Wood Wise

BEGUILING BEETLES

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WOODLAND TRUST

AN INORDINATE FONDNESS FOR BEETLES

THE HIDDEN BIODIVERSITY OF OUR WOODS

SPOTLIGHT ON WOODLAND LADYBIRDS

THE BEETLES SPREADING TREE DISEASE

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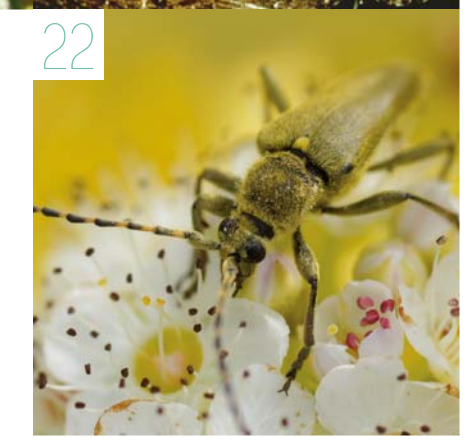

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WTML Richard Becker

Essential biodiversity

Beetles are key to the continuity of healthy ecosystems, yet they don't always get the recognition and attention they deserve.

The sheer diversity in form and function of beetles is breathtaking. They come in a huge variety of shapes, sizes and colours, from the 0.25mm-long featherwing beetle to the 16cm-long South American longhorn beetle; while the goliath beetle can weigh up to 115 grams (4oz)! Some beetles have spectacular colours and a metallic sheen, such as the jewel beetles, which are prized by local people in South America for making jewellery. The adaptations that beetles have evolved in order to improve their chances of survival and reproduction are extraordinary and have even inspired new technologies, such as the self-filling water bottle, based on the Namib desert beetle.

Beetles represent one fifth of all living organisms and are the largest group of insects. Many are associated with woods and trees for at least part of their life history. The lifecycle of beetles is complex; they develop by complete metamorphosis from larvae, through a non-feeding pupal stage, before emerging as adults. Some larvae, such as those of the stag beetle, take several years to mature, living and feeding on dead or rotting wood. Dead wood is an extremely important and diminishing resource for many other species of animal too.

The many roles that beetles play

As the eminent biologist E.O. Wilson aptly put it, "If insects were to vanish, the environment would collapse into chaos."

Beetles provide important ecosystem services and are intertwined with human culture. They perform a number of ecologically important roles, such as pollination and the decomposition of organic matter. Dung beetles (Scarabaeoidea), for example, are a 'superfamily' that support a number of ecosystem functions: they are extremely important recyclers of nutrients; perform secondary seed dispersal; and suppress parasites through removal of dung[1]. It has been estimated that dung beetles save the United States cattle industry an estimated $380 million annually through burying livestock faeces[2].

In early human history, before people had tools to hunt, beetles would have been a key component of their diet. Even today, many societies across Africa, Asia and Latin America rely on beetles (often the larvae) as an important source of protein.

Beetles also play an important role in biological control. Ladybirds prey on aphids (to the great appreciation of gardeners), and many ground beetles eat slugs as well as alien species, such as the introduced New Zealand flatworm, which kills native earthworms. In the US, the value of natural pest control attributable to native insects (not just beetles) was estimated at a massive $4.5 billion annually[2]. Ground beetles also eat weed seeds, reducing the amount of seeds in the soil and thus the need for herbicides[3]. Beetles can, however, also be a nuisance. Larvae or adults can act as vectors of disease, or are pests themselves. Examples include the invasive harlequin ladybird and the large elm bark beetle, which spreads the fungus that causes Dutch elm disease.

Beetle conservation

It is clear that beetles are an essential component of biodiversity for both people and the environment. Yet they face many threats, often due to poor management or lack of protection of their habitats. Beetles that are highly specialised and unable to survive elsewhere are particularly at risk. Fortunately, there are some dedicated entomologists and researchers working for beetle conservation in the UK who are trying to raise public awareness of the importance of these tiny creatures, so that they are no longer overlooked and undervalued.

This issue of Wood Wise provides fascinating insights into beetle diversity and ecology, with a particular focus on the variety of beetles found in woodlands, wood pasture and parkland. We also look at the impacts of non-native beetles and some species associated with the transmission and establishment of tree diseases. Finally, we learn about past extinctions, which may inform ecologists working for the survival of Britain's beetles.

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2. Losey and Mace. 2006. BioScience, 56 (4): 311-323.
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An inordinate fondness for beetles

Jon Webb

There are 4,200 recorded species of beetle in Britain, and more than 1,000 live in trees and woodland habitats.

Worldwide over 400,000 species of beetle have been described, with at least that many further species yet to be discovered. Based on the huge diversity of beetle species in the world, the distinguished British biologist, J.B.S. Haldane, on being asked by a group of theologians what one could conclude as to the nature of the Creator from a study of his creation, is said to have answered, "An inordinate fondness for beetles."

Beetles belong to the order Coleoptera, which means 'sheath-wing', and refers to their hard wing cases (elytra). These wing cases are the main reason for their success. They provide an armoured defence against harsh environments, would-be predators and water loss. Beneath the wing case, most beetles still retain fully operational wings. As anyone watching a beetle take off will note; they often take an age to open their wing cases, unfold their wings and, eventually, fly. The power of flight, even if it is just once, means beetles are also good colonisers. The combination of the armoured defence and the ability to colonise new locations makes beetles very successful creatures. In Britain, we currently have over 4,200 species, although this number is always changing as we discover new species because of colonists, non-native introductions or the whim of ever changing taxonomy.

We know a fair amount about our beetle fauna. British history of wildlife recording, spanning from the Victorian age to the present, has made Britain one of the best studied locations for insects in the world. That there are millions of records of all species on the newly launched National Biodiversity Network Atlas (nbnatlas.org) is testimony to this history of recording wildlife in Britain.

Beetles come in all shapes, sizes and colours – broad-nosed weevils, bloody-nosed beetles, and the devil's coach horse to name just a few. Species span in size from less than 1mm in length to our largest species, the stag beetle, whose males can reach over 75mm in length.

I have a passion for beetles – I love them. To me they are like little robots; not creepy crawlies, a description that defies their elegance, drive, grace, beauty and exquisite alien nature. They are found in almost all terrestrial and freshwater habitats – only the marine world has not been readily conquered by beetle life. Their lifestyles are as rich and varied as are their forms; leaf beetles browse on leaves, flowers and shoots of vegetation; ground beetles trundle over the surface of woodland, voraciously hunting slugs and snails; dung beetles dive bomb fresh piles of dung in order to break the surface crust and feed on the matter beneath.

Lesser stag beetle (*Dorcus parallelipipedus*)

The author (Jon Webb) looking for beetles in Grimsthorpe Park

Tree associations

To properly understand how beetles live in our wooded habitats we can look to the data in Pantheon (brc.ac.uk/pantheon) for an overview. Pantheon is an analytical tool developed by Natural England and the Centre for Ecology & Hydrology to assist invertebrate nature conservation in the UK. A list of invertebrates can be entered into Pantheon, which then attaches associated habitats, resources and conservation status to them.

Pantheon retains data on 3,540 beetles. Of these 1,005 are tree associated. You will note that I have not used the term woodland, as this can be somewhat misleading. Beetles living in tree canopies can be found in woodland, but they will also occur in gardens and parklands as well as along roadsides and hedgerows.

Tree-associated beetles can further be broken down:

Tree-associated habitat	No. of beetles*	Includes
Decaying wood	682	Species living under bark, in birds' nests in trees and in veteran trees and fallen logs.
Arboreal	177	The tree canopy, including leaf, flower and shoot eaters. Lichen feeders. Predators of both of the above.
Shaded woodland floor	153	Feeding on plants of the ground layer under trees (e.g. dog's mercury), ground hunters and those in leaf litter.

*You will note that the total number is slightly higher than 1,005, as some beetles utilise both habitats and have been counted more than once.

By far the highest number of tree-associated beetles are associated with decaying wood. This group also contains a large number of our rarer species, such as the violet click beetle and the noble chafer. It might seem odd at first that so many beetles are associated with this habitat. Is there really that much eating to be had on what we perceive as a hard and unpalatable substance?

Looking more closely, decaying wood can be broken down into two main constituent parts; firstly, decaying bark, and secondly, heartrot.

Decaying bark and sapwood – the area of wood just under the bark contains the phloem. When a tree's leaves photosynthesise, they produce sugars and other soluble organic compounds. The phloem transports these around the rest of the tree, to areas that are growing. When this starts to decay (mostly by fungal activity), it allows many beetles to exploit this rich source of food.

Heartrot – (what a great name for a heavy metal band!). Trees grow by forming new growth rings around their trunks and become fatter with age. The living sapwood rings only work for a limited period of between 30-60 years or so and move out from the centre of the tree, or dead heart wood, which then loses its ability to transport water. As the tree ages and the moisture content in the central wood reduces, it can then be colonised by bacteria and fungi. Non-living wood cannot defend itself, but some compounds in the wood may inhibit the growth of some fungi, although not specialist decay fungi, and eventually all trees hollow. It is even thought that the hollowing process is good for the tree. A cylinder has high strength for its volume and is more flexible, and as its circumference increases, its stability increases exponentially. Once bacteria and fungi have started to break down the heart wood, the beetles get interested. Many beetles ingest this wood but are actually feeding on the fungi and microbes.

As well as feeding on this wood decay (or the fungal element within the wood), many beetles live on the tree and can be predatory on other species. Some live in old birds' nests, feeding off organic matter, and others live in fungal fruiting bodies budding from trees.

So, as you can see, there is a good reason why so many species feed in wood decay. And where do you find the best sources of wood decay? On a veteran tree!

Our wood pastures and parklands especially abound with beetle life. Many different species can be found living within tree canopies, on woodland plants and in veteran trees. It is my hope that after reading this, you, too, will have an increased fondness and appreciation of the beetles in Britain.

Jon Webb is a principal specialist at Natural England.

Cardinal click beetle (*Ampedus cardinalis*)

Parkland longhorn beetle (*Phymatodes testaceus*)

Standing dead hulk in Windsor Park

Underground, overground

Sholto Holdsworth

Over the past 15 years the Soil Biodiversity Group in the Natural History Museum, London, has run both short-term and long-term surveys in the closed canopy broadleaf woodlands of the New Forest in Hampshire, researching a wide range of invertebrate groups. The largest of these in terms of species numbers are the beetles (Coleoptera), which are one of the most diverse groups of animals on the planet; found in almost all terrestrial ecosystems.

Woodland biodiversity

British woodlands are vital for a large diversity of beetles and other invertebrates. This is partly due to the large number of habitats in which they live, particularly at different heights in trees. This generates many different environmental niches, ranging from below ground in the soil, to the tops of trees. The large number of habitats provides homes for lots of species with different natural histories.

An important question is; how many species are there in woodlands and what essential roles do they play? Scientists have tried many sampling techniques and survey methods to answer this question.

One survey, carried out between 2010 and 2012 (the New Forest Quantitative Inventory (NFQI)), catalogued diversity from the soil to the treetops in nine very similar woodland sites in the New Forest, using a variety of sampling methods[1].

The nine sites included a combination of ancient woodlands and seeded oak plantations. When the plantations were created they were originally separated by stock fences[2]. These have now mostly disappeared, merging the enclosures with the ancient woodlands. This merging has led to very similar flora with the dominant tree species being beech *(Fagus sylvatica)* and oak *(Quercus robur* and *Q. petraea)*. The New Forest has many habitats and environments including both deciduous and coniferous woodlands, and a variety of heathlands and grasslands[3]. The New Forest is designated as both a Site of Special Scientific Interest (SSSI) and a Special Area of Conservation (SAC).

New Forest, Whitley Wood.

Victoria J. Burton

Beetles beneath your feet

One of, if not the most, biodiverse hotspots in a broadleaf woodland is under your feet. The highest number of beetle species in the NFQI survey was measured in the leaf litter using Winkler bags - this sampling method extracts invertebrates from suspended leaf litter. A separate 10-year survey of Whitley Wood in the New Forest found about 300 species of beetle in the leaf litter using the same technique. Some of these species were found very occasionally, if not just once, due either to not being adapted to living in the litter layer or because they were genuinely rare. Many of the species which are commonly found in the leaf litter are rove beetles (Staphylinidae) in the subfamilies Aleocharinae and Scydmaeninae. These are generally small predators that feed on springtails and mites. The most abundant beetle species surveyed is a tiny featherwing beetle (Ptiliidae) named *Acrotrichis intermedia* which feeds on fungal spores and effectively swims through the air with its feather-like wings. It has not been uncommon to see about 500 individuals of this species within one square metre of leaf litter.

Larger individuals include the ground beetles (Carabidae) and other predators. These can often be seen roaming freely at ground level in these woodlands. In the nine woodland plots surveyed, the violet ground beetle *(Carabus violaceus)* and the devil's coach horse beetle *(Ocypus olens)*, a species of rove beetle (Staphylinidae), were often observed.

The soil below the leaf litter generally has a lower diversity of beetles, but still plays a vital role in the life cycle of many species. The larvae of a few different family groups, including click beetles (Elateridae), develop and mature underground in the soil and then emerge as adults to fly off into other habitats in the woodland.

Winkler bag room.

Featherwing beetle *(Acrotrichis sp)*

Beetles above the ground

Above ground level the assemblage changes and you will start to observe beetles a lot more active in flight, with different life cycles and feeding requirements. Scientists have used a variety of sampling techniques to study these environments, ranging from various Malaise trap types, to flight interception traps and light trapping. To sample specific groups of beetles, bait traps and pheromone trap types are often used. In the nine woodland sites for the NFQI, Malaise traps and aerial Malaise (SLAM) traps were set up to sample beetles in the understorey and lower canopy areas. Trap numbers are generally kept low to minimise any disturbance in the woodlands.

In the understorey a large number of different beetle families can be observed using these techniques. Families such as the longhorn beetles (Cerambycidae) and the soldier beetles (Cantharidae) were often seen in the understorey, but rarely at ground level. The longhorn beetles, along with other families such as the false flower beetles (Scraptiidae), are also seen in high numbers, mostly having a saproxylic lifestyle, which means they are dependent on dead wood for their larval development. Dead wood, both standing and on the ground, is a very important microhabitat for beetles and other invertebrates in woodland, increasing the abundance and diversity of a lot of arthropod groups[4]. Species of the soldier beetle family (Cantharidae) are often carnivorous and feed on other insects in the understorey and canopy.

The canopies in these woodlands have a similar set of beetles to the understorey levels, although in lower abundance. This is likely to be due to higher fluctuations in temperature and humidity, along with wind exposure in the canopy. This can force saproxylic beetles downwards towards the understorey. One group commonly found in the canopies in these woods is the bark beetle (Curculionidae: Scolytinae), particularly the European hardwood ambrosia beetle *(Trypodendron domesticum)*, which was observed in abundance. Many bark beetle species live in dead wood and galleries under the bark of living trees. Some species can be serious woodland pests, attacking living trees and spreading fungal disease. Many other weevil subfamilies and species are also recorded from the canopies of these woodlands, such as the acorn weevil *(Curculio glandium)*, whose female lays eggs in the centre of acorns for the larvae to feed on and develop in. Plant feeding (phytophagus) broad-nosed weevils (Entiminae) such as the common leaf weevil *(Phyllobius pyri)* can also be found in the canopies of these woodlands.

The importance of these findings

Broadleaf woodlands such as those in the New Forest, are home to many beetle species due to the variety of microhabitats from the soil layer to the top of the canopies. This biodiversity can be an indicator for a number of other animal groups in these habitats not directly recorded. Beetles act as both predators and prey for lots of organisms in woodland. They are a vital component in the food web, and contribute to other ecological processes, such as nutrient flows and litter decomposition.

The woodland environment as a whole is essential for this huge diversity of life and proves a solid argument for the lasting conservation and management of these slowly declining yet vital habitats.

Sholto Holdsworth is a research associate with the Soil Biodiversity Group, Life Sciences Department, Natural History Museum.

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Oak click beetle – a rare click beetle associated with dead and decaying oak. It breeds in red rot in dead or fallen trunks and branches of oak, but not in stumps. The larvae are thought to be predatory, feeding predominantly on the larvae of hairy fungus beetles. Only known from Windsor Forest in Britain.

Back from the brink

Sarah Henshall

Ancient trees, historic wood pasture and parkland provide one of the most important habitats for wildlife in the UK – dead and decaying wood. In Britain, 7% of all native animals are saproxylic, meaning they are dependant during some part of their lifecycle upon dead or decaying timber, wood-inhabiting fungi, or the presence of other saproxylic species. A new partnership project between Buglife, Plantlife and Bat Conservation, supported by The Heritage Lottery Fund, will secure improved conservation status for 28 highly threatened species of invertebrate, lichen, fungi, moss and bat, and aid the recovery of a further 39 species.

Ancient pollarded oak at Savernake Forest.

The Ancients of the Future project is one of seven integrated habitat projects within the Back from the Brink initiative (naturebackfromthebrink.org). It is a three-and-a-half-year partnership project, starting in July 2017, to be delivered by Buglife, Plantlife and Bat Conversation Trust. A wide range of partners will assist with delivery including The Crown Estate, National Trust, Natural England, Forestry Commission, People's Trust for Endangered Species (PTES), Woodland Trust and Ancient Tree Forum. The project will work with landowners and managers on key sites and treescapes across England to secure both continuity of some of our most iconic landscapes as well as a positive future for the rare and scarce species that they support. The project will help both to sustain and increase resilience of our ancient tree resource and to tackle current and emerging threats by improving habitat condition, continuity and connectivity between patches at a site, and landscape-scale.

Historic landscapes

Scattered ancient trees, standing within an otherwise open, grassy landscape, provide one of the most valuable habitats for wildlife in the UK. Wood pasture and parkland is descended from medieval deer parks, royal hunting forests, chases and commons, and forms an important component of many designed landscapes created in the 18th and 19th centuries. Now highly restricted in range and number, such areas support numerous rare and often spectacular species of wildlife. Notwithstanding the small total area of 278,050 hectares (687,000 acres) estimated to be occupied by this priority habitat in England, the UK supports some of the most important collections of ancient oak and beech trees in north west Europe, such as the world famous and renowned Windsor Park and Blenheim Palace oaks.

Wood pasture and parkland is a 'priority habitat', which supports 41% of the species listed in section 41 of the Natural Environment and Rural Communities Act (hereafter 'S41') associated with woodland[1]. Ancient trees, which encompass ancient, veteran and mature trees, especially open-grown and high forest (often pollarded) beech, oak and ash, contain important late-stage decaying wood. The key features important to biodiversity come about due to the age of these mighty statues that are gnarled, holed and often hollow. Crucially, the fungal induced wood decay found within ancient trees is found nowhere else and provides ecological continuity spanning centuries. Trees improve with age, as Oliver Rackham[2] explained, "A single 400-year-oak, especially a pollard with its labyrinthine compartment boundaries, can generate a whole ecosystem of such creatures for which ten thousand 200-year-oaks are no use at all."

As trees mature, decay and eventually die, they produce hulks, stumps, fallen trunks and branches, exposed root plates and decaying roots. Wood decay features provide a mosaic of micro-habitats that support a huge array of threatened species, especially saproxylic invertebrates. Invertebrates select specific sites for egg laying and larval development, such as heartwood rot, wood mould, hollow trunks, dead attached limbs, water-filled rot holes, decaying roots, sap-runs and partially detached bark. Other micro-habitats are provided by the specific fungi, mosses and lichen associated with old trees. These micro-habitat conditions can vary greatly depending on where the tree is located, for example, in an open, sunny situation or a partially shaded, humid location.

Invertebrate specialists

More than 1,800 invertebrate species rely on decaying wood in Britain and Ireland[3,4], including 14 S41 species[5]. Seven of these are at risk of extinction in England by 2020, such as the royal splinter cranefly *(Gnophomyia elsneri)* and violet click beetle *(Limoniscus violaceus)*, and many are found on just a single site or are restricted to a very small number, such as the oak click beetle *(Lacon querceus)* and the variable chafer *(Gnorimus variabilis)*.

Within saproxylic fauna, beetles are well represented with around 700 species of saproxylic beetle in Britain[4]. Nearly 11% of the saproxylic beetles found in ancient trees are considered 'threatened' in Europe, with a further 13% considered 'near threatened'[6]. Saproxylic beetle fauna is incredibly diverse, including the impressive stag beetle *(Lucanus cervus)* that spends between three and seven years underground as a larva; the metallic noble chafer *(Gnorimus nobilis)*, an orchard specialist; and an array of black and red click beetles such as the cardinal click beetle *(Ampedus cardinalis)* and many smaller fungi specialists, such as clown beetles (Histeridae) and rove beetles (Staphylinidae), to name but a few. Not only do saproxylic beetles need decaying wood to complete their lifecycle, but many also require blossoming hawthorn,

Beech tree at High Standing Hill, Windsor, perfect habitat for saproxylic diptera due to its hollow cavity and an accumulation of wet wood mould in the base.

Royal splinter cranefly – this extremely rare fly is associated with wet wood mould in decaying beech trees and is only known in two locations in the world, Windsor and a one-off recording from a light trap in Slovakia.

Violet click beetle – a rare beetle afforded European-wide protection, found at just three sites in Britain. It is associated with old broadleaved trees, namely ash and beech, within wood pasture. This beetle requires a substantial number of trees to provide continuity of breeding habitat; undisturbed wood mould at the base of central cavities. The low density of apparently suitable trees at its known sites is a serious cause for concern.

umbelifers (notably hogweed), thistles and brambles, which provide food, mating opportunities and shelter. Hence the habitat structure within a wood pasture or parkland is very important alongside the decaying wood resource.

Decline and pressures

The use of ancient-wooded landscapes as the hunting grounds for royalty, nobility, poachers and outlaws has ensured that such areas have significant cultural and historical value. Yet much of the country's – and Europe's – wood pastures and parkland have been suffering from a range of pressures, so too has the wildlife associated with ancient trees. Historic timber demand has removed the majority of the big, old 'unproductive' trees.
Moreover, on-going pressures, such as intensive forestry management, which favours fast growing and often non-native species; weak protection that allows important trees to be felled for development; inappropriate management; and the overzealous removal and 'tidying' of wood decay (both standing and fallen) have eroded the very value of such ancient trees.

Past planting has sometimes resulted in a flat age structure of tree populations which spells disaster for dependent wildlife when the trees eventually die of old age. Addressing the age gap between the existing ancient trees and their successors is a big challenge. Management techniques such as pollarding and stock grazing, which were in widespread use in the past, created the right conditions for wood decay to develop and be maintained. These techniques are no longer practised on many wood pasture sites. Beech trees established across the south of England in the early 1800s are now reaching the end of their lives. Their loss is likely to have a significant impact on the biodiversity reliant on this resource. Trees in the wider countryside and in hedgerows are disappearing at a faster rate than they are being replaced. These past and on-going pressures on our ancient trees are heightened by a suite of current escalating and emerging threats.

New problems

To compound these historic drivers of decline, new and rapidly spreading tree diseases (notably ash dieback, acute oak decline and various *Phytophthora* species) and tree pests are now adversely impacting on our ancient trees, and this trend is set to increase. Climate change is also likely to exacerbate the problems faced by many tree-dependent species, particularly those which are rare or restricted in range. For example, beech is particularly sensitive to drought and is declining in southern England. Storms, which are becoming increasingly frequent and severe, have caused significant losses, such as at Windsor in 1987. New invasive plants are spreading into lowland woodlands, often outcompeting native species. Air quality continues to impact upon epiphytic lichen communities and some root-associated fungi, reducing their species diversity. Furthermore, very few of the ancient trees that provide the habitat for these threatened species are legally protected - only 12 Sites of Special Scientific Interest (SSSI) citations (that describe the reason a site is designated) mention either the habitat wood pasture and/or parkland, or a population of veteran trees as an interest feature. The majority of wood pasture and parkland SSSI's are designated for species rather than the trees and habitat.

Attitudes and value

Conservationists have long recognised the exceptional biodiversity value of ancient trees. However, how these trees and landscapes are perceived and valued more widely (i.e. by the public, land and estate owners, arborists, local authorities, and historic landscape architects) is highly varied. Ancient gnarled trees with decaying limbs or cracks and hollows can be viewed negatively, as dead or unhealthy, and fallen deadwood considered messy. Trees that have died but remain standing can be considered unsightly or pose health and safety concerns. Within historic landscapes dead and decaying trees and wood is often removed and replaced with newly planted trees - striving to retain or reinstate historic landscape plans, vistas and avenues. Moreover, ancient trees are often overzealously pruned or felled due to perceived health and safety risks or ill-informed responses to tree disease.

The Ancients of the Future project will raise public awareness and change attitudes towards both ancient trees and decay-loving fauna and fungi through innovative interpretation, walks and close-up encounters with some of our most threatened and elusive ancient tree wildlife. Crucially, the project will target a wide range of practitioners from land managers to tree surgeons and historic landscape architects, providing targeted, up-to-date advice, guidance and training to ensure project sites and treescapes are sustained, and best practice established to influence how sites are managed in future.

Dr Sarah Henshall is lead invertebrate ecologist at Buglife.

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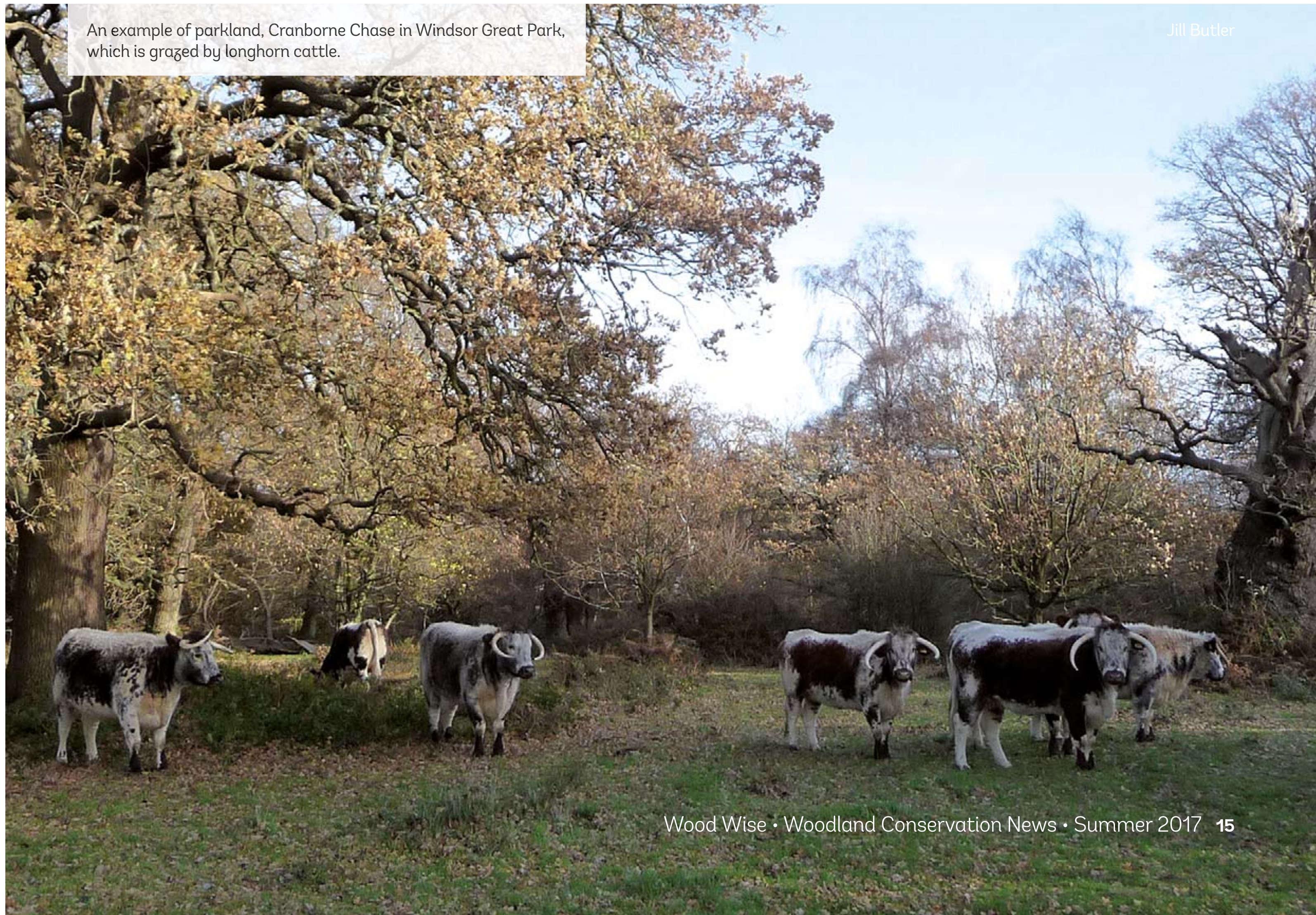


An example of parkland, Cranborne Chase in Windsor Great Park, which is grazed by longhorn cattle.

Woodland ladybirds

Rachel Farrow & William Fincham

Harlequin ladybird *(Harmonia axyridis)*

Woodlands host a rich variety of plant species which in turn attracts a wide diversity of animal species. This is particularly true for insect species and it has been shown that woodland (especially deciduous) provides vital habitats for hundreds of notable and rare insect species, such as the black hairstreak butterfly, golden hoverfly and bearded false darkling beetle. Together with the vast number of insect species that are not at risk, this makes woodlands a treasure trove for insect enthusiasts. A multitude of beetle species make their homes in woodland, including one very well-known beetle family, the ladybirds (Coccinellidae).

Endearing insects

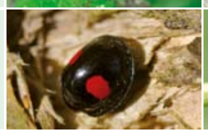
Ladybirds are captivating – their colourful wing casings endear them to wildlife enthusiasts and their consumption of aphid pests ensures their popularity with gardeners and farmers. Some of the UK ladybird species are commonly found and easily recognisable to most people, such as the 7-spot *(Coccinella septempunctata)* and 2-spot *(Adalia bipunctata)*. There are 47 ladybird species in the UK and Ireland, with 26 species that are conspicuous and readily identifiable. The other 21 species are generally quite small (less than 3.5mm long) and inconspicuous[1]. Some of the common species are less well known, for example, the kidney-spot ladybird *(Chilocorus renipustulatus)* and the eyed ladybird *(Anatis ocellata)*, as these tend to be found in more specialised habitats than the 7-spot and 2-spot ladybirds. There are also rare ladybird species in the UK: the 5-spot ladybird *(Coccinella quinquepunctata)* is only found on unstable river shingle in Wales and Scotland, and the scarce 7-spot *(Coccinella magnifica)* is only found living near wood ant nests.

Approximately 90% of UK ladybird species are predators and consume a range of aphid species and scale insects. The remaining species have a diet of mildew, plants or pollen. Some species will also prey on the eggs and larvae of other ladybird species, in what is known as intraguild predation. Ladybirds defend against natural enemies by releasing a fluid from their leg joints called reflex blood. The reflex blood is yellow in colour and contains bitter and toxic alkaloids to deter predators.

Woodland ladybirds

Ten of the most common woodland ladybirds in adult and larval form are detailed in Figure 1. Five of the native ladybird species listed are considered to be generalists, indicating that they can be found on a wide variety of vegetation and will also consume a wide variety of prey[1]. These five generalists can all be found in woodlands, for example on lime, sycamore or field maple. The 10-spot *(Adalia decempunctata)* can also be found on oak and hawthorn, while the 2-spot ladybird prefers mature trees, both deciduous and coniferous. In addition to inhabiting these tree species, the 7-spot and 14-spot *(Propylea quattuordecimpunctata)* also frequent herbaceous understorey. The pine ladybird *(Exochomus quadripustulatus)*, as suggested by its name, is found in coniferous woodland, but also in deciduous woodland, on the tree species listed above as well as ash, beech, birch and hazel. Both the 7-spot and 10-spot can also be found in coniferous woodland, particularly on Scots pine. The eyed ladybird is the largest UK ladybird (7-8.5mm) and is a specialist in coniferous woodland, specifically Scots pine, Douglas fir and larch. In late autumn, however, it is possible to see this ladybird on oak and lime trees. The orange ladybird *(Halyzia quadripunctata)* and cream spot ladybird *(Calvia quattuordecimguttata)* are both deciduous woodland specialists and prefer ash, sycamore, lime, sallow and hawthorn. The kidney spot ladybird is also a deciduous woodland specialist and is more likely to be found on field maple, oak, ash and willow, especially on the bark rather than the foliage.

Figure 1. 10 most common woodland ladybirds

Ladybird	Adult	Larva	Habitat	Food
Harlequin ladybird *Harmonia axyridis*			Generalist near human buildings such as churches as well as deciduous & coniferous woodland	Aphids, scale insects, ladybirds, fruit
7-spot ladybird *Coccinella septempunctata*			Generalist in deciduous, mixed & coniferous woodland	Aphids
2-spot ladybird *Adalia bipunctata*			Generalist in deciduous & coniferous woodland	Aphids
14-spot ladybird *Propylea quattuordecimpunctata*			Generalist in deciduous woodland	Aphids
10-spot ladybird *Adalia decempunctata*			Generalist in deciduous, mixed & coniferous woodland	Aphids
Pine ladybird *Exochomus quadripustulatus*			Generalist in deciduous, mixed & coniferous woodland	Scale insects
Eyed ladybird *Anatis ocellata*			Specialist in coniferous woodland	Aphids
Orange ladybird *Halyzia sedecimguttata*			Specialist in deciduous woodland	Mildew
Cream spot ladybird *Calvia quattuordecimguttata*			Specialist in deciduous woodland	Aphids
Kidney spot ladybird *Chilocorus renipustulatus*			Specialist in deciduous woodland	Scale insects

Harlequin and single 2-spot *(Adalia bipunctata)* ladybirds

An invasive ladybird

Of the 26 conspicuous ladybird species, the majority are native to the UK. Two of the non-native species currently in the UK are the bryony ladybird *(Henosepilachna argus)* and the cream-streaked ladybird *(Harmonia quadripunctata)*. These species have not been found to have a negative impact on native ladybirds and are not considered invasive. The same cannot be said for the harlequin ladybird *(Harmonia axyridis)*, which has spread rapidly through the UK since its arrival in 2003.

The harlequin ladybird was introduced to the USA and some European countries as a biological control agent in an attempt to control aphids on crops, but its introduction into the UK is thought to have been accidental. The harlequin ladybird is native to central and eastern Asia. It is a large ladybird (5-8mm) and is highly diverse in its colouration and so individuals can look very different from one another. The number of spots can range from zero to 21 and the background colour can vary from yellow to red to black. Similar to the native 7-spot, the harlequin is strong during flight and can fly at speeds of up to 30km per hour. This invasive species is also less susceptible to parasites and fungal infections that are common in native UK ladybird species. The harlequin ladybird is a generalist predator consuming a large number of aphid species – up to 60 different aphid species have been recorded as prey of the harlequin[2]. If its preferred prey is unavailable, the harlequin ladybird will also engage in intraguild predation by consuming the eggs, larvae and pupae of other ladybirds. Even though other ladybird species do the same, research has determined that the harlequin ladybird is more successful in these interactions, partly as it has better physical and chemical defences[3].

The harlequin ladybird is also a generalist in terms of its habitat preference. The species is found in many habitats covering both urban and rural areas. In woodland, the harlequin can be found predominantly on sycamore and lime, but also on several other tree species including oak, field maple, Scots pine, ash and yew[1]. Since it arrived in the UK, the spread of the harlequin ladybird has been closely documented by scientists with the engagement of citizen scientists as part of the UK Ladybird Survey (ladybird-survey.org). Data collected through the UK Ladybird Survey has shown declines in several native ladybird species following the arrival of the harlequin ladybird. The 44% decline in 2-spot ladybird numbers is attributed to the increase in harlequin numbers and increased competition for prey.

Overwintering ladybirds

Ladybirds are most likely to be spotted on warm, sunny days, although it is possible to find them during colder months. In temperate climates, such as that of the UK, ladybird species must either migrate during the winter or become dormant. In the UK, ladybirds become dormant and choose a suitable site in which to overwinter. Prior to entering this dormant phase, ladybirds will consume as much food as possible to ensure they have the reserves needed to get them through to spring, when they can emerge ready to reproduce[4].

In woodland, the harlequin can overwinter in a variety of sheltered locations, including tree crevices and spaces under bark. However, the favoured location for an overwintering harlequin ladybird is inside houses. Many people will be familiar with large groups, or aggregations, of ladybirds congregating in their houses on windows, ceilings, sheds or fence posts. These are often large groups of harlequin ladybirds, but can include a mix of harlequins and other species such as the 2-spot ladybird, which also likes elevated positions such as attics. Where possible, harlequins tend to move from woodlands to overwinter near human settlements in sheltered locations such as churches, sheds and houses. This is when the species is often noticed, especially as harlequin aggregations can be up to thousands strong.

Native woodland ladybird species tend to remain near their usual habitats. Here, the majority of ladybird species tend to overwinter in leaf litter, low herbage or shrubs, such as gorse. Some, like the cream spot, pine and 2-spot ladybird, prefer to spend winter in the crevices within tree bark. Depending on the winter conditions, many species can be found where the branches meet the tree trunk.

There is some evidence that ladybirds are accurate long-term weather forecasters. Research has shown that the proportion of ladybirds that remained on trees each year was positively correlated to the summed minimum daily temperature for November to February inclusive. The interesting aspect of this is that once they have chosen their overwintering sites in early October, the vast majority of ladybirds rarely move from these sites[2].

Overwintering sites can be revisited year after year. It is thought that pheromones released by previously overwintering ladybirds persist as markers for individuals the following year[4]. Overwintering ladybirds indoors are very unlikely to cause anything more than a nuisance. While allergic reactions are possible, they are rare, and staining from the yellow reflex blood is a more likely side effect.

Pine ladybirds *(Exochomus quadripustulatus)*

How can you contribute?

It is well known that human actions have impacted the UK's wildlife, and ladybirds are no exception. Habitat loss attributed to urbanisation and intensification of agricultural practices, as well as the arrival of invasive non-native species, such as the harlequin ladybird, impose an increasing pressure on native ladybirds. Records of ladybirds from members of the public are invaluable, not only in the warmer months, but also during the winter period. Recording ladybirds (adults, pupae and larvae) is relatively quick and simple and can be done by several means, especially via the free iRecord Ladybirds recording app (iPhone or Android) or website (ladybird-survey.org/recording.aspx).

Rachel Farrow is a PhD student at Anglia Ruskin University. Her work researches the effects of invasive non-native species and how best to implement conservation measures for native species.

William Fincham is a PhD student at the University of Leeds and the Centre for Ecology & Hydrology. His work focuses on the impacts of invasive non-native species.

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Disease transmission by insects

Emma Bonham

A range of insect groups, such as beetles (Coleoptera), aphids (Hemiptera), wasps and ants (Hymenoptera) have all been associated with the transmission and establishment of tree diseases.

Some insects are linked to tree disease and declines in tree health by acting as vectors; they transmit pathogens amongst individual trees of the same species or between different tree species. They can also weaken the health of the tree, creating suitable conditions for disease to take hold.

Symbiosis and disease transmission

Symbiosis is a term used to describe a close association or interaction between species. Insects often exist in symbiosis with microbial organisms, such as bacteria and fungi[1]. For insects with a diet of plant and/or woody tissues, micro-organisms within their gut can aid in the digestion of the components of plant cell walls. In particular, cellulose and lignin, found in wood and bark, which are hard to digest.

Nutrients such as nitrogen are often missing from an insect's diet and micro-organisms can also help to release these nutrients from the plant tissues as they are digested. Symbiosis can exist in another way, too, with micro-organisms acting to break down tree tissues, which can then be eaten by insect larvae.

Many symbiotic relationships are not harmful to either species. However, some bacteria and fungi are known to cause tree diseases or contribute to a decline in tree health. Interactions where an insect acts as a vector of a pathogen are often a focus for research to better understand the role an organism plays and to inform strategies to mitigate their impact.

Some of the best known examples of symbiosis exist among the bark and ambrosia beetles (Scolytidae). While some insects carry the spores of fungi with them in their guts or mouthparts, ambrosia beetles carry the fungi inside specially adapted organs, called mycangia. As the beetles bore into a host tree, they introduce the fungi directly into the tree. The fungi form colonies on which the ambrosia beetles then feed.

Elm bark beetles

(Scolytus scolytus and S. multistriatus)

Both species of native UK elm bark beetles are known to spread the two fungal pathogens, *(Ophiostoma ulmi* and *O. novo-ulmi)* that are the cause of Dutch elm disease.

The fungi grow in the galleries created by the tunnelling bark beetle larvae and within the xylem of infected trees, blocking the movement of water. The spores can become attached to newly emerging adult beetles, which then carry the spores with them into a new host elm.

Eight-toothed European spruce bark beetle

(Ips typographus)

This bark beetle is not currently present in the UK, but has been intercepted on imported material. The blue stain fungus *(Ceratocystis polonica*, formerly *Ophiostoma polonicum)* is known to infiltrate the phloem tissues of spruce, and has been found on the surface and in the gut of adult beetles. As the adult and larvae form galleries, the fungal spores are transferred into the bark tissues of the tree. Tree defences are weakened by the combined feeding actions of the beetle and the decay caused by the pathogen. This can lead to discoloration of the timber and the death of the tree[2].

Overcoming host plant defences

In the case of wood boring insects, some micro-organisms can help to overcome host plant defences[1]. Insects may introduce the organism to allow easier establishment or to protect newly laid eggs or larvae.

Lesser Horntail wasp or European wood wasp

(Sirex noctilio)

A native European species, also found in Asia and North Africa, the European wood wasp *(Sirex noctilio)*, lays its eggs on pine trees. Within its native range, the wasp is a lower threat, as it is kept in check by natural enemies. However, where it has been introduced, it can be a significant invasive and economic pest of pine plantations[3].

Female wasps bore holes through the bark to reach living tissues, into which they lay their eggs. They primarily seek out weakened trees, although they can target healthy trees. As the female lays eggs, she deposits a mucus like substance, which is toxic to the trees, along with spores of a fungus *(Amylostereum areolatum)* which decomposes the tree's tissues and upon which the larvae feed[3]. Both of these strategies create the right environment for the larval wasps, but simultaneously contribute to the tree's decline and potentially its death.

Adaptability is a key means by which an insect can exploit a new habitat or range of hosts. This is particularly true for an insect outside its native range. One such species that is able to successfully adapt is the citrus longhorn *(Anoplophora chinensis)*[4]. A UK non-native invasive species, the citrus longhorn, unlike many other native longhorns which primarily select dead or dying trees, is capable of infesting healthy trees[5]. The beetle can adapt its gut bacterial community depending on its host plant, allowing it to select and survive on new hosts. This is partly how a generalist insect species is able to utilise multiple host trees.

Tree resistance to attack

Trees have defence strategies to help combat insect attack and keep the extent of damage under control, allowing the tree to recover[6]. Some defence traits are produced continuously by the tree and are called constitutive defences. These include leaf hairs, spines and various chemical compounds.

A tree can induce defences as well. This means that the presence of an insect causing damage triggers the tree into action. Induced defences include localised thickening of cell walls to isolate the area of damage, flooding of larval galleries and, in the case of conifers, producing resin to block the tunnels of burrowing insects. Some tree species are also able to produce specific compounds toxic to the invading organism, and certain trees can induce volatile compounds that attract natural enemies of the attacking insect herbivore.

Defence mechanisms are costly to the tree both in resources and energy required. Sustained insect attack and induced defence reactions are likely to weaken a tree beyond its capacity to respond effectively and will increase its vulnerability to other tree pathogens.

The unknown future

There is still much we do not know in relation to insects and their connection to tree health. One such area in which knowledge is lacking is with acute oak decline, where there can be a co-occurrence of bacterial infection causing bleeds and the exit holes of the oak jewel beetle *(Agrilus biguttatus)*. Studies are underway to understand the exact cause and spread of this condition and to determine if this native buprestid beetle plays any part in this disease complex.

The capacity of insects to act as vectors for tree disease has been recognised, but there is still much to understand about the relationship between the insect host and its associated microbial community. With an increased awareness of tree disease also comes a need to fully understand the potential role insects play in their development and spread.

Emma Bonham is a PhD researcher with Harper Adams University, funded by Woodland Heritage, and is looking into the relationship between Acute Oak Decline, insects and the woodland environment.

More information on tree pests and disease can be found via the Forestry Commission website forestry.gov.uk/pestsanddiseases

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Lessons from extinctions

Philip Buckland

Many beetles are very good at colonising new areas when changes in the landscape open up new possibilities. Equally, they are highly susceptible to local extinction in the face of landscape scale changes in their environment.

From what we know of the Quaternary fossil record (the last 2.6 million years), this capacity for colonisation has allowed beetles to migrate as species, rather than rapidly evolve under new selection pressures or become globally extinct. Their mobility means that they are able to track their often very precise habitats, except where that habitat, particularly on remote islands, has been entirely lost. So far, there are only a couple of species that have been found as fossils which cannot be found living somewhere today, and this probably reflects more the limits of modern collecting than actual extinction. It's a testimony to the success of beetles over more than 260 million years of evolution (Figure 1), at least since the late Permian age (299 to 252 million years ago), when the earliest definite beetles appear as fossils.

Beetles have hard, almost chemically inert exoskeletons, which preserve well in anaerobic and desiccating sediments, including waterlogged deposits such as peat bogs, forest hollows and archaeological features, such as wells and latrines. They are, therefore, common fossil finds, and their diversity and abundance in almost all types of habitat makes them extremely useful for studying the past. While there are numerous methodological issues to consider, the basic principle of palaeoentomology (the study of fossil insects) is simple: if we find a beetle in a sample, then the sample must have been deposited in, or close to, an environment that allowed that beetle species to survive.

Philip Buckland

Longhorn beetle (*Lepturobosca virens*), Klabbole, Sweden.

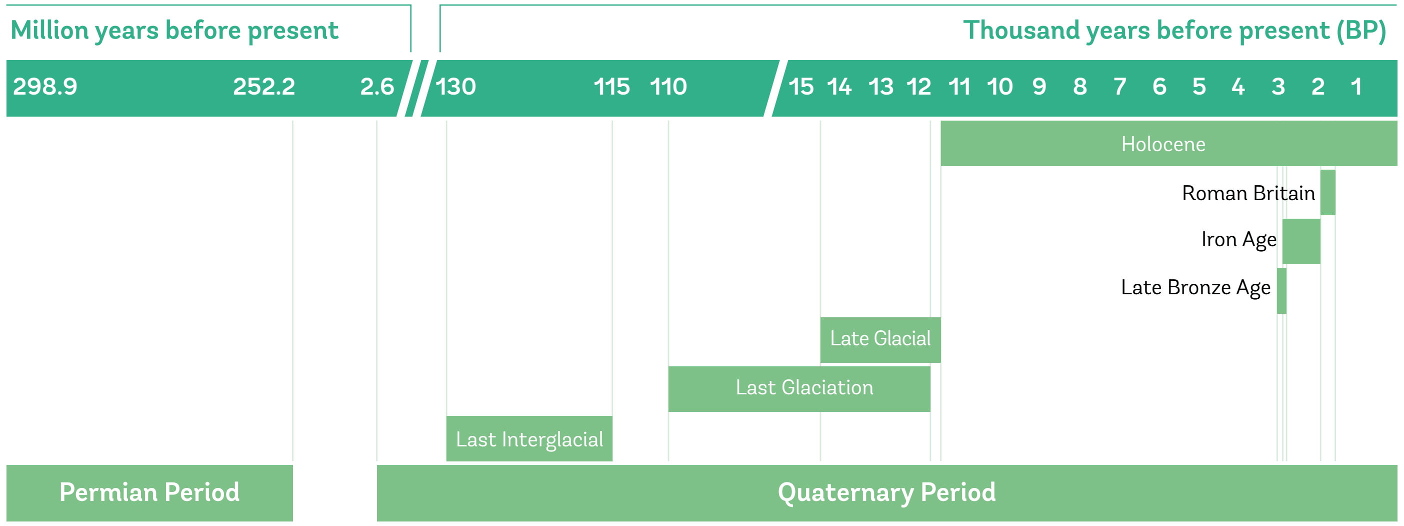

Figure 1. More than 260 million years of beetle evolution

Habitat traits

The environmental requirements of any beetle species can be summarised in terms of general habitat characteristics, or traits. For eurytopic (generalist) species, these may describe a wide range of environments, such as 'open ground' or 'shade'. For more specialised 'stenotopic' species, traits may be quite narrow, such as 'ectoparasites' or 'coniferous trees indicators'. For example, the larvae of the longhorn beetle (*Lepturobosca virens*), now extinct in the UK, are associated with dead wood and the adults are usually found in wooded regions of northern Europe and Russia; the longhorn is therefore classified as a general 'wood and trees' species. Building a database of these traits for the fossilised species, obtained from modern collecting data, allows us to investigate past beetle finds in terms of their environmental significance.

Palaeoenvironmental reconstruction

Mobility varies considerably between species. At one end of the spectrum, this is illustrated by the reliable habit of critically endangered fire indicator (pyrophilous) species turning up after forest fires (Figure 2). These beetles are considerably rarer than the weevils, bark and longhorn beetles that are considered pests by the forestry industry. When either of these groups are found as fossils, they serve different purposes for our interpretation of the past. Individual finds of rare species are considered significant, as the probability of them having been present at the site without the specific environmental conditions (such as a forest fire) having been met is extremely low. Finds of more common species allow us to build models of past landscapes by aggregating the traits of all the individual species found in a sample (and doing some simple statistics).

By examining changes in the aggregated traits of the beetles found in a series of dated samples, we can track environmental changes at a site over time. With many suitably well dated deposits, we can use the beetle signals to build broad scale models of landscape changes and derive conclusions on the driving forces behind them.

Migration is key to continued existence

It follows that, as a region transforms as a result of vegetation succession or climate change, or is changed by people or other animals, the beetles which can survive there will change. If we chop down the trees, then the beetles requiring wood, leaf and shade will disappear. Depending on their level of mobility, those individuals which survive the deforestation will either actively seek suitable alternative areas, or move more slowly as a population through a process of expansion and attrition. If the change is more gradual, then the beetles may become less commonly found by collectors or in biodiversity surveys, and become marked as threatened or critically endangered on the International Union for Conservation of Nature red list for the region. If there are no suitable alternative sites close enough, then the species may become regionally extinct (extirpated). Significant barriers, such as mountain ranges or the English Channel, increase the likelihood of extirpation when a species is pressed at the edge of its range. From a modern day perspective, extirpation is of course a regretted if inevitable event, but we can learn a lot from past extirpations – particularly when viewed as the consequence of past climate change, environmental change and human impact on the landscape.

Regionally extinct beetles

As far as we know, about 220 beetle species have become extirpated from the British Isles during the Quaternary period[1]. This is undoubtedly an underestimation, as the fossil record is patchy and biased towards well preserved natural deposits and archaeological sites. That some beetles have become regionally extinct during such a long period of time is of no surprise, considering the dramatic contrasts in climate between glacials (Ice Ages) and interglacials; but the details of exactly which species disappeared, and when, have interesting implications for our understanding of the past.

Palaeoentomologists usually use the entire fauna of a sample to reconstruct the environment, the aggregation of species habitat traits allowing for a nuanced picture of the landscape. If we instead look only at the traits of the beetles which have become extinct, we should be able to see more of the environments that have been lost. Assuming that the last known find of a species is a reasonable approximation for its date of extinction, we can reason that the environment and/or climate required for the species to survive was no longer available after that date.

Figure 2. Vindeln nature reserve, Sweden, with fire damaged fallen trees in the foreground.

Woodland species lost during the Holocene period

According to the habitat traits of those beetles which have become extinct in the British Isles during the current warm period (the Holocene i.e. the last 11,500 years; Figure 3), the loss of woodland habitats has been the most significant landscape change. Many of the extirpated species have their last finds from some 4,500 to 2,000 years ago. This fits in well with current understanding of the scale of landscape change in the late Bronze Age and Iron Age[2], where archaeological and palaeoenvironmental evidence suggest larger scale forest management and clearance started to have more dramatic landscape scale effects.

The absence of many of the large herbivores and their predators, of straight-tusked elephant, rhinoceros and hippopotamus, compared with the previous interglacial period, already marks out the Holocene as different from its initial warming onwards, and inevitably the dung fauna is different. There is still much debate on the nature of mid-Holocene woodland, and the roles played by both humans and the remaining large herbivores in shaping them. Beetles have contributed to this discussion[3], but more research is needed before any firm conclusions can be drawn. Proportionally there appears to be a higher loss of conifer-related beetle species than deciduous in Britain, a feature of the virtual disappearance of pine from the lowlands by the Roman period. Several of the species now present probably re-immigrated with forestry. This trait-based approach shows that, as well as woodland species, we have lost a number of open ground species. Further research is needed to look at the timing

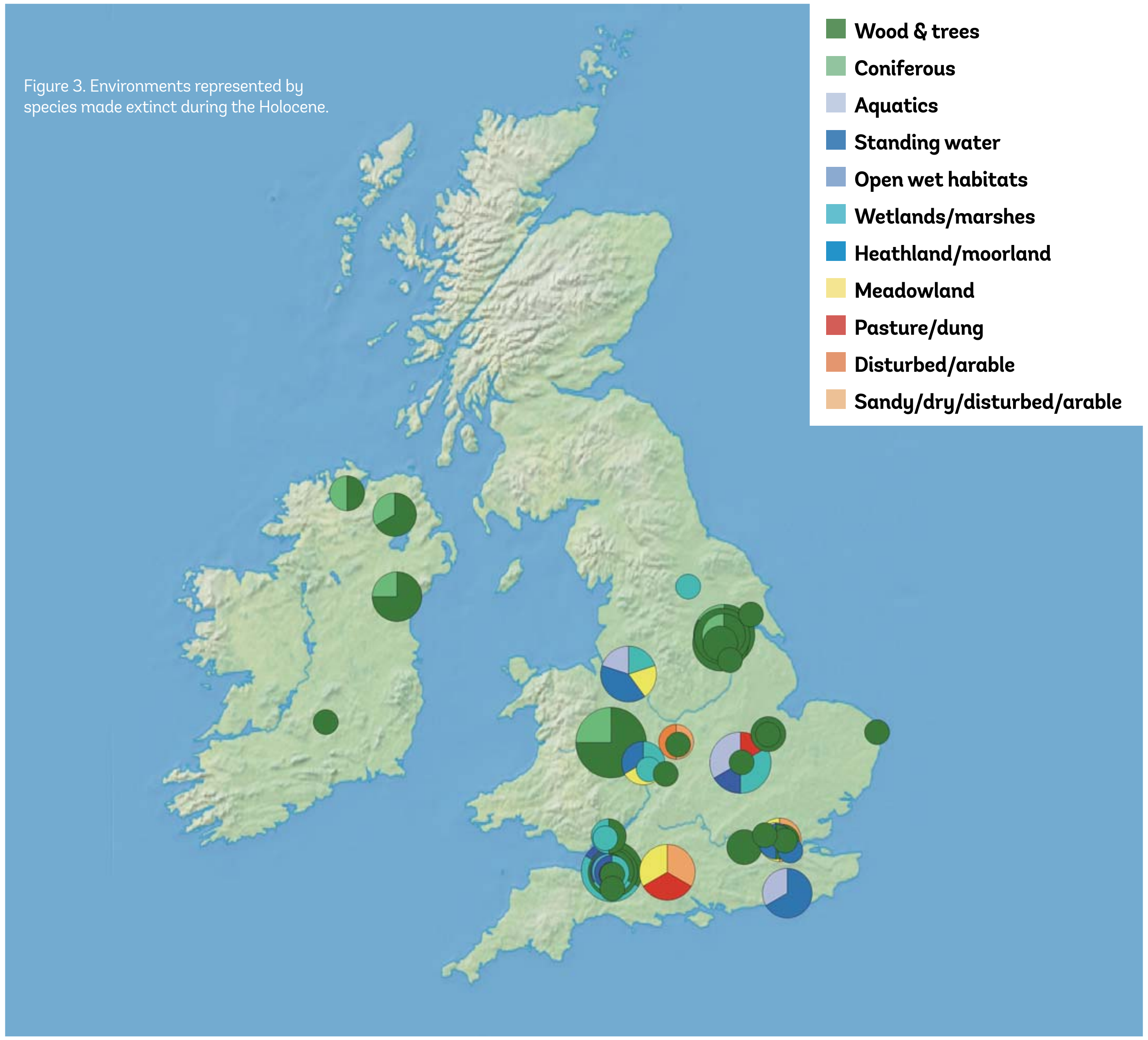

Figure 3. Environments represented by species made extinct during the Holocene.

and context of these extinctions, which could be more recent and related to a range of factors including the eutrophication of waters (excessive growth of plants and algae), draining of wetlands, disappearance of traditional meadows and, more recently, the use of helminthicides to kill parasitic worms in livestock.

Wetland species lost during the Late Glacial period

Contrast the Holocene picture with the traits of species for which the last record dates from the Late Glacial period (an era of rapid climatic change stretching from the last Glacial , 14,500 – 11,500 years ago; Figure 4). Aside from the considerably larger number of species and samples involved, here we see a dominance of extirpations among wetland species, water beetles and heathland/moorland species. While woodland may have begun to establish itself in the British Isles by 10,000 years ago, the environment was probably more like the edges of the modern day northern Swedish boreal forest, with dwarf birch and pine scrub intermixed with lakes and bogs (Figure 5), if significantly warmer. This is a landscape long since lost to the UK, although some remnants of it may exist in the Scottish Highlands.

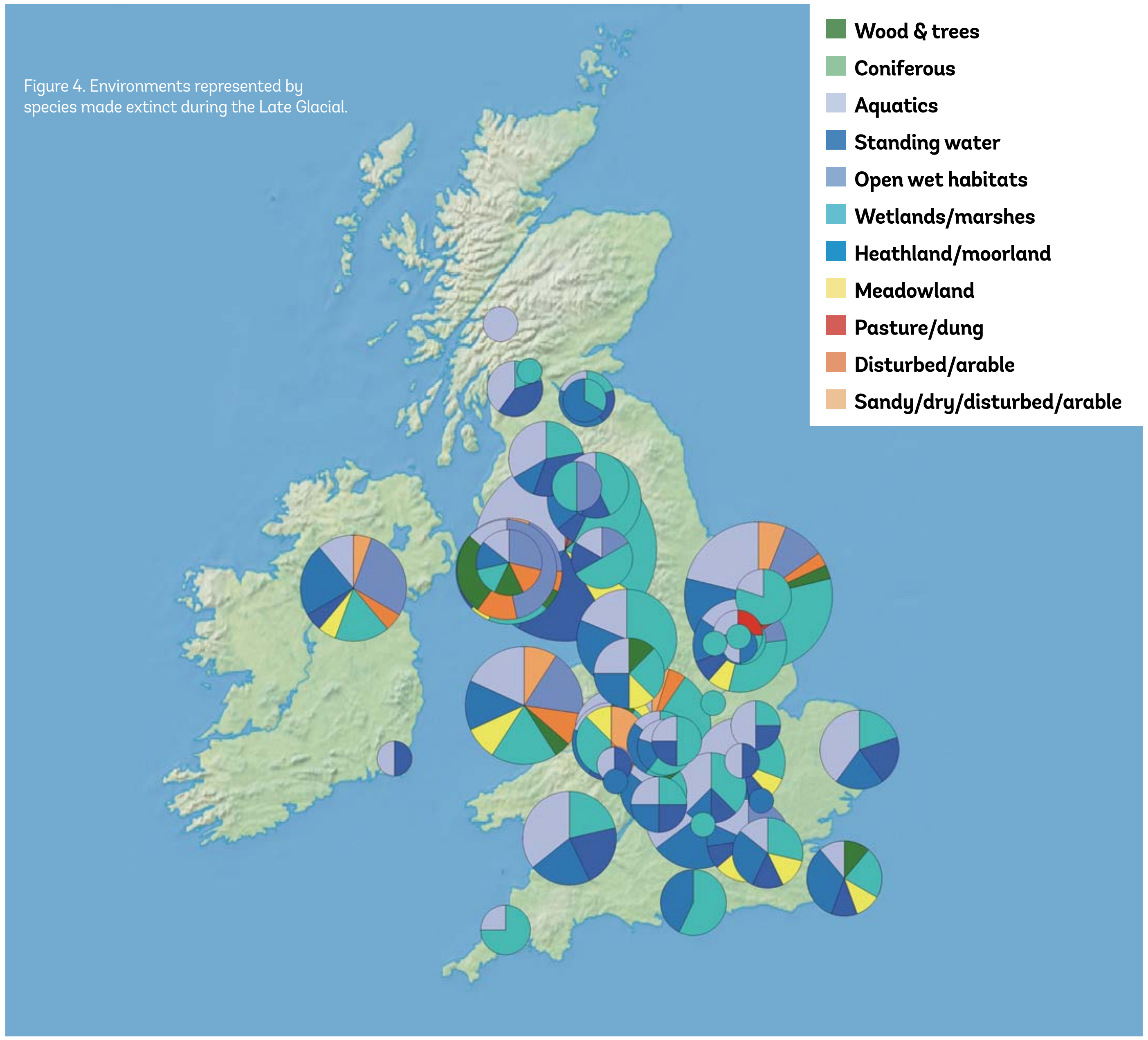

Figure 4. Environments represented by species made extinct during the Late Glacial.

Figure 5. The treeline in northern Sweden

Future work

There is much work still to be done on all these data, which are freely available in the BugsCEP database[4] and the UK Coleoptera Checklist[5]. The results are heavily skewed by the selection of sites available, as the larger number and size of points for the Late Glacial illustrates. Much more basic field and laboratory work needs to be done to build on this dataset. For many of the sites, the dating evidence is poor, and the results of the fossil beetle work need to be cross-correlated with other proxies to build a more holistic picture of environmental change and its implications for the survival of species in the British Isles.

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