in sunny situations?

Some mining bees are found in gardens, e.g. the Lawn Bee, *Andrena fulva*.

More infrequent visitors are usually celled tourist species perhaps being found in gardens by chance or species in dispersal searching for favourable nesting sites or may be just rare species.



Lawn Bee *Andrena fulva*

Andrena cineraria

An index called the Parasitic Load (PL) measures the percentage of solitary bees that are cleptoparasites.

- Percentage of parasitic solitary bee species = Parasitic Load (PL) = 25-40% nationally in semi-natural sites

- York Victorian Cemetery – 25 Nesters, 5 Parasites
  PL = 16.7%, ie a relative lack of cleptoparasites

- Leicester Garden
  Species taken in 1-7 years – 14 Nesters, 7 Parasites
  PL = 33.3% - within national limits
  Species taken in 8-27 years (ie frequent visitors) – 20 Nesters, 4 Parasites
  PL = 16.7%, rather low

- 12 Nest Study
  Found in 1-4 gardens – 71 Nesters, 36 Parasites
  PL = 33.6%, within national limits
  Found in 5-11 gardens – 33 Nesters, 5 Parasites
  PL = 13.2%, rather low

Aerial Nester Frequency (AF) and Parasitic Load (PL) in Urban Sheffield and York

	Sheffield		York	
	PL	AF	PL	AF
Gardens	6.3%	33.3%	16.7%	40.0%
Urban	30.4%	22.9%	30.4%	29.2%

The relative lack of cleptoparasitic species can be related to their behaviour of tending to occur around the nesting sites of their hosts. Since there is a relative lack of mining bee species in gardens there will be a relative lack of cleptoparasitic species.

The relative lack on mining and cleptoparasitic bees has also been found in garden studies from Liège (Belgium), New York (U.S.A.) and Salamanca (Spain). These results show that gardens are relatively not so good for mining bees and their cleptoparasites.

In the wider urban area surrounding gardens the Parasitic Load increases and Aerial Nester Frequency decrease (e.g. York, Sheffield) due the greater occurrences of subterranean nesting sites, e.g. river banks, paths.

A third index attempts to measure species quality or conservation interest by dividing the solitary wasps and bees into six groups.

The three low quality groups (Universal, Widespread, Restricted) are found in more than 70 decade squares with varying distributions in England, Wales and Scotland. The three high quality groups (Scarce, Rare, Very Rare) depends on the number of decade squares (1-70) in which each species is found The slide shows how the quality score (QS) and species quality score (SQS) for the 100 solitary species of the Leicester were calculated. It has been found that the QS tends to increase with the area of a site while the SQS is relatively independent of site area so can be used to compare sites of different areas.

Species Quality Coding of Solitary Wasps and Bees - Conservation Importance

Leicester Garden

National Status	Status Value (A)	No. Species (B)	Quality Score (AxB)
Universal	1	45	45
Widespread	2	46	92
Restricted	4	0	0
Scarce	8	8	64
Rare	16	1	16
Very Rare	32	0	0
Total		100	217

Quality Score = 217 Species Quality Score (SQS): 217/100 = 2.2

Species Quality Score (SQS)

Site	SQS
York Garden	1.5
Urban York	2.0
Urban Sheffield	2.0
Manor Farm	1.4
Hopewell Farm	1.2
19 English Heritage sites	1.7
Semi-natural sites in Yorkshire	2.4-2.8
Leicester garden	2.2
Midlands	2.6-3.4
12 garden study	1.2-3.8
Nationally	1.2-5.5

The SQS for the York garden (1.5) and for the urban areas (York, Sheffield, 2.2) are lower than semi-natural sites (2.4-2.8) in Yorkshire. Similarly the SQS of the Leicester garden (2.2) is lower than Midland semi-natural sites (2.6-3.4). Again the frequent visitors of the 12 garden study (1.6) fall within the lower part of the range for English semi-natural sites (1.2-5.5). The lower SQS values for gardens are due to the relative lack of high quality species indicating that gardens are still an important refuge for the low quality species.

Two further comparisons of sites in Yorkshire may be made. The SQS of two farms were an effort had been made to increase biodiversity have the lowest SQS values (1.2, 1.4). The SQS of 19 English Heritage sites was 1.7, midway between gardens and urban areas.

So, to encourage solitary mining bees in gardens it is necessary to expose dry friable soils by removing the plants so that the sun can heat the soil. Part of a lawn could be bulldozed to expose the soil with the bulldozed part formed into a bank. In contrast for most bumblebee species need a densely vegetated area to attract small mammals whose burrows provide nesting sites for many species. Other species nest at ground surface level when a good leaf litter layer and dense grass or herb growth is needed.

Afternoon Visit to the Museum's Wildlife Garden

Dr. Matthew Shepherd shows delegates the microscopic life in a trowel-full of the garden soil.

Investigating pond life with Adrian Rundle, Learning Curator