Natural England Commissioned Report NECR225a

The role of trees outside woodlands in providing habitat and ecological networks for saproxylic invertebrates

Part 1 Designing a field study to test initial hypotheses

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Foreword

Natural England commission a range of reports from external contractors to provide evidence and advice to assist us in delivering our duties. The views in this report are those of the authors and do not necessarily represent those of Natural England.

Background

This work was commissioned as a preparatory phase to explore options to design and plan a practical research study which answers the question: what is the role of trees outside woodlands in providing habitat and ecological networks? In order to help increase our knowledge of the role of non-woodland trees to providing landscape connectivity.

It reviews and summarises what is known about the underlying biology of the veteran tree ecosystem, the biogeography of trees in the English landscape, and the various techniques which have been developed to study the saproxylic invertebrate fauna associated with those veteran trees. A rationale is developed for targeting the proposed study at the heartwood-decay fauna of oak using transparent cross-vane window flight-interception traps.

There are three parts to the study:

- Part 1: Designing a field study to test initial hypotheses (NECR225a)
- Supplement to Part 1 (NECR225b)
- Part 2: Supplementary literature review and other notes (NECR225c)

Part 2 was funded by the Woodland Trust.

The work makes recommendations for a suitable design for the proposed study, based on a standardised sampling protocol. Four locations are identified as possible sites for field-testing the protocol, but significant shortfalls in our current knowledge of the local treescapes have been identified, and it is clear that further baseline tree survey is needed before the fully developed study can begin.

In the meantime, a field trial will be considered at one or more of the four identified study sites, possibly using combinations of site staff, the biological recording community and/or students to provide logistical support.

WOODLAND TRUST

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SUMMARY

The current project is a preparatory phase of work to explore options to design and plan a practical research study which answers the general question:

- what is the role of trees outside woodlands in providing habitat and ecological networks?

This document reviews and summarises what is known about the underlying biology of the veteran tree ecosystem, the biogeography of trees in the English landscape, and the various techniques which have been developed to study the saproxylic invertebrate fauna associated with those veteran trees. A rationale is developed for targeting the proposed study at the heartwood-decay fauna of oak using transparent cross-vane window flight-interception traps. The Ancient Tree Inventory has then been used to pick out key sites across England which might be suitable to include within the study – supplemented to some extent by the contractors' own knowledge of potential sites - and a selection of these sites has then been identified as potential study sites using knowledge of both their fauna and their treescapes:

- Killerton Park Estate, Devon (National Trust)
- Knepp Castle Estate, The Weald, West Sussex (private owner)
- Stowe Park, Whittlewood Forest, Buckinghamshire (National Trust)
- Wimpole Hall Estate, Cambridgeshire (National Trust)

The report then goes on to recommend a suitable design for the proposed study, based on a standardised sampling protocol. The process of exploring options and then field-testing them has been instrumental in developing the final design. All four sites now have sufficient veteran oaks mapped and documented which have hollows and are judged suitable for the vane-trapping study design. The field-testing has however identified significant shortfalls in our current knowledge of the local treescapes, and it is clear that further baseline tree survey is needed before the fully developed study can begin – while the trap-suitable trees have been identified, analysis of the treescapes in terms of local densities of veteran oaks with cavities is not yet possible. A minimum 2 km buffer zone around each parkland has been recommended as a baseline for analysis of the fauna in relation to local tree density patterns; this has proved challenging to quickly survey and some private land has necessarily been temporarily omitted. Ideally the buffer zone should be extended to 3 km. Costings have been provided for the full vane-trapping study.

It is also recommended that further sites should be brought into the study, to expand the coverage, but these also require baseline tree survey before they can be adopted.

In the meantime, it is suggested that a field trial be established at one or more of the four identified study sites, possibly using combinations of the local National Trust teams, the biological recording community and/or students to provide logistical support.

The current situation at the four investigated study sites is:

- Wimpole – ready to start as soon as resources permit;
- Stowe – more or less ready but with a small amount of field survey work still needed in one out-lying private area once permission has been obtained;

- Knepp – trap trees all identified but requires more tree survey work in relation to analysis of local tree density, but this is in-hand;
- Killerton – trap trees all identified but requires a significant amount of tree survey to map other trees with cavities within the intervening landscape.

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1.1 Background to the present study

Tree-related ecological studies often focus on discrete patches or concentrations of trees, but trees also occur outside areas of forest and woodland. Those concentrations of trees also tend to be close-grown, and are typically enclosed and ungrazed. In English landscapes, scattered non-woodland trees occur, for example, in parkland and wood-pasture, in orchards, fields, hedgerows, and urban parks. Parkland and wood-pasture is a Priority Habitat recognised in the Biodiversity 2020 Strategy process and included in the Natural Environment and Rural Communities Act (NERC) 2006 as a habitat of principle importance. In such situations tree form may be very different to that of woodland trees, open-grown conditions permitting the full development potential of each tree without the constraints brought on by competition for light, etc. Trees outside woodlands can also reach a considerable age and size, something not usually possible in close-grown stands due to crown competition. Older trees may represent significant ecological continuity.

Studies in other countries have highlighted the important ecological role that scattered trees can play; they are considered keystone structures because their effect on ecosystem functioning is believed to be disproportionate relative to the small area occupied by any individual tree (Sirami et al 2008, Fischer et al 2010). This could be particularly important in England given the relatively low tree cover of most English landscapes in comparison to many other parts of Europe. Hall & Bunce (2011) provide one of the rare English studies which discuss this point. However, the value of scattered trees in England has not been studied in any great detail – a Woodland Trust study has been an important initiative (Brown & Fisher 2009). This is a particular concern given that losses of large old trees from the English countryside have been reported to exceed the rate of replacement, eg for hedgerow trees (Defra 2009), and that there are anecdotal suggestions that losses are continuing and probably increasing. These losses are likely to be exacerbated with climate change, if extreme events such as droughts and storms increase in frequency and/or severity, and in the increasing presence of invasive non-native diseases such as Chalara Ash Dieback and Acute Oak Decline. This has occurred before of course with Dutch elm disease which virtually eliminated veteran trees of an entire genus across the English landscape.

Given the increased awareness in recent years of the importance of landscape-scale ecological processes and a consequent interest among conservation organisations in ecological networks (Lawton et al 2010), one potentially important aspect of the ecological role of scattered trees is their contribution to habitat networks. Scattered trees could provide stepping stones or corridors that promote species movement between woodland patches. This is being considered to some extent in an existing Natural England project that is studying the effect of site and landscape features on species found in woodland patches (http://www.stir.ac.uk/natural-sciences/researching/groups/bes/ecologyevolutionandconservation/wren/). Scattered trees provide permeable landscapes through which both tree-associated and open vegetation species can cross, unlike woodland blocks which may act as barriers to movement (Alexander 2003a). Scattered trees may also function as 'islands' of habitat in their own right, supporting and enabling movement between populations of species that depend on the trees themselves, as has been shown for Hermit Beetle *Osmoderma eremita* populations in Sweden (Ranius 2002, Ranius & Hedin 2004). The features of an individual tree, and the spatial configuration of trees in relation to each other – both current and historical - and other habitat features, might have a strong influence on species occurrence and movement.

We know veteran trees are important for rare saproxylic invertebrates which depend on dead and decaying wood to complete at least part of their life cycle, as well as supporting the fungi species which create that decay. These invertebrate species are widely acknowledged to be one of the two most threatened ecological groupings of invertebrates across Europe (Nieto & Alexander 2010); some are listed in the NERC Act as species of principle importance, and some listed as threatened or near-threatened on the European Red List of Saproxylic Beetles (compiled by the International Union for the Conservation of Nature and Natural Resources). In England the role played by trees outside woods in providing opportunities for saproxylic invertebrates to move around the landscape is not yet fully appreciated; most published evidence is from studies carried out in other countries. Müller et al (2013) have identified the importance of hollow beech trees as keystone structures for saproxylic beetles in Germany, and Manning et al (2006) and Fischer et al (2010) assert that scattered trees are keystone structures in a wide range of landscapes. There is evidence from the Czech Republic (Horak et al 2014) that the species composition of saproxylic invertebrates differs in different landscape structures, but most saproxylic taxa prefer more open and light conditions (Vodka et al 2009, Horák & Rébl 2013). It has been shown that most stands of open-grown oak are threatened by succession, a result of which is that saproxylic organisms are facing decline throughout the world and managing woodlands as wood pasture or by coppicing appears to be one solution to mitigate biodiversity loss. Ranius and colleagues in Sweden (Ranius 2002, Ranius & Jansson 2000, Franc et al 2007, Ranius et al 2011, Widerberg et al 2012) have identified the particular value of open-grown oak trees to the species that depend on them, including saproxylic invertebrates. Widerberg et al (2012) in particular has shown that increased openness around oaks increases species richness and abundance of oak-associated beetles. This has also now been demonstrated in England, in Epping Forest (Wilde 2005a & b)

The current project aims to develop a practical research study which answers the general question:

- what is the role of trees outside woodlands in providing habitat and ecological networks?

With a focus on saproxylic invertebrates, and particularly those listed in Section 41 of the NERC Act 2006. The proposed study will aim to understand better the characteristics, density (i.e. number of trees in a given area), and spatial configuration of trees outside woodlands required to support robust populations of saproxylic invertebrates, and thus inform decisions about the retention and replacement of such trees. It will investigate the hypothesis that scattered trees are vitally important as matrix features between other habitat patches, and as patches in their own right for species that live within them. Specifically, the hypotheses are that:

- open-grown, veteran trees contain fungi and late stage decaying wood that provides ideal conditions for rare and declining populations of saproxylic

invertebrates; scattered trees in the landscape are as valuable as those sites where the density of trees in the landscape is high;
- the populations of saproxylic invertebrates using non-woodland trees are affected by the characteristics of the individual trees such as age, trunk diameter, presence of fungi species and state of decay, and size of cavities;
- invertebrate populations are also affected by the spatial configuration of these trees, for example the distance between trees, whether trees are in lines or clumped, the number of trees within a given geographic area, how open the vegetation is around the trees;
- the degree of movement between and mixing of sub-populations found in individual trees is also affected by the factors mentioned above.

By addressing these hypotheses it is hoped to answer some more specific questions that would enable 'rules of thumb' to be developed for practitioners on appropriate strategies for planting and maintaining trees for the conservation of saproxylic invertebrate species, such as:

- how many trees are needed in a given area to support saproxylic species? How important are small groups of veteran trees? For example, less than 10?
- Do trees need to reach a certain age, or attain other characteristics, before they are able to support saproxylic invertebrate populations? How well does the English landscape provide these conditions?
- Does it matter in what spatial configuration new trees are planted?
- Do groups of trees need to be within a certain distance of each other to provide ecological continuity? Is there a relationship between distance between trees and diversity/abundance of saproxylic invertebrates? If so what is it?
- What role do isolated trees play in providing connectivity between groups of veteran trees in parklands and wood-pasture sites? Do rows of individual trees help connect isolated groups of trees?
- What is the relationship between density of trees, diversity of saproxylic species and the health of the invertebrate populations?
- What can we infer about the movement of saproxylic species through the landscape and how do populations relate to each other?
- What is the role played by fungi in late stage decay of trees in making the tree attractive to key species of saproxylic invertebrates?

This report is for a preparatory phase of work to explore options to design and plan a study that could be carried out in future to test the above hypotheses and thus increase understanding of the role of scattered trees in the development of coherent ecological networks as set out by Lawton et al (2010) and inform future plans for the conservation, management and replacement of such trees. The aim is to provide a detailed proposal for a field-based study, with sites identified and work costed, and an indication of the ideal length of time for which the study would run.

The vision for the overall long term study is that a network of sites will be established across England where interception traps are set up to sample saproxylic invertebrate populations. Their focus will be wood-pasture sites set in a landscape with hedgerows, hedgerow trees, and possibly in-field trees. The full series of sample sites will include tree populations in a variety of situations, although the initial study covered by the present design will need to focus on similarity rather differences in order to be able to answer at least some of the questions which have been posed. The hypotheses are ambitious and it is expected that there may need to be several stages in a research programme to answer all of the questions.

1.2 Timing

The present study was carried out to a tight deadline and it did not prove possible to carry out the detailed review of key literature than was considered desirable. It was agreed therefore that a less thorough review would be adequate at this stage and that a fuller review could be considered at a later stage.

2 The underlying biology

2.1 Growth and development of trees

Growth and development of trees varies considerably in relation to tree density. The ideal growing situation is an open one, without competition for space from other trees, where the individual crown and root system are able to explore their environment fully in order to maximise/optimise the tree's resources – gathering light, water, minerals, etc. The older annual rings within the centre of the trunk are gradually stripped down of accessible materials and waste products deposited, before they die. Secondary plant compounds which resist fungal decay may be laid down too, the tree species being referred to as having a durable heartwood (such as oak and sweet chestnut). In oak for example the annual rings are genetically programmed to die at around 25 years of age (D. Lonsdale, pers. comm.), so all oaks older than this contain a core of dead heartwood tissues. In other tree species, sections of annual ring die fairly randomly and so no clear division forms between the living wood and the dead heartwood – this condition is termed ripewood (as found in ash and beech trees).

At some stage these dead woody tissues – durable heartwood and ripewood - are colonised by specialist heartwood-decay fungi which begin to break down the main components of the wood – primarily lignin and/or cellulose. The residues of this decay begin to accumulate in the base of the cavities which form within the trunk and a process of composting begins. Additional materials may be brought in by nesting birds and roosting bats, and these are thought to be important in the nutrition of colonising invertebrates – it has been shown experimentally for example that wood mould with dead birds is more productive for wood-decay beetles (Jansson et al, 2009b).

Ranius et al (2009a) have used tree ring data from individual oak trees *Quercus robur* to estimate when hollow formation commences in southeast Sweden. At ages of:

- <100 years old, less than 1% had hollows
- 100-200 years, only 4% had hollows
- 200-300 years, 50% of the trees had hollows
- all >400 year old trees had hollows.

Hollows formed at earlier ages in fast-growing trees than in slow-growing trees. In an oak with an average growth rate, the probability for the presence of a hollow reached 50% when the tree was 258 years. In commercially exploited oak stands, final felling is at 120-150 years in order to harvest while the hollowing probability is very low.

This is a key reason why hollow trees are rare in exploited oak stands. They comment that this is a unique dataset in Europe – equivalent data is not available in Britain.

The crown of the individual tree also changes in character with age. Once the optimum form has been developed (for the species concerned) expansion effectively ceases. However, the increasing circumference of the trunk eventually reaches a point where the new annual rings are stretched too thinly to function properly and can no longer supply sufficient water and minerals to the whole crown; the tree responds by reducing the upper crown, a process termed retrenchment. New growth forms below the now dead upper branches in response to increased light levels within the lower crown, and a new full crown develops at a much lower height.

In the case of trees in direct competition with other trees – as in woodlands and plantations – retrenchment is not normally possible and trees die relatively young. The trunks tend to be drawn up through competition for light and lateral branching is suppressed by the shady conditions lower down. Once retrenchment begins the tree becomes vulnerable to shading from neighbouring younger trees, with vigorous high crowns, and the lack of lateral branches means that the older tree is unable to produce much new growth lower down anyway

These are the two extreme situations - open-grown v overcrowding - and there are many tree densities feasible in between, of course, and a gradation of effects from tree form, tree aging, light levels, etc. But the poor growing conditions inside the densest woodland mean that – in general – older trees with heartwood decay may not develop at all. This is a key reason why open-grown trees within wood pasture and parkland situations are richest in wood-decay assemblages, and why open-grown trees in the surrounding landscape have the potential to be important for the same assemblages.

Secondary canopy closure can also be very damaging, especially in oak - ’crown retreat’ occurs when adjoining crowns touch each other, the foliage dying back from points of contact (see for example Spector et al 2006). Thus the form of an open-grown tree can be impaired through subsequent crown competition and this may lead to early death of an oak with retrenched crown, the neighbouring competitor eventually over-shading much of the reduced crown.

All trees also develop dead branches in the lower crown in response the growth and development of the higher crown and the consequent reduced light levels lower down. Branches may also die as a result of physical damage, from storms, etc.

2.2 The process of fungal decay of dead woody tissues

As discussed in 2.1 above, trees naturally develop internal dead tissues as they age, as well as aerial dead branches, etc. These dead tissues are not available to the tree for recycling as trees cannot breakdown the complex carbohydrate structures of lignin, cellulose, etc. In the case of tree-controlled death of annual rings, crown retrenchment, and out-shaded lower lateral branches, it is able to withdraw materials and deposit waste before the tissues die. In the case of accidental damage, eg from storms, such withdrawal is unable to take place and hence the resulting deadwood has a different chemical composition. Wood is a complex fibrous material consisting predominantly of a diversity of hollow elongated cells (eg fibres, vessels, etc) which differ in structure. The principle components of the wood cell are hygroscopic complexes of cellulose, hemicelluloses and lignin. Decomposition is a complex process regulated by a number of variables; arguably the two most important factors influencing decay rate, via their effect on the decomposer organisms, are resource quality and the nature of the prevailing climatic environment. The major agents of wood decomposition in temperate broad-leaved systems are fungi (Boddy 1984 & 1994).

Specialist wood-decay fungi are able to break down the lignin, cellulose and other complex carbohydrates. Most of these fungi are able to break down both cellulose and lignin, either simultaneously or selectively, and the initial result is softened woody tissues – generally referred to as white-rot. In the case of certain very specialist fungi, however, only cellulose is degraded and the lignin left behind, and the resulting hard dry degraded wood is referred to as either red-rot (entomology) or brown-rot (arboriculture and forestry). Red-rot is particularly typical of tree species which have a durable heartwood, although both red-rot and white-rot may occur in the same individual tree or a wide variety of tree species. Thus oak most typically has red-rot fungi associated (including *Laetiporus sulphureus* and *Fistulina hepatica*) but may also be decayed by white-rot fungi (such as the oak specialist *Inonotus dryadeus* or the generalist *Ganoderma australe*). In contrast ripewood tree species such as beech and ash most typically are decayed by white-rot fungi, but may also be colonised by red-rot fungi. These bracket fungi all typically operate internally within the dead heartwood tissues, and colonise live host trees, although continue to decay the wood after the tree has died. They are especially important species ecologically as they create wood-decay within the living host trees and provide and maintain essential habitat for specialist invertebrates and other organisms.

A different range of fungi are involved in the decay of branch wood and are of special interest as many are endophytic, occurring within the living branches and able to begin activity as soon as the host branch dies. Shaded-out aerial lateral branches of oak are typically decayed by specialist fungi such as *Peniophora quercina* and *Vuilleminia comedans* which exploit the tree-controlled impoverished wood. Other species exploit sudden death of oak branches such as *Bulgaria inquinans*, decaying the richer woody material.

Further wood-decay fungi specialise on already dead timber, such as *Daedalea quercina* on exposed and seasoned aerial dead branches of oak (a white-rot), and *Hymenochaete rubiginosa* on seasoned large branches, trunks and stumps within shadier woodland situations (a red-rot). One bracket fungus *Ganoderma applanatum* appears to only decay wood of dead stumps and trunks.

In conclusion, there are a large number of fungi species involved in wood decay, and most specialise on different parts of the tree and different conditions generally. Many are present within the live tissues and are able to exploit dead wood as it forms, while others occur externally and colonise later. Once dead wood is in contact with the soil it is exposed to a very wide range of these latter species.

More detail is provided by Rayner & Boddy (1988), Boddy (1994) and Stokland et al (2012).

2.3 Specialist saproxylic invertebrates of veteran trees

Decaying wood habitats in veteran trees are known to support an exceptionally diverse invertebrate fauna. Alexander (2002a) has shown that in Britain alone, there are at least 700 native species of beetle (Coleoptera) and 730 species of two-winged fly (Diptera) which appear to be dependent on decaying wood at some stage in their life cycles - this represents about 17% of the 4072 Coleoptera in the current British checklist (Duff 2012) and about 11% of the 6668 Diptera (Chandler 1998). There are also smaller numbers of other groups, especially wasps (246 species), moths (44 species), thrips (21 species) and bugs (14 species). These all have very specific requirements, in terms of stage of decay, position of decay in tree, volume of available decay, humidity, temperature regimes, etc, and these often link very closely with the process of fungal decay as outlined above. Many species are only found in sites known to have had continuity of sufficient habitat availability at site level over many centuries, and these are referred to as old growth species (Alexander 2004); there is however a continuous spectrum of species relationships with such continuity, from the very restricted old growth species through to the widespread and common, highly mobile species.

Undecayed wood and freshly dead wood tends to be the focus for invertebrates closely tied to particular tree species or genus, and are dominated by beetles. The distinctive species-specific secondary plant compounds are thought to be main reason for this, with certain insect species having evolved alongside the trees concerned and adapted to their specific features. As fungal decay of wood proceeds, so these distinctive chemicals are broken down and lost, and it tends to be the type (red or white-rot) or species of fungus causing the decay that determines which invertebrate area able to exploit the resulting conditions. The fauna of red-rot is very distinctive in composition in comparison to species inhabiting white-rot. Again, as decay proceeds, this distinction begins to break down too, and the final wood mould stage is inhabited by more or less the same range of species irrespective of the red or white route of decay; this late stage decay is by its very nature the rarest and most threatened habitat for saproxylic invertebrates and - not surprisingly - supports many of the rarest species. Late stage heartwood decay in large old trees has the greatest requirement for time and lack of disturbance in which to develop, and is therefore the most susceptible to loss.

The concept of ‘ecosystem engineers’ has developed in recent years, with certain beetle species causing significant change to the conditions available in dead and decaying wood to the extent that it is enhanced for other species. The concept has been developed for Capricorn beetle *Cerambyx cerdo* which creates extensive gallery systems beneath dead bark and in the dead sapwood below (Buse, 2008) and – more relevant to the present study – for chafer beetles living inside tree hollows (Micó et al 2015).

The Invertebrate Species and habitats Information System (ISIS) developed by English Nature and Natural England attempts to categorise the more specialist invertebrate fauna into three distinct categories:

- Heartwood decay
- Bark and sapwood decay
- Fungal fruiting bodies associates

This enables separate analysis of species able to exploit the different categories. Bark and sapwood decay species are associated with the outer layers of the tree and so may be associated with young trees as well as older trees. However the heartwood decay beetle fauna is largely confined to veteran and ancient trees, and requires much more time for suitable habitats to develop. This makes them especially vulnerable to changing land-use patterns – an oak tree, for example, may be 150-200 years old before heartwood decay starts and optimal conditions may only be achieved after 500 years. It is no coincidence that the *IUCN European Red List of Saproxylic Beetles* (Nieto & Alexander 2010) is dominated by the latter species. Heartwood decay Diptera are more readily accommodated in younger trees as they tend to require smaller pockets of suitable decay, of the sort that develops behind scars formed on the tree trunk where branches have broken away or have been cut off by people.

2.4 Mobility of saproxylic invertebrates and ecological continuity

The relatively low mobility of most saproxylic invertebrates is a widely accepted hypothesis among invertebrate conservationists (eg Warren & Key 1991, Bratton & Andrews 1991, Vandekerkhove et al 2011) but this hypothesis has been subject to very little scientific testing. The hypothesis is primarily based on the very consistent association between rich saproxylic assemblages, on the one hand, and historic woodland and wood-pasture sites, on the other (Harding 1977, Stubbs 1982, Garland 1983, Harding & Rose 1986, Alexander 1996). The ecological explanation has been that these species evolved under continuous open forest conditions – a natural high density of suitable habitat, i.e. sufficient density of hollow trees - and there was not therefore selective pressure for relatively high mobility.

This needs to be tempered with known variations in mobility across the broad assemblage of 'saproxylics'. It is known, for instance, that certain species that are linked with highly ephemeral habitats such as dying or freshly dead woody material have a relatively high dispersal capacity, eg many bark beetles (Scolytidae) and certain longhorns (Cerambycidae) and jewel beetles (*Agrilus* species of Buprestidae). At the other extreme are those species which inhabit stable and long-lived microhabitats such as accumulations of wood mould in large tree cavities, where low dispersal rates are characteristic (Nilsson & Baranowski 1997, Jonsell et al 1999, Köhler 2000, Ranius & Hedin 2001, Vandekerkhove et al 2011). Brunet & Isacsson (2009) found that common species were not affected by isolation from old-growth forest, but for rare and red-listed species there was a significant effect after a few hundred meters, and some species appeared unable to cross a section of 2km of unfavourable habitat. In a study on saproxylic beetles on beech trees by Weiss & Köhler (2005) the level of isolation of the tree also proved to be a significant factor in the colonisation rate of suitable trees. Jonsell et al (1999) concluded that the fungi-inhabiting species they studied could colonise suitable substrate within 1km of their point of origin, but noted a reduced colonisation over a distance of only 150 m. Irmler et al (2010) found an asymptotic decrease of species richness of saproxylic beetles with distances of more than 80m from source populations. For some species, dispersal over distances of as little as 200m is even unlikely (Speight 1989, Nilsson & Baranowski 1997). Moreover some of these non-mobile species are very selective in their habitat. They are dependent on sites with high spatio-temporal continuity of habitat and are therefore often used as indicator species for habitat continuity (Alexander 2004, Brustel 2004a, Jansson et al 2009a, Müller et al 2005, Sebek et al 2012a).

The various listings of species thought to be characteristic of long-established and least disturbed habitats include specialists of open sunny conditions as well as shade-loving species; despite the various terminologies – forest, mature timber, pasture-woodland, primary woodland, etc - no particular tree density or age structure is implicit. Continuity of physical structure is however the key to understanding the habitat requirements of these invertebrates. This is quite different to the approach taken with vascular plant indicator species where continuity of tree cover/shade and soil structure are the key factors (Peterken 1974). Garland (1983) stressed the weakness of the indicator approach and the need to restrain speculation. However, Sebek et al (2012a) have analysed beetle data from 67 biodiversity surveys and ecological studies carried out from 1999 to 2010 with standardised trapping methods in France and Belgium, and concluded that the lists of continuity species provide the best fit to site quality for monitoring networks – the implication being that identification of these species alone from trap samples is an acceptable cost-cutting surrogate for monitoring purposes.

Franc et al (2007) evaluated the potential influence of 45 factors (multiple regression, principal component analysis (PCA)) on saproxylic oak beetles in 21 smaller stands of broad-leaved trees of conservation importance in Sweden (woodland key habitats). They found that two landscape variables were the main (and strong) predictors of variation in local species richness of oak beetles:

- Area of oak-dominated key habitats within 1km of sites – as opposed to larger distances, and
- Regional amount of dead oak wood.

The result was similar for red-listed beetles associated with oak. Canopy closure had a significant negative impact on species composition. It is very interesting that it was the regional amount of dead wood that was important, not the local amount. A key point is that the oak deadwood beetle assemblages seem to be operating at a 1 km or lower scale. For oak species, the volume of other broad-leaved tree species had a negative impact on species-richness – increasing tree density was a negative factor.

Jansson et al (2009b) comment that observed dispersal distances of saproxylic beetles of conservation interest are within 100-2000 m in the Swedish oak areas. Their study using artificial wood mould boxes demonstrated that the beetle assemblages in the boxes differed with distance from the core area with hollow oaks. This is partly because the probability of colonisation decreases with distance from dispersal sources. This is consistent with a previously observed limited dispersal propensity of invertebrates inhabiting tree hollows (Ranius 2000), which may reflect the relatively stable and long-lived habitat (Nilsson & Baranowski 1997). In contrast, other obligate saproxylic assemblage species did not exhibit the decreasing pattern with distance from the hollow oak sites. The study sites were grazed wood pastures with a surrounding landscape dominated by mixed forests, so those particular species were probably able to use dead wood of other tree species within the immediate area.

3 Trees in the English landscape

Trees occur in a wide variety of situations in the English landscape and it is important to appreciate that these situations may be dynamic and change over time in response to changing human land-use. Rackham (2004) has pointed out that one of the chief values of historic parklands is that - through their creation - samples of the countryside were removed from the normal pressures of agriculture, and features such as trees, vegetation, and antiquities were preserved from earlier landscapes.

Ancient woodlands – in the now accepted sense of dense stands of trees within defined enclosures - attracted considerable interest among British ecologists during the latter half of the 20th century (e.g. Peterken 1981) and have become important through the planning process in England in protecting areas, labelled as ancient woodland, from development. The broader sense of ancient woodland includes types of ancient wooded countryside such as wood-pasture and parkland, which have until more recently been largely overlooked – despite extensive literature review and field survey during the late 1970s, the abundant evidence for their exceptional conservation values (Harding & Rose 1986) it wasn't until the Biodiversity Action Planning process that the value of this special ecosystem began to be more fully appreciated.

In medieval times woodlands were enclosed by people to exclude large herbivores in order to protect re-growth following cutting from browsing (Rackham 2003). As such they are artificial structures as much as wood-pastures, as much a product of human land use, of equal cultural value. Enclosed woods were regularly cropped for timber products, preventing the development of diverse wood-decay invertebrate assemblages (Bratton & Andrews 1991).

Definitions of woodland are hard to find but the Forestry Commission has need to define woodland in order to provide criteria for grant support of the timber industry. The UKFS definition uses the term 'forest' to describe land predominantly covered in trees (defined as land under stand so trees with a canopy cover of at least 20%), whether in large tracts (generally called forests) or smaller areas known by a variety of terms (including woods, copses, spinneys or shelterbelts).

Wood-pastures are areas which combine trees and large herbivores. The term does not imply human land-use but it is often interpreted so. It is logical to use the term to describe landscapes with trees in the post-glacial period, as the vegetation of Britain re-established following warming climate – wild large herbivores were on the scene before trees arrived and during tree establishment. No particular density of trees is implied, which makes describing the various manifestations of the habitat extremely difficult.

3.1 Biogeographical patterns

Many of the British saproxylic invertebrates have central European ranges, and this has been used as an explanation of why so many seem to favour a continental climate. The British climate can therefore be limiting and so - with increasing distance from central Europe - the species are increasingly favoured by less precipitation, more sunshine and higher temperature (Palm 1959). Franc et al (2007) noted a trend for increasing species-richness in Swedish oak fauna from west to east, which is consistent with this idea. In contrast, a study of fungus gnats (Sciaroidea) found the increase in species-richness towards north-west (Økland et al 2005) – precipitation had a strong positive influence on fungus gnats. This suggests that results for saproxylic beetles cannot be generalized to other saproxylic insects, at least not without further studies. Although it is widely assumed among Diptera specialists that closed canopy conditions favour saproxylic Diptera (see Chandler 2010, for example), the fungus gnats in a large area of ancient woodland in central Ireland were shown to be most species-rich in the opened-up recent coppice coups (Alexander & Chandler 2011).

3.2 Changing land-use patterns

Vandekerkhove et al (2011) comment that old-growth elements in the north Belgian (Flanders) landscape – such as veteran trees and coarse woody debris – have disappeared through intensive management and exploitation of the land. They also point out that these features have progressively redeveloped in parks, lanes and forests in recent decades and have now reached their highest level over the last 500-1000 years. The ability of species to recolonise the newly available habitat is strongly determined by limitations in their dispersal and establishment. Their investigations have shown that 'hotspots' of secondary old growth – even isolated small patches – may have more potential for specialised biodiversity than expected, and may provide important new strongholds for recovery and recolonisation of an important share of old-growth related species. Signs of recovery of old-growth type saproxylic beetle species are fragmentary but indicate a long lag phase.

Studies of the darkling beetle *Bolitophagus reticulatus* on the Continent have shown that it is normally a short distance disperser, moving only up to 100 m (Sverdrup-Thygeson & Midtgaard 1998, Rukke & Midtgaard 1998), but with the capacity for incidental long distance dispersal (Jonsell et al 2003).

3.3 Dynamics - the problem of interpreting static data

The tree population at a particular date – either from historic mapping, aerial photography or modern GPS records - primarily reflects what is there at that time; it provides no information on the dynamic of the treescape. While a particular veteran tree may currently be relatively isolated, with the nearest trees of a similar age and condition some distance away, there may well have been other such trees closer during its long lifespan. Their former presence may be suspected from, for example, the old root-pit left from wind-blown trees, but such features rapidly disappear over time. Thus the present fauna associated with a particular tree may be more influenced by the past treescape than the present one. Former close neighbouring trees may have provided stepping stones/habitat islands making it more likely that in past landscape beetle species could successfully cross the unfavourable habitat between trees. This has been shown to be true for lichens, for example – that the current high density of species can be best explained by the density of oak trees 100 - 200 years ago (Paltto et al 2006 & 2010).

The dynamics of the tree population can be studied to some extent on the better documented sites, combining early six inch scale OS mapping- which often mapped each significant tree accurately - with any historic aerial photographs which may exist, early site photographs generally, any other historic mapping, and perhaps even the memory of local people who know the site well. Multiple sites would need to be studied to try to overcome the inherent limitations of such a study - if the same patterns were found in different places it might suggest that there are associations with current spatial configuration of trees. Historical maps might also be used to provide additional variables to include in the analysis.

3.4 Ancient Tree Inventory

The Ancient Tree Inventory is a live database of ancient and special trees. More than 110 000 trees have been recorded by volunteers and partners. This is a major project organised by the Woodland Trust in partnership with the Ancient Tree Forum and the Tree Register of Britain and Ireland (TROBI). It was initially funded by the Heritage Lottery Fund. The first phase of data gathering has been completed, analysis has been carried out, and target areas for conservation development have been identified. A list of Priority Resilient Ancient Treescapes (PRATs) has been drawn up and events are being organised to celebrate the local treescape and to stimulate wider interest and further recording, as well as ancillary events (J. Butler, pers. comm.). PRATs are defined as landscapes which contain some of the largest concentrations of documented notable trees, and have been identified in order to develop projects with stakeholders to establish how the data may be used to inspire the communities concerned to improve the resilience of those priority areas, eg by protecting existing trees and encouraging establishment of new generations of trees. A secondary list of possible priority areas is also available. Some of these areas naturally coincide with areas known to be of national significance for their saproxylic invertebrate faunas, and - as in 3.4 - may identify areas of historic forests, some of which remain (eg New Forest, Forest of Dean, Savernake).

A key drawback of this record is that the landscape has not necessarily been systematically explored and so there is no record of where areas have been searched and no notable trees found.

3.5 Wood Pasture & Parkland Inventory

Aerial photo based site identification has been organised by Natural England and is now available as a layer on the MAGIC website. There are also a wide range of county or other regional inventories which have been produced during the past 20 years; a full listing is outside of the scope of the present report.

4 Quantitative sampling techniques for saproxylic invertebrates

A key aim of the project is to generate objective and comparative data that is statistically valid. While the standard approach for Common Standards Monitoring of saproxylic invertebrate assemblages is hand searching supplemented by the use of nets and possibly supported by trapping (Drake et al 2007), the requirements of the present study strongly suggest that trapping alone would be the best option. Standardised trapping eliminates the variable of the particular skills and expertise of the surveyor, and therefore provides an unbiased sampling approach that is repeatable across and between sites. However, it is well-known that an experienced surveyor is more effective in terms of detecting a wider range of species (eg Hammond & Harding 1981). A key issue in trapping is whether or not the relationships between the trap and the decaying wood habitat can be standardised and repeatable – each tree is a unique organism and the representation of decaying wood in each tree is similarly unique.

Much has been written about trapping methodologies (eg Muirhead-Thomson 1991, Southwood 1978) but the present brief review focuses primarily on studies of saproxylic insects.

A wide range of trapping techniques has been developed to target saproxylic invertebrates. They each depend on the activity of the invertebrates themselves to bring the targets into the collecting devices.

4.1 Flight interception trapping

Although interception trapping does not provide accurate information about the micro-habitat, it is many times more efficient compared to extraction methods (Bouget et al 2008). Flight trapping has many advantages over other trapping systems in that the catch is taken incidentally during normal flight activity – the traps do not act as attractants. The catch sizes might therefore be considered independent of the trap itself and might therefore be used quantitatively. However, the situation of the trap in relation to the natural attractions of the various tree features may impose complications. By intercepting flying insects it naturally reduces the activity-abundance of the local insect populations and thereby may influence local pheromone levels, for example. A trap positioned directly across the entrance to a rot-filled cavity will catch a different proportion of the flying insects to one placed to one side.

The window trap is a highly effective trap with many advantages (Bouget et al 2008): it is easily standardised and replicable, simple to construct, not labour intensive, and large numbers of small cryptic flying taxa can be caught. It does also have some shortcomings: high cost per unit, difficulty of installation and sample retrieval, susceptibility to high winds, tourist insects possible and a less substrate-specific set of sampled species, only flying-active species, risk of flooding (dealt with through the use of roofs, drainage holes or frequent servicing), visibility to passers-by, subject to vandalism.

The increase in interest in trapping saproxylic beetles has led to the development of a wide range of devices for intercepting their flight and thereby capturing them. Terminology began rather loosely, with expressions like ‘window traps’ meaning different things to different researchers and some published papers have been imprecise or vague about the construction of the traps utilised. Bouget et al (2008) have helped to clarify terminology.

4.1.1 Malaise traps

The Malaise trap (Malaise 1937) has been used by entomologists for many decades and is popular for taking general samples within woodland, etc, but is unwieldy to operate and not readily targetable for small-scale habitats such as decaying wood (see Fig.1). They also have a reputation for killing large volumes of flying insects which then become a logistical problem to sort and identify. The position of Malaise traps also has a major influence on catch size and composition.


Fig.1. Malaise trap on Thoresby Estate, Sherwood Forest

4.1.2 Single-plane window flight traps and trunk-window traps

Window flight traps appear to have first been devised by Chapman & Kinghorn (1955) in Canada. They consist of a vertical barrier to insect flight that is considered to be invisible to the insect. On colliding with the barrier, most beetles drop down and fall into a collection container with liquid preservatives. Window traps are much more selective than other traps, and can be used to target saproxylic insects in particular by careful choice of situation in relation to decaying wood habitats.

In recent years, simple window traps have been extensively used by researchers on Hermit Beetle *Osmoderma eremita* in Sweden (Ranius & Jansson 2000 & 2002, Jansson & Antonsson 2003, Jansson & Lundberg 2000): a transparent plastic sheet is hung from a horizontally growing lateral branch close to the trunk of a standing tree, and a tray is attached along the base, to receive falling intercepted beetles. The gutter is filled with preservative. Plastic sheets of various sizes have been used, eg 30 x 40cm (Ranius & Jansson 2000), 30 x 50cm (Jansson & Lundberg 2000, Jansson et al 2009a), and 30 x 60cm (Jansson & Antonsson 2003). Ranius & Jansson (2002) studied the effectiveness of window traps in comparison to i) pitfall trapping in the wood mould within hollow trunks and ii) extracting and sieving the wood mould, and sorting through it manually. They found that each method partially targets different assemblages of species. Window trapping caught all groups of saproxylic beetles, whereas pitfall trapping and wood mould sampling mainly caught beetles associated with tree hollows which are rarely collected by window traps. Wood mould sampling is, they say, the cheapest method to use. A comparison between sampling methods showed that the numbers of saproxylic beetle species collected per tree with each method were positively correlated. Thus, if species richness is to be compared between individual trees, similar results are to be expected independent of the sampling method chosen. The authors point out that certain species found by pitfall-trapping in wood mould inside hollow trunks - or by extracting and sorting through wood mould - are rarely taken by flight trapping. The examples they list include two important British species: *Ampedus cardinalis* and *Elater ferrugineus*.

Ranius & Jansson (2002) also investigated the impact of microclimate by dividing their study oaks into three groups with different vertical coverage of the canopy in the surroundings: free-standing; half open; shaded. A tendency was observed for more species and more individuals to be captured in free-standing oaks.

Similar window traps may be used as free-standing traps, the plastic vane attached to a pair of wooden poles (e.g. Burns et al 2014). Commercially available window traps use black terylene netting rather than a transparent plastic pane, based on a design by Owen (1992a). These have been used to some extent in the UK by A.P. Foster (National Trust Biological Survey Team) in order to increase species-recording effort and thereby to enhance site quality assessment. Experience has been that they act more like Malaise traps as they are large and so less useful for targeting for, eg, saproxylics (Andy Foster, pers. comm.).

A trunk-window trap is a transparent plastic pane attached vertically against a standing tree trunk or on a fallen log, with a plastic vessel beneath to catch falling insects (Franc et al 2007, Burns et al 2014). The vertical pane aims to be invisible to flying insects which crash into it and fall into the preservative fluid in the vessel below. The vessels may have small holes, 2cm below their upper edge, for drainage of excessive rainwater. A simple version of this type of trap was developed for use in a multi-national European study of the response of saproxylic beetles to various types of veteranisation – eg cutting to provide surrogate exposed sap habitat - carried out on mature oak trees (see Fig. 2).

Bouget et al (2008) compared freely-hanging single vane traps with cross vane traps and found that the former caught the higher number of individuals and species. Nevertheless, given time/cost constraints, they recommended cross-vane traps should be used in preference. They also compared black and transparent cross-vane traps and found that they yielded similar saproxylic samples in terms of abundance, richness and overall composition.

Fig.2. Single-plane trunk-window trap as used in the veteranisation study

4.1.2.1 Costing

Costings for single-plane window flight traps are available. Burns et al (2014) quote ‘less than £1 per trap’ although this presumably refers to materials rather than labour costs. Vane traps used for a veteranisation study across a number of European countries had materials costing £8 each for about 100 traps (V. Bengtsson, pers. obs.).

4.1.2.2 Longevity/durability

Experience suggests that most vane traps are very durable, being built from durable plastics, and may be re-used for many years without replacement.

4.1.3 Transparent cross-vane window flight-interception traps

Multi-directional cross-vanes traps with interlocking panels were first used by Hines & Heikkenen (1977). These “vane traps” have become established as the main standardised sampling tool for saproxylic beetles across Europe. While precise designs vary between researchers, the standard features are two transparent and colourless Perspex sheets slotted together to form an X in cross-section, the assembly positioned immediately above a funnel which directs falling intercepted insects down into a jar or pot containing a preservative medium. Bouget et al (2008) carried out an extensive comparison between single-plane window traps and cross-vane traps, and recommended that the best trap to be standardised should be a low (2m high) transparent cross-vanes window-flight trap, and established the “Polytrap” as a commercially available standard which has subsequently been modified to make it less visible, as well as easier to post, carry and set up (Brustel 2012). However, researchers have tended to favour a smaller trap design for ease of transportation and application.

Brustel (2004b) identified the key features of the “Polytrap” as:

- Efficient; improves species-richness of saproxylic beetles captured

- Selective; favours species-richness over abundance, and captures Coleoptera in particular
- Easy to manage by non-entomologists
- Solid, light, easy to transport, easy to assemble
- Already made and available commercially.

However, he used pack-horses to transport the traps to his study sites in the Pyrenees.

Ranius & Jansson (2002) compared vane traps, pitfall traps placed inside the tree in the wood mould, and manual wood sampling, and concluded that these techniques partially targeted different assemblages of beetles. Wikars et al (2005) found that the relationship between the type of dead wood and species richness was statistically significant when they used bark sieving and emergence traps, but not when they used window traps; they attributed this result to the fact that window traps are less discriminating in the source of the catches, with tourists as well as local residents.

Quinto et al (2013) compared vane traps with free-standing baited tube traps and emergence traps (see 4.4) covering tree hollows. Baited tube traps are an active method (see 4.2) traditionally used to evaluate and control forestry pests, and rely on chemicals such as ethanol or acetates to attract target insects. They found the vane traps and emergence traps similarly effective in assessing species-richness and provided an accurate profile of both the flying active and hollow-linked saproxylic beetle assemblages. The two were complementary however, combining to detect a greater range of species than found bu each method alone. The baited traps were the least effective as they sampled only a biased portion of the beetle assemblage.

Schlaghamerský (2005) reported on studies where vane traps were placed at 1m and at 12 m and 25 m up on monitoring towers. He was able to show that the trunk layer (12 m) was richer in saproxylic species than the canopy layer (25 m). He also commented that vane traps do not capture all groups with the same efficiency (which is true for other methods as well); for example, soldier beetles (Cantharidae) seem under-represented in the catch, and he suggests that this probably applies to all beetle families of slow flight or with small, light bodies as their representatives tend to alight on the plastic panels and fly off again instead of hitting them hard and falling into the collection container. Flight interception traps with an additional upper funnel and collection container may be more effective because species belonging to these groups often avoid obstacles by flying upwards – Bußler et al (2004) have used such a modification.

Sverdrup-Thygeson (2009) used ten traps arranged two per each of five hollow oak trees, with one in the crown the other in front of the opening to a trunk cavity. This array was repeated across 11 sites, some in oak forest (not precisely defined), others in parkland or agricultural landscapes. Only sites with at least 5 oaks close to each other (<250 m) were included and the minimum diameter was set at 30 cm at breast height. Sampling covered a three month period (mid May to mid August, emptied monthly) in a single year. Trap placement seems to strongly influence the species composition of the catch: more hollow associated species were found in the cavity traps than in the crown traps, although this was not statistically significant due to the large number of singletons. Exact placement of the window trap matters. While the mean number of red-listed species was similar in parks and forest, the species composition differed. The number of oak trees and amount of dead wood were important factors explaining this difference, together with differences in tree quality. There seems to be heterogeneity in the species composition both between traps at the same tree, between trees in the same site and between sites in hollow trees.

Sverdrup-Thygeson & Birkemoe (2009) investigated how placement of vane traps affects the beetle species assemblage, abundance of habitat specialists, saproxylic species and vagrant species. They also tested the correlation between beetle trapping and beetle exit holes in wood. They showed that traps located on tree trunks resulted in a different species assemblage than traps hanging freely. Traps mounted on aspen trunks caught more aspen associated beetles and less vagrant species than free-hanging traps. The differences were larger when the trees were dead than alive. There was a significant positive correlation between presence of individuals in the trunk traps and presence of exit holes for three aspen associated species. These trapping results indicated successful reproduction, showing that aspen associated beetles are not only attracted to but also utilise the aspen trees for breeding.

Ramírez-Hernández et al (2014) have shown that the composition of the fauna in vane traps on particular individual hollow trees changes across the season. Their dehesa study site had peaks in species-richness between May and June and again between September and October; the pattern was not reflected in the abundance of the catch only the species-richness.

Meriguet (2007) and Meriguet et al (2009) have developed an ultra light vane-style flight interception trap. The innovation lies in the replacement of the synthetic glass by a 35 µm polypropylene film stretched over a frame, which can be removed in one piece without any tools. The collecting funnel is very light and can be easily folded. The whole device weighs less than 700 g and is easily transportable.

Bouget et al (2008) compared single vane traps with cross vane traps and found that the former caught the higher number of individuals and species. Nevertheless, given time/cost constraints, they recommended cross-vane traps should be used in preference. They also compared black and transparent cross-vane traps and found that they yielded similar saproxylic samples in terms of abundance, richness and overall composition. Their results also confirmed the vertical differentiation of saproxylic beetle assemblages – low cross-vane traps yield more species-rich and individual-rich samples than canopy traps. Apart from Melyridae, no abundant species showed a strong association with canopy traps.

Vane trap studies have been progressing within England in recent years, using a design from Sweden, although very little has been published about the results, eg:

- Drane and Warrington (2010) report on the results of vane trap use in tree crowns but do not provide comparable data for using the traps at other heights.
- A major study has been conducted in SW Essex as part of a EU European Regional Development Fund project named Multi-For (D. Fisher & P.M. Hammond in 2010) but, again, the results have not been published – general presentations and a newsletter account are available on Essex County Council’s website. A total of 19 sites had 5 vane traps each; the study included five previously studied ancient wood pasture sites and so was able to compare known important sites with previously unstudied areas.

Fig.3. Cross-vane window trap in position in Hatfield Forest (copyright Stuart Warrington)

Where sufficient traps have been applied and where the data on tree location and species trapped have been maintained, there is the potential for trial analyses of the impact on isolation on fauna. This is the case at Richmond Park (N.J. Reeve, pers. comm.) and may also be so at Hatfield Forest and Epping Forest (see Wilde 2005b). Analysis of the data could focus either on the assemblage level using Site Quality Index, or on the species level using indicator species.

The basic vane trap tends to be relatively bulky - those used by Webb & Perry (2014) measure approximately 80 cm in height and 35 cm depth.

A different style of vane trap has been used in Chigwell Row Wood Local Nature Reserve, on the edge of Hainault Forest, Essex (Schulten et al 2005). This trap consists of a domestic plastic washing-up bowl into which are set four Perspex vanes at right angles. The trap is protected by a piece of wood above the vanes. It is suspended by a 16 m long rope, which is attached to the trap by four cords tied to a knot above. Additional ropes attached to the bowl can be used to steady the trap in windy conditions. In use the rope is thrown over a branch, the washing-up bowl is filled with preservative solution and the device then raised into the tree. The trap is simple and sturdy in construction.

4.1.3.1 Costing

Sixty traps were constructed for Natural England in 2013, using 3 mm poly-carbonate at 450 mm vane height and with a spare set of collection bottles, at a cost of £2000. This covered the sourcing of the materials as well as construction and delivery (S. Perry, pers. comm.). This is equivalent to a cost £33 per trap, including materials and labour. The traps used by Schulten et al (2005) cost a very similar amount, the quote obtained was for about £30 each (Curt Lamberth, pers. comm.)

4.1.3.2 Longevity/durability

Experience suggests that most vane traps are very durable, being built from durable plastics, and may be re-used for many years without replacement.

4.1.4 Carrel four-bottle traps

The four bottle trap is based on a trap designed by Carrel (2002) for studying field and shrub layer invertebrates, and modified by Lush et al (2007) for use on veteran trees.

- Four 2 litre capacity plastic drinks bottles have large windows cut into the side, 15 cm high and removing half the circumference of the bottle;
- The bases are screwed into a wooden base, the four windows facing outwards, providing a 360 degree capture potential – the wooded base provides the framework but also acts as a roof to some extent, reducing both desiccation and flooding from rainwater;
- The wooden base is suspended in an appropriate position on a tree using baler twine, with the bottles hanging upside down beneath; baler twine can also be used as guy ropes where necessary to prevent excessive lateral movement from wind;
- The lower parts of the upside-down bottles are filled with a preservative solution (commercial antifreeze 50/50 with tap-water, plus a little washing up liquid to reduce surface tension);
- The solution and catch can then be drained through the neck of the bottle by removing the plastic cap and draining the contents into a collecting pot for later sorting under a microscope.

Positioning of the traps needs to take into account the potential for interference from livestock and people. Experience has shown that such traps may be left in situ for one to three months without attention. Sheep-grazed pastures are an exception to this as commercial sheep herds tend to attract large numbers of Diptera and the traps can become clogged with undesirable dung flies.

The small size of this trap – 40 cm high by 20 cm depth - makes it very flexible for targeting particular situations such as rot-holes and the interior of hollow tree trunks. It has been demonstrated to be very effective in catching saproxylic Diptera in particular (Alexander 2010a & 2012, Alexander & Chandler 2010 & 2011, Alexander & Perry 2013) but also the smaller Coleoptera (Alexander 2009a & b, 2010b & 2013) which can otherwise be difficult to detect without resorting to time-consuming extraction techniques such as Berlese funnels or by rearing from samples of wood mould. Larger insects such as hoverflies (Syrphidae) and longhorn beetles (Cerambycidae) however appear to be poorly represented in catches, although no studies have been made to test the effectiveness of such traps in direct comparison with traps of other designs.

Fig.4. Four-bottle flight interception trap at Shorne Woods Country Park, Kent

4.1.4.1 Costing

The great attraction of the Carrel four bottle design is that the individual components are relatively inexpensive and readily available. The plastic bottles (containing mineral water) are available at supermarkets at less than £1 each and the wooden bases from DIY stores. The material costs are less than £2 per trap. Construction is relatively easy, taking less than 30 minutes per trap. In real terms therefore each trap costs in the region of £22.

4.1.4.2 Longevity/durability

The plastic bottles can be used and re-used over again for many years without degradation, but the wooden bases are best replaced annually as wetting from rainwater leads to loosening of the fibres and they become increasingly likely to fail.

4.2 Attraction trapping systems

Most trapping tends to be un-baited, in order to gain an independent catch size which reflects the local activity-abundance of the species concerned. However, baiting is often used for more targeted surveys.

4.2.1 Pheromone trapping

It has been known for a very long time that insects use a range of volatile long-chain hydrocarbons to attract mates – with male and/or female pheromones being produced by most species, each varying in chemical structure. These chemical signals are also exploited by specialist predators and almost certainly also by specialist parasitic insects. It follows that once the specific chemicals have been analysed and can be reproduced in commercial quantities they provide a powerful means of detecting the presence/absence of the target species at particular sites and of trapping these species selectively.

Pheromone trapping has been developed by the commercial forestry sector in particular as a means of attracting and controlling flying insects which are regarded as seriously damaging to trees being grown for timber or to the prepared timber. The specific nature of the pheromones makes them ideal for targeting particular species or species groups. While most research has been targeted at commercially important species, the approach is increasingly being explored for conservation purposes. Pheromone lures have been found to be very effective in attracting clearwing moths for recording purposes, and the chemical structure of the pheromones used by Hermit Beetle *Osmoderma eremita* and a key predator Rusty Click Beetle *Elater ferrugineus* have recently been shown to be similarly effective (Svensson et al 2004, Tolasch et al 2007, Zauli et al 2014, Larsson et al 2015). Pheromone traps have been adopted as a means of studying population size and mobility of *Elater ferrugineus* (Larsson & Svensson 2009 & 2011, Musa et al 2013) and field trials have been carried out across England by D. Harvey (unpublished). The main shortcoming at present is the lack of information available on the specific pheromones used by the majority of saproxylic species.

4.2.2 Light trapping

Light traps operated by moth recorders are reported to also attract a range of night-flying saproxylic insects. No list appears to have ever been compiled of the affected species and this data is effectively being lost. The traps are designed to capture night-flying insects in general and so are not targeted at saproxylics. Many saproxylic insects are known to be night-fliers, eg *Stenagostus rhombeus* and *Prionychus ater*, and therefore the adult insects may be found by diurnal surveyors in their daylight refuges as well as in larval habitat. This has the potential to cause confusion in the understanding of their ecology, when recorders merely note the situation without considering the reason behind the presence. There is a clear need for study of this nocturnal flight activity of saproxylic insects. An advantage of flight interception trapping is that the traps operate throughout the day-night cycle and thereby eliminate the bias from qualitative hand-searching approaches.

4.2.3 Water traps & Combi-traps

Water traps are designed to attract flower-visiting insects and so also catch flying saproxylic insects in the process. The traps are normally brightly coloured bowls – typically white or yellow – and are filled with a preservative liquid – see 4.4 below. Flying insects are attracted to the 'super-flower' effect created and sink into the liquid when they alight on the surface expecting a solid petal, etc. Such traps are not however targeted at saproxylics and are not therefore relevant to the current project.

Combi-traps combine a conventional vane trap with a yellow water pan (Moretti & Barbalat, 2004). They have been used with transparent vanes and with black vanes (Barbalat, 2009), when transparent vanes were shown to be the most efficient in terms of catch content.

Fig.5. Combi-trap in Lagern Reserve, Zurich

4.2.4 Other attractants

The commonest attractant or bait used in trapping is alcohol (Sebek et al 2012b) as this preserves as well as attracts. A wide range of other baits have been used (see Southwood 1978, for example) but are outside of the scope of the present project which aims to study natural beetle activity using non-attractive static traps.

4.3 Canopy fogging

Canopy fogging has been developed as a technique applicable to the high canopy of tropical rain forests but has been used to a limited extent in Britain. Hammond and Harding (1981) reported some of the results of canopy fogging at Richmond Park and Burnham Beeches, although full details have not been published. The insects are knocked down by an insecticide fog being directed into the canopy. The results were very comparable to those from flight interception trapping carried out concurrently, but nowhere near as productive as conventional hand searching techniques employed by an experienced fieldworker.

4.4 Emergence or eclector traps

A particularly efficient and well-targeted survey approach which also provides valuable information on the biological requirements, species assemblages and faunal succession is ex-situ emergence trapping (Gibb et al 2006, Kappes and Topp 2004, Wikars et al 2005). Owen (1989a, b, & 1992b) developed a particularly practical emergence trap based on the design of traditional tents – it is well-known that insects entering tents tend to accumulate in the peaks in the roof. The trap is essentially a small netting tent with a plastic floor into which deadwood may be placed. Emerging insects are trapped in a Malaise-style collector at the highest apex of the tent-trap. It can be used close by the source of the dead wood to be extracted or the wood can be transported to another site for extraction. He demonstrated its efficacy using wood samples from Windsor Great Park. A study using Owen traps has also been carried out in Hatfield Forest, Essex, comparing the value of wind-blown wood from four different species of tree (Alexander 1994). The design is however too small for use with heartwood decay in trunks, although it could be scaled up for this purpose of course.

Gouix et al (2009 & 2011) investigated a population of *Limoniscus violaceus* by using white nylon mesh to cover the whole opening of the tree cavity on 111 oak trees across six stands in old coppice woodland in the Grésigne forest, in France. A plastic tube is used to accumulate the catch into a container. White mesh was in preference to black in order to minimise any influence on the shading of the cavity. The plastic collector tube (7 x 3.5 cm) was fastened to the net with sticky tape; a plastic zip tie was then attached to prevent detachment due to humidity. The mesh was stapled to the bark of the tree with 6mm long staples so that the net would stay in place without damaging trees too much. At ground level the bottom of the net was buried in the soil up to a depth of 20 cm. Similar studies have taken place in Spain aimed at assessing the whole assemblage within hollow trees (Quinto et al, 2014).

4.5 Preservatives used in collection vessels

The majority of traps are operated for periods of from a few days to a few months, and so the specimen collecting device is normally filled with a preservative. The most commonly used is a mixture of 50% water, 50% ethylene glycol, with a few drops of detergent to decrease surface tension. Some researchers add a bitter agent to deter vertebrates (Jansson & Antonsson 2003, Franc et al 2007). Gouix et al (2009) used water and salt (100/10) with a little detergent.

Increasingly propylene glycol is being used in place of ethylene glycol, for Health & Safety reasons.

4.6 Numbers of traps and frequency of sampling

Hyvärinen et al (2006) has shown that the number of traps used has a profound effect on the average number of species recorded per study site. Engen et al (2008) analysed the spatial structure of species diversity using the correlation between the log abundances of the species in the communities. They showed that correlations between beetle communities, even in trees close to one another, were not high, and that correlations dropped quite quickly with distance, with a scaling in the order of 200 km. They estimate that one year sampling as per Sverdrup-Thygeson (2009) samples only about half of the total number of species actually present at these sites. The high number of singletons illustrates the fact that chance plays an important part when it comes to which species are caught in a single year's sampling event. Therefore, extensive sampling – especially in terms of repeated sampling over years - is necessary if the objective is to measure the species-richness in hollow oaks with high precision, and to be able to predict trends in population sizes of the red-listed beetles. This is in line with other studies on the correlation between red-listed and/or rare beetles and sample size (Martikainen & Kouki 2003, Martikainen & Kaila 2004). Another study (B. Dodelin, pers. comm.) has found that species-richness continues to rise at more or less the same rate in response to trapping effort with a minimum of ten vane traps over a period of 20 years.

The analysis of French and Belgian survey datasets (Sebek et al 2012a) provides a useful overview of the intensity of trapping that has been carried out in recent decades by a wide variety of researchers: they analysed 67 datasets comprising 1521 transparent cross-vane flight-interception traps, ie an average of 23 traps per site studied.

4.7 Pitfall trapping in wood mould in hollow trees

A number of studies have successfully used a pitfall-trapping approach to detect the presence of saproxylic beetles – a jar or cup is dug into the accumulated debris within a trunk cavity and the opening set flush at the surface level so that beetles walking across the surface fall into the trap. The bottom of the receptacle may include a killing/preservative fluid, a bait, or nothing. A key study is that by Ranius & Jansson (2002) who compared the results with those from window trapping and hand-searching through the wood mould. They found that useful information was obtained from each methodology, but that each partially targeted different assemblages of species. Window trapping collected the highest number of species. Pitfall trapping collected beetles associated with tree hollows which are rarely collected by window traps. The approach is more labour-intensive than flight-trapping and more difficult to standardise.

4.8 Synthetic logs/ wood mould boxes

An early study using synthetic logs – boxes of compressed oak sawdust – was carried out in Wytham Woods by Fager (1955 & 1968). The approach was taken in order to control initial differences between types of logs and to provide exact replicates, in order to study the effects of log characteristics, season and locality separately and also to obtain some idea of the interaction between these environmental factors. Natural logs were also used for comparison. The synthetic logs were placed on the ground beneath the oaks which had provided the natural logs and were left in situ over the summer (May to October) before the contents were extracted and analysed.

The synthetic logs were boxes approximately 5 cm square by 30 cm long made of 6mm thick, rough-sawn, seasoned oak. Seven holes (8 mm diameter) along each of the four sides and three holes in each end-piece provided access. They were filled with oak sawdust that had been washed with boiling water and dried thoroughly. Four types of log were prepared:

1. Packed solidly with oak sawdust
2. Packed with oak sawdust after insertion of lengths of cane (13 mm diameter) in two opposite corners; withdrawal of the cane after packing left two longitudinal channels, or 'bore-holes'
3. Packed solidly with oak sawdust that had been enriched by the addition of 10% by weight of a 3/5 (w/w) mixture of bone flour and maize meal – a medium developed for stimulating the growth of wood-decaying fungi on sawdust [examination of samples left in the field indicated that this enrichment increased the amount of fungus growth]
4. Packed as 2, with sawdust enriched as 3.

A small amount (<0.5%) of finely ground decaying oak wood (from a common stock) was mixed with the sawdust and the whole was moistened with 1 ½ times its weight of water before packing.

The two types of logs – synthetic v natural - did not differ significantly in regard to the statistic, individuals per log, but the synthetic logs had significantly fewer species/log than the natural logs. The synthetic logs proved to be very attractive to mites and springtails but few Coleoptera or Diptera were found. The natural logs were favoured by subcortical species such as larvae of the craneflies (Limoniidae) *Epiphragma ocellaris* and *Austrolimnophila ochracea*, and the click beetle (Elateridae) *Denticollis linearis*. The synthetic logs however proved more attractive to the mould-feeding feather-winged beetles (Ptiliidae) *Ptinella limbata* (British Red Data Book) and *Pteryx suturalis*.

This early study was extended by Larkin & Elbourn (1964) who studied logs at heights of 1 to 6 m above the ground in various locations on oak trees. While they comment that their results were far from being a complete representation of the fauna of dead oak wood in trees, they did find a surprisingly varied assemblage. Although the samples contained on the average only ¼ of the numbers of animal recorded by Fager (1955), there were more than ½ the number of species. Very little seasonal change was detected, suggesting that the boxes support a relatively stable association, which colonised the boxes soon after they were set up and changed little over the year. The synthetic logs clearly simulate an advanced stage of decomposition – the material is highly fragmented at the start of the study, and is therefore closest structurally to late-stage heartwood decay (see section 2.2 above). High and low positions on the tree were significantly different in composition, although the detail was not presented. The authors comment that the dead oak on trees is probably more significant to the rare forms than to the abundant ones, the latter being even more abundant in the dead logs on the ground. While the raw data is not included in the paper, a full species list is provided and this demonstrates the greater significance of the aerial dead branches for specialist saproxylic beetles in particular, including a number of beetles which are now assessed as having conservation status: *Bibloporus minutus*, *Phloiophilus edwardsii*, *Cryptarcha strigata* and *Conopalpus testaceus* (Nationally Scarce) and *Pediacus dermestoides* (DD in IUCN Red List) – in marked contrast to the results from logs on the ground.

More recently hollow tree trunk sections have been re-erected and filled with an artificial wood-mould as an attempt to replicate the habitat for the rare Violet Click Beetle *Limoniscus violaceus* in Windsor Forest; the first trial (1988-1994) proved very successful (Green 1995) and the approach has since been expanded using domestic compost bins as surrogate hollow trees and even plastic bin liners. Experience found that the artificial wood-mould needed to be kept topped-up while it composts down, otherwise the overall volume decreases and the material increasingly loses its important moisture content (Ted Green, pers. comm.). The first trial with three 300 litre capacity compost bins was carried out by local English Nature staff on Bredon Hill NNR (Whitehead 2009); the bins were set up over the winter of 1996-97 and emptied during the winter of 2008-9. Saproxylic species were found to be very limited, but most notably included the Nationally Scarce wood-mould beetle *Pseudocistela ceramboides* (Tenebrionidae) in one bin – larval exuviae as well as fragments of adult beetles, thereby demonstrating successful breeding.

This successful approach is currently being developed by Nicklas Jansson (Jansson et al 2009b, Hilszczański et al 2014) who has been exploring the use made of wood mould boxes by saproxylic beetles in Sweden.

Large wooden boxes (0.70 x 0.30 x 0.30 m, ie a volume of about 60 l) have been constructed with the intent that they should resemble the conditions in hollow oaks regarding temperature and moisture. The boxes have been constructed of oak wood (25 mm thick walls and roof, and 50 mm base) joined together with brass screws. The bottom inside of each box was covered with 50mm clay, formed into a bowl shape, to help to retain moisture. The appearance of the boxes is comparable with large bird nest boxes, with a circular opening of 80 mm diameter. They were 70% filled with potential substrate for saproxylic organisms: 60% oak wood sawdust, 30% oak leaves, 10% hay, plus a litre of lucerne flour and 5 l water. Additional ingredients which were varied in tests were: i) five potatoes, ii) 1 l of oat flakes and an additional litre of lucerne flour, iii) 1 l chicken dung, and iv) a dead hen *Gallus domesticus*. The potatoes were used to obtain a moist environment, the flour and oat flakes to raise the protein content, and the dung and dead hen to emulate occupied and old bird nests.

The boxes were set at a height of about 4 m on the shadiest side of standing oak trees, the shaded side to minimise differences in microclimate between boxes, but also created a relatively stable environment in the boxes over time. These boxes were then attached to the tree trunk with a metallic band. The roof and one side of the box could be opened but behind the door at the side there was a transparent plastic window so that the activity in the wood mould could be studied. A cross was milled on the roof and four holes drilled in the corners (8mm diameter) to let in some rainwater.

The results of using such boxes were then investigated by placing them on hollow oaks and on younger oaks, at varying distances apart and leaving them for a full season to be colonised before sampling the beetle fauna. Samples were taken by using small pitfall traps set in the top of the wood mould mixture. During the fourth season the boxes were closed, using an emergence trap approach: the whole box was covered and sealed with a dark cloth. And a hole made in the cloth to which a white plastic bottle was fastened. Emerging beetles were attracted to the bottle by the daylight.

The authors found that the efficacy of using these boxes for saproxylic beetles was surprisingly high, with artificial substrates carrying nearly as many species as captures in a study of real hollow trees in the area. Capturing beetles in the final emergence traps indicates that larval development has taken place in the boxes (even though some individuals may have been hibernating). Some red-listed tree-hollow species that were relatively frequent in the hollow oaks, however, have never been captured in the boxes. These include the click beetles *Ampedus cardinalis* and *Procraerus tibialis*. The observed differences in species composition may be due to the decay type – the box contents replicate a late stage wood-mould decay system. Some beetles lacking from the boxes are specialists on early stage red-rotten oak wood, such as *Dorcatoma chrysomelina*, *Mycetophagus piceus* and *Pentaphyllus testaceus*. Beetles characteristic of early stage decay would not be expected with the ingredients that were used.

Among the four additional substrates compared, a dead hen resulted in the highest number of individuals for obligate saproxylic beetle species, for saproxylic hollow-oak species, and species and specimens in total. This supports the view that bird nests above the wood mould do influence the faunal composition. No advantage was demonstrated of increasing nutrient contents (chicken dung or potatoes) but an increased protein content (lucerne flour and oat flakes) had a positive effect on the number of specimens of red-listed species.

The authors suggest that wood mould boxes could be useful as stepping stones between stands of hollow oaks but should not be placed more than a few 100 m from dispersal sources. The wood mould volumes decreased by 15-30% over the three year period of the study, as observed by Green (1995) in a similar study. This reduction is most likely from fungal and bacterial activity as well as larval consumption. This means that boxes might need to be refilled after some years.

4.9 Potential impacts of trapping on source populations

Multi-trapping studies need to consider the impacts of taking large samples on the source populations. Is it feasible that a trap targeted at catching beetles emerging from a particular cavity might actually damage the source population? Alexander et al (2014) has recently raised this issue.

Existing datasets might provide some answers. There are a number of sites in other European countries where trapping has been carried out over many years, although in most cases in extensive forest environments. Dodelin (pers. comm.) has examined about 20 years of data from his study sites in France and was able to demonstrate that species richness was continuing to rise, with no tailing off of the rate of finding additional species over time. He found no evidence that any particular rare and threatened species had gradually declined and disappeared.

4.10 Conclusions re most suitable traps for the proposed study

Transparent cross-vane window flight-interception traps do appear to be the most sensible option for the current study – they have been widely used across Europe and so there is a baseline of experience and existing data. Increasingly these are being used in a standard way both for survey and monitoring purposes (Bouget et al 2008, Sebek et al 2012). However, recent developments in the use of wood mould boxes are very relevant and the situation should be monitored. As experience with the latter boxes develops it may be sensible to expand the study to use these in parallel with the vane traps. It is clear that the two methodologies result in different assemblages of beetles and so it is unlikely that the wood mould boxes will replace vane traps as the standard methodology.

5 Genetic aspects

The contract brief included: Methods for data processing (e.g. species identification from trap samples, possible genetic analysis to look at genetic structure of invertebrate subpopulations found in different trees and sites, and so make inferences about movement between subpopulations) should be explored and discussed.

Max Blake, a PhD Student working on 'Conservation Genetics of Saproxylic Beetles' within the Population Genetics and Genomics Department at Aberystwyth University provided the following information.

The topic can be broken down into two areas which would need very different genetic markers:

- Species ID needs barcoding markers; as long as the species can be identified to a fairly restrictive taxonomic group (Tribe or Genus really) then primers for a barcoding gene can be built and the species identified. Irritatingly, considering most saproxylics are really poorly studied, actually doing something like this even for one genus (say something slightly tricky to ID with a number of British species like *Ampedus*) requires a surprising amount of work if there aren't sequences already published for the genus. Genbank is an open access site where people can publish sequences before publication - always worth checking it to see if there are any sequences online for a species of interest - there are actually 75 sequences for *Ampedus* there at present, most being CO1 which is the main gene used in barcoding.

- Genetic structuring is more difficult, and it's the area where most time has been spent working on with *Gnorimus nobilis*. There are a huge number of methods for looking at genetic structuring in populations, but most of them are species-specific and need separate investigation in different species, even if they are closely related. However, things like Microsatellites offer probably the best all-purpose way to look at population sub-structuring, including dispersal (sex biased, or not) and mating patterns. My lab group (Prof Paul Shaw & Dr Niall McKeown) and I are about to finish a pair of papers on Stag beetles looking at sex-biased dispersal within and between sites using microsatellites, just as an example of how they can be used.

His PhD studies are not yet published but a useful overview has appeared (Blake et al 2015).

Oleksa et al (2013) used AFLP (amplified fragment length polymorphism) markers to compare the spatial genetic structure of two ecologically and taxonomically related beetle species, *Osmoderma barnabita* and *Protaetia marmorata* – neither occur in Great Britain - which both develop in tree hollows. Analyses of spatial autocorrelation showed, in line with the predicted low dispersal potential of these species, that both species are characterized by a strong kinship structure, which was more pronounced in the specialist *O. barnabita* than in the generalist *P. marmorata*. The studied populations were significantly inbred.

There is clearly great potential in genetic studies to enhance our understanding of the implications of isolation and fragmentation on populations of saproxylic beetles, and hence on their conservation management requirements. This type of study is however likely to be relatively expensive, at least in the short-term while the approach is being pioneered and developed. It will be worth revisiting this in future.

6 Proposals for initial field-based study

6.1 Should the study focus on a particular tree species or on a particular type of decaying wood?

It would be overambitious for the study to focus on all saproxylic invertebrates in all wood-decay situations. From a practical viewpoint it would be advisable to narrow down the variables to a considerable extent, to focus on particular associations. The most vulnerable and therefore the most threatened section of the saproxylic fauna in England is dependent on the formation of large cavities through fungal decay of the heartwood in older generation trees, the types of heartwood decay which develop in the tree species which are capable of developing large girth trunks over time (see also 6.2 below).

The two main types of heartwood decay – red/brown rot and white rot - are a key determinant of the species of saproxylic invertebrate that may be present. While there is some degree of specificity to particular tree species, it can difficult to ascertain which type of decay is proceeding deep within a particular individual tree, and both types may be present in the same individual tree. This situation creates practical difficulties in focusing on decay type.

A wide range of trees present in the wider English countryside have the capacity to grow large girth trunks and are also known to develop suitable cavities. Ideally the study needs to focus on tree species which are widespread across England and occur in good numbers in a wide range of situations. This immediately restricts the choices.

The suggested criteria are therefore tree species that are:

- Common in the wider countryside
- Have the capacity to develop large girths
- Prone to cavity formation
- Known to be capable of supporting a diverse fauna of saproxylic invertebrates

Alexander, Butler & Green (2006) have assessed the value of different tree and shrub species to wildlife in Britain and provide a table which weights the values of each tree species for wood decay fungi and invertebrates. The highest values are associated with: Scots pine, elms, beech, native oaks, birches and ash. Birches are too small in girth, and Scots pine, elm and beech too restricted in range and situation to provide the most useful study subjects. The two most widespread species of hedgerow tree in England are oak and ash, with regional and local variation in relation to soil type. Ash is probably the more restricted of these, and is currently under severe threat across England from disease, and so that leaves oak as the obvious choice for the subject of a long-term study. Oak is also under threat from disease but not to the same extent.

Gough et al (2014) very clearly summarise the significance of old oaks with heartwood-decay. Oak-based systems are global hotspots of biodiversity (Buse et al, 2010; Sverdrup-Thygeson, 2009) and are considered as one of the most important habitats in a variety of ecosystems across the temperate zone from boreo-nemoral woodland (Andersson et al 2011), lowland European wood-pasture and woodland (Bouget et al 2014, Vera 2000) and Mediterranean forests (Buse et al 2013) to North American savannah (Brawn 2006) and American and European agricultural lands (Gibbons et al 2008). Ancient, hollow oak trees are an integral component of these systems (Gough et al 2014). They are keystone structures, their great size and age conferring vital ecological roles that cannot be replicated by younger, smaller trees (Lindenmayer et al 2014). Hollow oaks are ‘habitat trees’ (Bouget et al 2014) that contain varied micro-habitats including cavities, wood mould, dead wood, and fissured bark which support a multitude of different species (Ranius et al 2011, Stokland & Siitonen 2012) including fungi, lichens, birds, small mammals and insects (Bergman et al 2012, Siitonen 2012). While few saproxylic invertebrate species are exclusive to oak (Milberg et al 2014), this tree species tends to provide some of the best habitat available. Oak ecosystems are also suffering a drastic decline due to direct removal, a lack of traditional management in areas where it historically occurred, intensive forestry and climate events such as severe drought (Bjorkman & Vellend 2010, Horak et al 2014, Paillet et al 2010, Vera 2000) and large hollow trees are often disproportionately affected (Lindenmayer et al 2014). Hollow oak trees are incredibly rich in wood-living beetles, a group of animals with one of the highest proportions of threatened species across Europe (Davies et al 2008, Nieto & Alexander 2010, Speight 1989).

Oak is a tree that naturally becomes older and larger than most other tree species in northern Europe (Nilsson & Baranowski 1997). When the trees age, a large number of microhabitats develop that are absent in younger trees. In old oaks, hollows form, generally started by specialist heartwood-decay fungi. These fungi work alongside insects to expand the hollows and the resulting debris composts as wood mould. This is in turn enriched by remnants of nests and droppings from birds, bats and insects as well as other detritus. The characteristic coarse bark structure with deep fissures is also typical of aging oaks, and this bark creates a microhabitat varying in exposure to rain and sun on a very small scale. Another characteristic of old oaks is the presence of dead branches of varying sizes within the tree canopy.

Sverdrup-Thygeson (2009) has demonstrated that hollow oaks are hotspots for red-listed beetle species in Norway, in comparison to other tree species. The number of old hollow oaks is decreasing all over Europe (Read et al 2003, Ranius et al 2005).

6.2 Should the study focus on a particular saproxylic invertebrate assemblage?

Alexander (2002a) has reviewed the saproxylic invertebrate fauna of Britain, and has identified Coleoptera and Diptera as the predominant taxa dependent on dead and decaying wood; with 700 and 730 species respectively. He also demonstrated that – at that time – 54% of British saproxylic beetles had conservation status while the equivalent figure for Diptera was 33%, although not all groups of Diptera had been assessed. Interestingly the 54% figure is very close to the equivalent figure for Sweden (Jonsell et al 1998) and may well be representative of the European continent as a whole.

It is generally accepted that the most threatened assemblage of saproxylic invertebrates is the heartwood decay fauna. There are a number of key factors:

- Host trees require considerable time for the habitat to develop and so the probability of survival is relatively low and suitable host trees are naturally relatively rare as a result
- The invertebrate species concerned are dominated by those believed to have relatively low mobility, in comparison to species which exploit the short-lived early successional stages of freshly dead woody tissues.

It follows that the specialist fauna of heartwood decay should be a key target of the present study.

The Species of Principal Importance for the conservation of biodiversity listed in Section 41 of the 2006 Natural Environment & Rural Communities (NERC) Act includes a large number of heartwood decay beetles. This provision makes it a statutory duty on planning authorities and other decision makers to consider these species when carrying out their duty to further the conservation of biodiversity.
It follows therefore that enhanced understanding of the habitat associations and mobility of these particular species would be instructive and the present study has the potential to better enable these bodies to achieve good conservation practice.

6.3 Sites of potential value for study

6.3.1 Criteria and analysis

Alexander (2004) lists the richest sites across Britain for saproxylic Coleoptera and this listing has been kept up-to-date by the author. It provides a readily accessible list of the key saproxylic sites across England. Adrian Fowles also maintains a comparable list at http://khepri.uk/main/. No equivalent source is available for sites rich in other saproxylic taxonomic groups. The list covers a broad range of levels of interest, from the very top Great Britain sites down to regionally important sites.

This list has been examined with a set of criteria:

- Oak the predominant tree;
- Preferably no co-dominants which might over-complicate the project;
- Availability of sufficient suitable veteran trees, both within the known site and preferably within the surrounding landscape;
- Ownerships known, to some extent at least, and potentially sympathetic to the proposed project (a lower priority criterion);
- Availability of areas where traps may be safely left in situ for prolonged periods, without a high risk of vandalism.

This leaves a listing of about 70 potential study sites. The on-line Ancient Tree Inventory (ATI) has then been used to examine the extent of documentation of trees locally – the ATI data has also been supplemented to some extent by the contractors own knowledge of sites across the country plus information from the National Trust.

The ATI project has revealed some major concentrations of ancient oak across six areas of England:

- Central Midlands
- East Anglia
- North
- South East
- South West
- Thames & Chilterns
- Welsh Borders & SW Midlands

Each of these ancient treescape areas includes a few sites - at least – known to be relatively species-rich in oak heartwood saproxylics.

The ATI project has also identified a series of Priority Resilient Ancient Treescapes (see section 3.4), where the mapping has shown up major concentrations of ancient and veteran trees at a more local level. These in particular may provide some potential target areas for the Natural England study.

The vision for the overall long term study is that a network of sites will be established across England where interception traps are set up to sample saproxylic invertebrate populations. Their focus will be wood-pasture sites set in a landscape with hedgerows, hedgerow trees, and possibly in-field trees. The series of sample sites will include tree populations in a variety of situations. It follows therefore that – ideally – one site should be selected from each of these ancient tree regions.

The candidate sites which appear to be the strongest are discussed in the next section, organised by the ancient treescape areas listed above. The intention is that, for each area, the most suitable site for the current study becomes clear, together with one or more alternative sites as potential back-up sites should the most suitable site prove unavailable.

6.3.2 Central Midlands area

6.3.2.1 Calke Park NNR

Calke Park has been identified as a possible Priority Resilient Ancient Treescape by the Ancient Tree Inventory project (J. Butler, pers. comm.). The National Trust's Calke Abbey Estate on the Derbyshire/Leicestershire border (SK368227) contains the exceedingly rich Calke Park at its heart, surrounded by about 890 ha of tenanted farmland. The saproxylic fauna of the core parkland trees is well-documented (Johnson 2011, Alexander & Abrahams 2006), and the farmland includes red-rotten veteran oaks which are known to support species such as the Nationally Scarce *Anitys rubens* (National Trust Biological Survey). The Calke Park Site of Special Scientific Interest (SSSI) was designated primarily for its saproxylic interest and has subsequently been declared a National Nature Reserve (NNR).

Saproxylic beetles recorded include the following:

- Red-rot: *Micridium halidaii, Dorcatoma chrysomelina, D. flavicornis, Anitys rubens, Mycetophagus piceus, Euglenes oculatus*
- White-rot: *Plegaderus dissectus, Abraeus granulum, Aeletes atomarius, Ptenidium gressneri, Mycetophagus populi*
- Either type: *Procraerus tibialis, Ptinus subpilosus, Prionychus ater, Mycetochara humeralis*

The best concentration of in-field veteran oak in the tenanted farmland lies by Calke village immediately east of the visitor exit from the estate, although these are too few in number for the proposed study. The farmland along the western side of the park has been mapped in the ATI with a large number of veteran oak and ash, although most are along roadsides and public footpaths and may be too prone to interference as trapping sites. Ideally the National Trust's Biological Survey data needs to be examined to see if any more suitable areas occur within the estate.

6.3.2.2 Grimsthorpe Park SSSI

Grimsthorpe Park, near Bourne in Lincolnshire (TA0110) has been identified as a possible Priority Resilient Ancient Treescape by the Ancient Tree Inventory (ATI) project (J. Butler, pers. comm.); it is a privately owned estate near Bourne in Lincolnshire. It contains substantial remnants of both a medieval deer park and a Tudor deer park within an 18th century landscape park, all within a large agricultural estate. The site lies within the bounds of the former Forest of Kesteven. The veteran trees of the core area of the Site of Special Scientific Interest (SSSI) have been mapped in detail and the data entered onto the ATI, but only four veteran oak trees have been mapped in the landscape park area to the north – three in one enclosure on the south side of Bishopshall Wood. Suitable veteran oak trees are reported to be present in the adjoining farmland (J. Webb & S. Perry, pers. comm) but none have been mapped - at present the evidence available to the authors does not make this site an obvious candidate for the proposed study.

The saproxylic beetle fauna received some attention in the mid 20th century (Crowson & Hunter 1964, Hunter & Johnson 1966) and the core area was designated as an SSSI primarily for its saproxylic beetle fauna based on these early studies. It is increasingly being found to be exceptionally rich, and the beetle fauna has recently been reviewed (Webb & Perry, 2014).

Saproxylic beetles recorded include the following:

- Red-rot: *Dorcatoma chrysomelina, D. flavicornis, Malthodes crassicornis, Hypulus quercinus, Mycetophagus piceus, Euglenes oculatus*
- White-rot: *Plegaderus dissectus, Ampedus quercicola, Platycis minutus, Malthinus frontalis, Scraptia testacea*
- Either type: *Batrisodes venustus, Hypnogyra angularis, Quedius scitus, Q. truncicola, Velleius dilatatus, Procraerus tibialis, Prionychus ater, Mycetochara humeralis, Pseudocistela ceramboides*

Some preliminary studies using vane traps have recently been reported (Webb & Perry 2014).

6.3.2.3 Needwood Forest & The National Forest

Needwood Forest is a former area of medieval forest lying to the west of Burton-on-Trent, Staffordshire, and contains many remnants of historic deer parks. The main areas that have been mapped for their veteran trees in the ATI are Byrkley Park (Football Association, renamed St George’s Park) and Oakwood Pasture Nature Reserve (Staffordshire Wildlife Trust). Veteran oak are reported to be plentiful in the farmland around these two fragments of historic parkland (J. Webb, pers. comm.) but very few have been mapped.

Saproxylic beetles recorded include the following:

- Red-rot: *Microscydmus minimus, Anitys rubens, Mycetophagus piceus*
- White-rot: *Mycetophagus populi,Ptenidium gressneri*
- Either type: *Batrisodes vestustus*

6.3.2.4 Rockingham Forest

Rockingham, Northamptonshire, is another former medieval forest area. Rockingham Forest/Burghley is one of the Priority Resilient Ancient Treescapes identified by the Ancient Tree Inventory project (J. Butler, pers. comm.). The area appears not to have been mapped very intensively for the ATI, however, and has a general lack of known veteran oaks outside of the core sites. Lack of veteran trees across much of the area may be a reality, due to historic industrial land use of this area (J. Webb & S. Perry, pers. comm.).

The saproxylic beetle fauna of selected sites was studied by Tony Drane during the 1980s, especially Rockingham Castle Park (SP8691; Drane 1982 & 1984).

Saproxylic beetles recorded include the following:

- Red-rot: *Mycetophagus piceus*
- White-rot: *Plegaderus dissectus, Ptenidium gressneri*
- Either type: *Ptinus subpilosus, Prionychus ater, Mycetochara humeralis*

6.3.2.5 Sherwood Forest

Sherwood Forest, Nottinghamshire, is one of the Priority Resilient Ancient Treescapes identified by the Ancient Tree Inventory project (J. Butler, pers. comm.). The exceptionally rich saproxylic fauna of this very famous medieval forest area has recently been reviewed (Alexander 2011) and the forest's wider interests also described (Clifton 2012). The majority of the remaining forest oaks are now protected within two SSSI and very few veteran oak have been mapped in other areas for the ATI. There are known to be significant veteran trees on the Thoresby Estate which appear not to have been mapped.

Saproxylic beetles recorded include the following:

- Red-rot: *Micridium halidaii. Microscydmus minimus, Plectophloeus nitidus, Dorcatoma chrysomelina, D. flavicornis, Anitys rubens, Ampedus cardinalis, Mycetophagus piceus, Euglenes oculatus*
- White-rot: *Plegaderus dissectus, Abraeus granulum, Ptenidium gressneri, P.turgidum, Stenichnus godarti, Mycetophagus populi, Scraptia testacea*
- Either type: *Eutheia linearis, Batrisodes venustus, Euplectus nanus, Ptinus subpilosus, Procraerus tibialis, Corticaria alleni, Prionychus ater, P. melanarius, Pseudocistela ceramboides, Mycetochara humeralis.*

6.3.2.6 Hardwick Hall Estate

The National Trust's Hardwick Hall Estate - on the Derbyshire/Nottinghamshire border - has historic parkland at its centre which has been identified by Natural England as a proposed SSSI for its saproxylic beetles. The surrounding land is within a series of tenanted farms and the area has been surveyed by the National Trust's Biological Survey Team. However no farmland trees are currently shown on the ATI. The survey document needs to be examined to see if there is any potential here for the proposed study, although it seems the wider estate contains limited potential (C. Hawke, pers. comm.).

Saproxylic beetles recorded include the following:

- Red-rot: *Dorcatoma chrysomelina, Mycetophagus piceus, Euglenes oculatus*
- White-rot: *Plegaderus dissectus, Abraeus granulum*

6.3.2.7 Suggested study site

No obvious site stands out. At present, Needwood Forest may be the strongest candidate site.

6.3.3 East Anglia

6.3.3.1 Blickling Hall Estate

The National Trust's Blickling estate near Aylsham in Norfolk (TG1728; 1929 ha) has oak dominated parkland in the centre of a large agricultural land holding. The wider estate has been subject to a National Trust Biological Survey and the results could be examined in order to assess the presence of any suitable areas of veteran oaks. At present the ATI shows very few trees and it appears that this estate has not contributed any data so far. If it has any potential for the proposed study it is not currently apparent.

Some data is available on the saproxylic fauna, from NT Biological Surveys:

- Red-rot: *Dorcatoma chrysomelina, Anitys rubens, Eugelenes oculatus*
- White-rot: *Abraeus granulum*

6.3.3.2 Wimpole Park

Although a landscape park dominated by horse chestnut and common lime, and with oak a relatively minor feature, Wimpole Park in Cambridgeshire (TL3351; National Trust) does combine a historic parkland with a surrounding farmed landscape of 960 ha that is known to be relatively rich in hedgerow oak trees (S. Warrington, pers. comm.). The relative isolation of this historic treescape, within a region of large scale arable cultivation, has been the case for over 200 years – the landscape gardener Humphrey Repton commented on this feature as long ago as the late 1790s: "The counties of Cambridge and Huntingdon consist generally of flat ground and cornfields with few hedges and trees: while the few hills are yet more naked. But Wimpole abounds in beautiful shapes of ground and is richly clothed in wood. It is therefore like a flower in the desert, beautiful in itself but more beautiful by its situation" (Damant & Kirby 2005). The parkland has been much modified over time but there was an earlier deer park here in the medieval period which was subjected to landscape gardening from the 18th century onwards, with designs by Bridgeman, Brown and Repton all superimposed on the earlier cultural landscape. The surrounding farmed landscape includes an interesting concentration of ancient oak pollards which are remnants of a formerly much more extensive farm-scape dominated by such trees (S. Damant, pers. comm.)

The rich saproxylic beetle fauna of Wimpole Park has been documented by Kirby (2002) and Damant & Kirby (2005).

Saproxylic beetles recorded include the following:

- Red-rot: *Dorcatoma flavicornis*
- White-rot: *Plegaderus dissectus, Aeletes atomarius, Nossidium pilosellum, Ptenidium gressneri, Scydmaenus rufus, Euplectsu kirbii, Ischnodes sanguinicollis, Malthinus frontalis, Cryptophagus labilis, Cossonus parallelepipedus, Stereocorynes truncorum*
- Either type: *Hypnogyra angularis, Procraerus tibialis, Elater ferrugineus, Epiphanis cornutus, Hylis olexai, Megatoma undata, Korynetes caeruleus, Mycetophagus quadriguttatus, Prionychus ater, Pseudocistela ceramboides, Mycetochara humeralis, Aderus populneus*

This site clearly meets SSSI Guidelines for its outstandingly rich saproxylic fauna but has not been designated.

It is important to note that the Kirby survey relates solely to the parkland trees; he did not include the farmland trees in the detailed saproxylic work. The farmland feature of ancient oak pollards may therefore reveal a much richer oak red-rot specialist beetle fauna than is apparent from the previous survey work.

6.3.3.3 Selected study site

Following agreement from the Project Team in October 2014, Wimpole was adopted as the first choice in East Anglia.

6.3.4 North of England

The two key sites for saproxylic beetles are Duncombe Park Estate and Studley Royal Estate. Both are known to support a relatively good range of heartwood species.

The Duncombe Park Estate and the wider North York Moors National Park is one of the Priority Resilient Ancient Treescapes identified by the Ancient Tree Inventory project; Duncombe itself is a complex area with a NNR and a separate SSSI designated for saproxylic fauna, both being part of the former medieval deer park of Helmsley Castle (SE5883). It lies within the North York Moors National Park which also contains many other concentrations of ancient and veteran oaks. These are not well-documented however and the area may be best left for a later stage in the project.

Saproxylic beetles recorded include the following:

- Red-rot: *Dorcatoma chrysomelina, D. flavicornis, Anitys rubens, Malthodes crassicornis, Hypulus quercinus, Anoplodera sexguttata, Mycetophagus piceus, Euglenes oculatus*
- White-rot: *Aeletes atomarius, Ptenidium turgidum, Ampedus pomorum*
- Either type: *Batrisodes venustus, Pseudocistela ceramboides*

Studley Royal Park (SE2870) lies close to Ripon and is owned by the National Trust; the surrounding landscape remains in private ownership and is largely unknown for its veteran trees.

Saproxylic beetles recorded include the following:

- Red-rot: *Anitys rubens*, *Mycetophagus piceus*, *Euglenes oculatus*
- White-rot: *Ptenidium gressneri*, *P. turgidum* and *Mycetophagus populi*
- Either type: *Batrisodes venustus*.

Nidderdale is another area that would be worth investigation as Richard Muir has carried out detailed research into the landscape history of hedgerow trees here. The area does include a historic parkland, Ripley Park (SE2861; privately owned)), enclosed from medieval Royal Hunting Forest of Knaresborough. Natural history recording is very scant locally.

6.3.5 South East

There are few obvious sites across the South East. Many of the best sites for veteran oak also contain high proportions of hornbeam, beech or sweet chestnut, and this makes them much less suitable for the current study.

6.3.5.1 Cobham Hall Estate

Cobham-Ashenbank in West Kent is one of the Priority Resilient Ancient Treescapes identified by the Ancient Tree Inventory project (J. Butler, pers. comm.). The Cobham Hall area (TQ6868), between Gravesend and Rochester, contains a large area of former wood pasture and parkland which has largely become secondarily wooded through abandonment of grazing. It includes Cobham Hall Park (Cobham Hall Heritage Trust), Cobham Woods (National Trust), Shorne Woods Country Park (Kent County Council) and Ashenbank Wood (Woodland Trust). There are two SSSI involved: Cobham Woods SSSI and Shorne & Ashenbank Woods SSSI. It is a famous area entomologically, from the late 19th century onwards. The veteran trees of the core sites are well documented but no veteran oak have been registered for the ATI in the surrounding farmland. The known fauna has more of a white-rot character overall, reflecting the local presence of beech and hornbeam in addition to oak:

- Red-rot: *Dorcatoma flavicornis*, *Mycetophagus piceus*, *Euglenes oculatus*
- White-rot: *Abraeus granulum*, *Ptenidium turgidum*, *Hypnogyra angularis*, *Ischnodes sanguinicollis*
- Either type: *Ptinus subpilosus, Prionychus ater, Pseudocistela ceramboides*

6.3.5.2 Parham Park & Knepp Castle Estate

Parham-Knepp in West Sussex is one of the Priority Resilient Ancient Treescapes identified by the Ancient Tree Inventory project (J. Butler, pers. comm.). Parham Park SSSI (TQ0615; privately owned) is a site of major importance for saproxylic beetles, although remains under-surveyed. It lies in the Low Weald area of Sussex. The saproxylic beetle fauna is known to support three key heartwood associated species which are ‘Near Threatened’ across Europe (Nieto & Alexander 2010) – *Gnorimus variabilis* (S41), *Ampedus cardinalis* and *Elater ferrugineus* – as well as other uncommon species:

- Red-rot: *Gnorimus variabilis, Ampedus cardinalis, Euglenes oculatus*
- White-rot: *Elater ferrugineus*
- Either type: *Procraerus tibialis, Prionychus ater*

Barely 5 km away is the Knepp Castle Estate (TQ1521; privately owned; 1416ha). The parkland here is relatively modern (early 19C, Repton designed landscape) but was developed in an area where there had once been an earlier medieval hunting park within the ancient Forest of Anderida, and so some ecological continuity may be expected. The area was used extensively for iron-working during the intervening period (16th Century onwards). While not yet surveyed for its saproxylic invertebrates it is known to be exceptionally important for its bracket fungi which include the rare old forest species *Phellinus robustus* and *Podoscypha multizonata.* The surrounding estate had been under modern very intensive arable cultivation until relatively recently when the land was gradually put back to pasture - from 2001 - and is now run as a re-wilding initiative, the Knepp Wildland Project. The hedgerows are unusually rich in oak and other tree species as the present owner's grandfather had retained them in the mid 20th Century when all of his neighbours were busily grubbing them out under Government grants – the estate acts as a large island of particularly well-treed hedgerows in a landscape that is otherwise relatively denuded of such trees (in the context of the well-wooded Weald).

6.3.5.3 Selected study site

Following agreement from the Project Team in October 2014, Knepp was adopted as the first choice in the South East.

6.3.6 South West

6.3.6.1 Lower Fowey Valley

The Lower Fowey Valley has been identified as a key area for saproxylic invertebrates in Cornwall (Alexander 1993 & 2009b) and has been adopted as one of the Resilient Ancient Treescapes identified by the Ancient Tree Inventory project – as Boconnoc/Fowey (J. Butler, pers. comm.). It contains three core sites of known national importance for saproxylic invertebrates and epiphytic lichens: Boconnoc Park SSSI (SX1459; private owner), Lanhydrock Park (SX0963; National Trust) and Ethy Park and Woods (SX1357; National Trust). It also includes Restormel Manor Park (SX1061; Duchy of Cornwall) and Cabilla and Redrice Woods Nature Reserve (SX1365; Cornwall Wildlife Trust). The area is being developed as a landscape scale conservation project by the Woodland Trust, National Trust, Buglife and other partners. It has been subject to detailed mapping of veteran trees by the Cornwall Group of the Ancient Tree Forum.

Saproxylic beetles recorded include the following:

- Red-rot: *Dorcatoma chrysomelina, Mycetophagus piceus, Hypulus quercinus*
- White-rot:
- Either type: *Mycetophagus quadriguttatus, Epiphanis cornutus*

6.3.6.2 Killerton Park Estate

Killerton in East Devon has been identified as a possible Priority Resilient Ancient Treescape by the Ancient Tree Inventory project (J. Butler, pers. comm.). The National Trust's Killerton Park Estate contains the remnants of a medieval landscape of former wood pasture and drove road ancient and veteran trees, especially oak. One concentration of ancient oaks on the eastern flanks of Dolbury Hill was developed into a deer park for Killerton House (SS9700) at a date after 1575 (it is not shown on Saxton's map of that date). The former heath pastures of Sprydon Beacon and adjoining farmed fields were afforested from 1818 as 'Ashclyst Forest' (SX9999/SY0990) – this area retains some of its former hedgerow pollards within the secondary woodland although many have died from canopy competition, etc. Around and between these two areas are tenanted farms containing many veteran and ancient trees, mostly as hedgerow trees but also a few in-field trees, some within arable crops. The Estate therefore offers trees within:

- Typical parkland
- Plantations

- Hedgerows
- Fertilised pastures
- Arable fields

Some of the oak pollards in Killerton Park and Ashclyst Forest were cut back to the bolling in the early days of renewed interest in pollard restoration in the late 1980s and before it was appreciated that this was not the best way to conserve old pollards. Killerton was - at the time - in the forefront of this work nationally, but this pollard restoration initiative has not been continued.

The landscape surrounding the Estate has been explored to a more limited extent but appears to be much poorer in veteran trees.

The fauna is little studied overall but some notable finds have been reported (Alexander 2008):

- Red-rot: *Dorcatoma flavicornis*
- White-rot:
- Either type: *Prionychus ater, Aderus populneus*

6.3.6.3 Woodend Park, Shute

Woodend Park, at Shute in East Devon, is one of the Priority Resilient Ancient Treescapes identified by the Ancient Tree Inventory project (J. Butler, pers. comm.). The core of the site is Woodend Park (SY2497; privately owned), a substantial medieval deer park site which still retains its old park pale. The tree population was documented by Paul Harding as part of the Mature Timber Habitat project in the 1976 and still remains much as described then. The beetle fauna of the area was intensively studied by G.H. Ashe during 1939-1958, and some remarkable finds made, especially amongst the saproxylics. The rare saproxylics were found not only in the historic deer park but also across the surrounding landscape and especially towards Colyton where Ashe lived. The park is known to be of national significance for its veteran trees, its saproxylic beetles and fungi, and of regional significance for its epiphytic lichens, but has not been designated as a SSSI.

Saproxylic beetles recorded include the following:

- Red-rot: *Euglenes oculatus*
- White-rot: *Abraeus granulum, Ptenidium gressneri, Stenichnus godarti, Ischnodes sanguinicollis, Cossonus parallelepipedus*
- Either type: *Euplectus nanus, Eutheia linearis, Aulonothroscus brevicollis, Ptinus subpilosus, Mycetophagus quadriguttatus, Pseudocistela ceramboides*

Tree data currently available relate to the core medieval deer park site and to neighbouring more recent parkland at Shute Barton. Few outlying veteran trees have been mapped, so it is unclear at present if this are might be suitable for the proposed study.

6.3.6.4 Selected study site

Following agreement from the Project Team in October 2014, Killerton was adopted as the first choice in the South West.

6.3.7 Thames & Chilterns area

6.3.7.1 Blenheim & Cornbury Parks, Wychwood Forest

The medieval forest of Wychwood in Oxfordshire provides an ancient forest landscape containing two areas known to be rich in saproxylic beetles and especially heartwood species. Cornbury Park (SP3417) and Blenheim Park (SP4316) have both been identified as possible Priority Resilient Ancient Treescapes by the Ancient Tree Inventory project (J. Butler, pers. comm.). Blenheim Park SSSI has a notably rich saproxylic beetle fauna (eg Alexander 2003b).

Saproxylic beetles recorded include the following:

- Red-rot: *Plectophloeus nitidus, Ampedus cardinalis, A. elongatulus, Malthodes crassicornis, Dorcatoma chrysomelina, D. flavicornis, Aderus oculatus*
- White-rot: *Plegaderus dissectus, Abraeus granulum, Aeletes atomarius, Ampedus cinnabarinus*
- Either type: *Ptinus subpilosus, Procraerus tibialis; Prionychus ater*.

6.3.7.2 Stowe Park, Whittlewood Forest

The medieval deer park of Stowe, on the north side of Buckingham, was enclosed out of Whittlewood Forest, but the modern Landscape Gardens by the mansion (SP675375) were laid out in the C17 and C18 by the landscape gardeners Bridgeman, Kent and Brown. A former deer park lies immediately to the south of the gardens and dates from the same period. The National Trust acquired the Gardens in 1990 and has been acquiring parcels of the surrounding agricultural land subsequently. Stowe School retains ownership of further areas of farmland locally. The farmland is known to include a significant number of veteran and ancient oaks especially on Home Farm to the west but also towards New Inn and Stowe Castle Farms on the east side. Although not well researched for its saproxylic interests, the Trust's own Biological Surveys (1990-2000) have detected an interesting fauna (Alexander 1991).

- Red-rot: *Dorcatoma flavicornis, Anitys rubens, Mycetophagus piceus*
- White-rot: none
- Either type: *Prionychus ater, Aderus populneus*

The area is also rich in bracket fungi.

A tree survey of the estate has been carried out using trained volunteers and the trees all tagged. This has been supplemented by a selection being identified for submission to the Ancient Tree Inventory project. It is therefore readily feasible to create mapping of the oaks across the site, with ATI trees distinguished as well as those noted as hollowing.

6.3.7.3 Windsor Forest and Great Park

Windsor Forest and Great Park SSSI in Berkshire (SU96; Crown Estate) comprises a very extensive landscape of ancient and veteran trees within a much wider area known to be rich in veteran oaks (Ted Green, pers. comm.). The core area is a former medieval forest and has long been known to be exceptionally rich in saproxylic invertebrates. Many of the larger and older trees have been mapped by the Crown Estate over an extended period and most of this data is now available on the Ancient Tree Inventory. The Windsor area has been identified as a possible Priority Resilient Ancient Treescape by the Ancient Tree Inventory project (J. Butler, pers. comm.). The Crown Estate has long been supportive of conservation initiatives on the estate and has initiated many of its own. It would seem highly probable that they would be interested in contributing to the proposed project. While some areas are open to the public and might therefore be subject to vandalism, others (with veteran oaks) are in private areas and would be very suitable for long-term studies using vane traps.

Saproxylic beetles recorded include the following:

- Red-rot: *Micridium halidaii, Microscydmus minimus, Tachyusida gracilis, Plectophloeus nitidus, Gnorimus variabilis, Lacon querceus, Ampedus cardinalis, A. nigerrimus, Brachygonus ruficeps, Malthodes crassicornis, Vanonus brevicornis, Dryophthorus corticalis*
- White-rot: *Aeletes atomarius, Ptenidium gressneri, Stenichnus godarti, Ampedus rufipennis, Megapenthes lugens, Limoniscus violaceus, Elater ferrugineus, Scraptia fuscula, S. testacea*
- Either type: *Eutheia formicetorum, E. linearis, Euconnus pragensis, Euryusa optabilis, E. sinuate, Batrisodes adnexus, B. delaporti, Procraerus tibialis, Aulonothroscus brevicollis, Globicornis nigripes, Atomaria morio.*

This area is outstandingly rich in saproxylic beetles and, as such, is perhaps not representative of the average parkland surrounded by tree-rich agricultural land. The surrounding land ownership includes many mansions where the wealthy owners are very protective of their privacy and where access for surveying and trapping may not be feasible. On balance, it is suggested that other, more typical parkland areas, might be better suited to the current project.

6.3.7.4 Wytham Woods

Wytham Woods was the key study site chosen by Charles Elton for his Ecological Survey. The 'woods' actually comprise three very different ecological units: a large area of conventional enclosed ancient woodland (Wytham Great Wood), together with former wood pasture (Radbrook Common) and historic parkland (Wytham Abbey Park). As a well-established research site, with a history of investigation of saproxylic invertebrates, it has much to commend itself for the present study. The first extensive description of saproxylic invertebrate communities was written by Elton (1966) who devoted a whole chapter to 'dying and dead wood' supplemented by further chapters on 'natural fuel stations: concourses on flower and fruit', 'bracket fungi and toadstools' and 'carrion, dung and nests'. The Ecological Survey revealed the presence of a number of heartwood specialists, mostly recorded between 1949 and 1963:

- Red-rot: *Ampedus elongatulus, Mycetophagus piceus, Euglenes oculatus*

- White-rot: *Abraeus granulum, Plegaderus dissectus, Quedius microps, Cossonus parallelepipedus*
- Either type: *Batrisodes venustus, Ptinus subpilosus, Prionychus ater*.

6.3.7.5 Selected study site

Following agreement from the Project Team in October 2014, Stowe was adopted as the first choice in the Thames & Chilterns area.

6.3.8 Welsh Border & West Midlands

6.3.8.1 Attingham Park SSSI and Estate

Attingham has been identified as a possible Priority Resilient Ancient Treescape by the ATI project (J. Butler, pers. comm.). The National Trust's Attingham Park Estate near Shrewsbury (SJ550099) has an extensive historic park surrounded by a large agricultural estate of some 1510 ha; it lies adjacent to the former medieval royal forest of Haghmon. The estate also includes a small parkland area at Cronkhill (SJ535083). The saproxylic beetle fauna has been documented by Alexander & Lott (1992). Attingham Park was subsequently designated as an SSSI on the basis of this survey. More recent investigation as part of courses organised by the Field Studies Council from nearby Hall have confirmed the continued presence of many of the known species but failed to add any significant species. This may suggest that the resident fauna is fully documented. The National Trust Biological Survey Team in 1996 noted a whole series of veteran oaks within arable on the west side of Lower Brompton Farm and a scatter along field margins between the farm and the River Severn.

Saproxylic beetles recorded include the following:

- Red-rot: *Dorcatoma chrysomelina, D. flavicornis, Mycetophagus piceus, Euglenes oculatus* (all recent)
- White-rot: *Plegaderus dissectus, Abraeus granulum, Scraptia testacea* (all recent)
- Either type: *Prionychus ater* (recent) and *Batrisodes venustus* (old)

6.3.8.2 Brockhampton Park Estate

The National Trust's Brockhampton Estate near Bromyard in eastern Herefordshire (SO682546) contains a core of parkland around Brockhampton House surrounded by 700 ha of farmland and including areas with traditional orchards. The core parkland appears however not to be particularly rich in saproxylics and so this site might not be a good example of the type of site required for the proposed study.

Saproxylic beetles recorded include the following:

- Red-rot: *Dorcatoma flavicornis; Euglenes oculatus*
- White-rot:
- Either type:

6.3.8.3 Croft Castle Estate

The National Trust's Croft Castle Estate in north Herefordshire (SO455655) offers veteran oaks in a wide range of situations:

- Typical parkland oaks
- Former wood pasture oaks in secondary woodland
- Former wood-pasture oaks in conifer plantations
- Rough wood pasture on Croft Ambrey, an Iron Age hill fort

Saproxylic beetles recorded include the following:

- Red-rot: *Dorcatoma chrysomelina, Euglenes oculatus*
- White-rot: *Aeletes atomarius*
- Either type: *Batrisodes venustus, Ptinus subpilosus, Gnorimus nobilis, Prionychus ater*

The trees have been registered with the ATI but all appear to be effectively parkland trees. None are obviously farmland trees. None of the veteran trees on adjoining Bircher Common have been mapped.

6.3.8.4 Croome Park

Croome Landscape Park (SO880443) in central Worcestershire comprises 667 ha of agricultural land which retains many of the ancient and veteran trees which were incorporated in the earlier 18C Brown landscape park. The fauna has been surveyed (Lott et al 1999). The National Trust is engaged in a major restoration of the parkland with landscape gardening the primary objective.

Saproxylic beetles recorded include the following:

- Red-rot: *Ampedus cardinalis, Malthodes crassicornis, Dorcatoma chrysomelina, Mycetophagus piceus, Euglenes oculatus*
- White-rot: *Plegaderus dissectus, Stenichnus godarti, Scraptia testacea*
- Either type: *Eutheia formicetorum, Hypnogyra angularis, Aulonothroscus brevicollis*

Only three of the veteran parkland trees have been registered with the ATI. The vast majority have not yet been entered. Many of the trees were within arable land but the NT is in the process of restoring the whole area to parkland. Trees in the surrounding privately-owned farmland have not been mapped.

6.3.8.5 Forthampton Oaks

The Forthampton Court Estate in Gloucestershire contains a core area of ancient oaks which have been found to be exceptionally rich in saproxylic beetles (Alexander 2002b). The surrounding landscape is also relatively rich in veteran oaks and other trees, mostly in hedgerows but also in-field trees. The site has not been designated as an SSSI but is a County Wildlife Site (identified by the Gloucestershire Wildlife Trust). The land is privately owned.

Saproxylic beetles recorded include the following:

- Red-rot: *Ampedus cardinalis*
- White-rot:

- Either type: *Procraerus tibialis, Globicornis nigripes, Prionychus ater, P.melanarius*

6.3.8.6 Moccas Park NNR

Moccas Park (SO341425) and neighbouring areas of Herefordshire is one of the Priority Resilient Ancient Treescapes identified by the Ancient Tree Inventory project (J. Butler, pers. comm.). Moccas Park NNR is one of the top sites nationally for saproxylic invertebrates and originates as a medieval deer park site (Harding & Wall, 2000). The trees were first surveyed by Paul Harding as part of Nature Conservancy Council's Mature Timber Habitat project and oak shown to be the predominant tree species. Herefordshire is well known to have one of the largest concentrations of hedgerow and in-field trees in England, although most of these trees have not yet been mapped for the ATI.

Saproxylic beetles recorded include the following:

- Red-rot: *Ampedus cardinalis, Malthodes crassicornis, Dorcatoma chrysomelina, D. flavicornis, Anitys rubens, Euglenes oculatus*
- White-rot: *Plegaderus dissectus, Aeletes atomarius, Plectophloeus nitidus, Ampedus rufipennis, A. cinnabarinus, A. quercicola, Scraptia testacea*
- Either type: *Euplectus nanus, Procraerus tibialis, Aulonothroscus brevicollis, Ptinus subpilosus, Cryptophagus micaceous, Corticaria alleni, prionychus ater, Pseudocistela ceramboides*

6.3.8.7 Suggested study site

At present, Moccas may be the strongest candidate site.

6.3.9 Summary of recommendations for 2015 study sites

The sites which were initially recommended for the project are as follows:

ATI focal areas	First choice	Possible alternatives
South-East	Knepp Castle Estate (Private)*	Cobham Hall Estate (Private & NT)
Thames & Chilterns area	Stowe Park (NT & Private)*	Crown Estate, Windsor
East Anglia	Wimpole Hall Estate (NT)*	Blickling Hall Estate (NT)
Central Midlands	Needwood/National Forest (Private)	Calke Park Estate NT) Thoresby Estate, Sherwood (Private)
West Midlands	Moccas Park Estate (Private & NNR)	Forthampton Oaks (Private)
South West	Killerton Park Estate (NT)*	Woodend Park, Shute (Private)

*First choice sites where currently available information suggests that the area will be suitable for the study and where the ownership suggests that it should be relatively easy to get permission

The project team agreed in late October that the project would focus on the four asterisked sites.

A proportion of the local project work may be achievable using a combination of support by local volunteers (Knepp), local National Trust staff (Killerton, Stowe & Wimpole) and local saproxylic experts (Killerton & Stowe). It makes sense that this site-based work is organised locally rather than nationally, with the whole project being coordinated nationally.

With National Trust estates and their prominent public access, it would seem sensible to have signs about the project made up and attached to the trees holding traps. These would inform interested visitors about what the traps are for and hopefully avoid vandalism.

6.3.10 Recommendations for additional future study sites

The search for potential study sites has demonstrated a severe lack of knowledge about the tree populations within the landscapes immediately surrounding sites known to be rich in saproxylic invertebrates. Even sites located within large agricultural estates owned by the National Trust lack adequate tree data due to the past emphasis on mapping of ancient or notable trees rather than veteran trees. **Before any further sites can be added to the project there is a clear need for preparatory fieldwork to investigate the surrounding landscape and to map all potentially suitable veteran trees**. Some of this preparatory work might be achievable using suitably trained volunteers.

An additional difficulty is that tree mapping projects have conventionally focused on the larger girth suite of trees and in most cases have not covered smaller girth trees showing red-rotten heartwood in cavities. This raises difficulties in determining just how isolated individual trees actually are.

It is also important to note that previous survey work has not necessarily gathered the information about the trees required for this particular project. This means that even sites where surveys have been carried out, further work is required to complement the existing information with data in relation to decaying wood habitat.

6.3.11 Recommendations for analysis of existing data

There are additional sites where extensive use of vane traps has already taken place and where - it is suggested - some answers to the key questions may already be available were targeted analysis to take place; where species have been sampled from specific and localised trees across varied landscapes. A complementary study of existing data from Richmond Park, Epping Forest and Essex County Council sites, etc might best be achieved through a series of student projects.

6.4 What should the sampling strategy be?

Proposed study design 1

The sampling strategy should include three different types of tree configurations at each site. The first being the “source” population should contain a patch with at least 15 suitable veteran oaks not more than 250 m from one another. The second should include patches with between three and five veteran oaks also at a distance of not more than 250 m from one another. These small patches should be at varying distances from the “source” patch from between 500 m and 3000 m. The third should be individual veteran oaks, also at varying distances of between 500 m and 3000 m.

The identification of suitable locations within each proposed site will depend on complementary field work in combination with existing survey data.

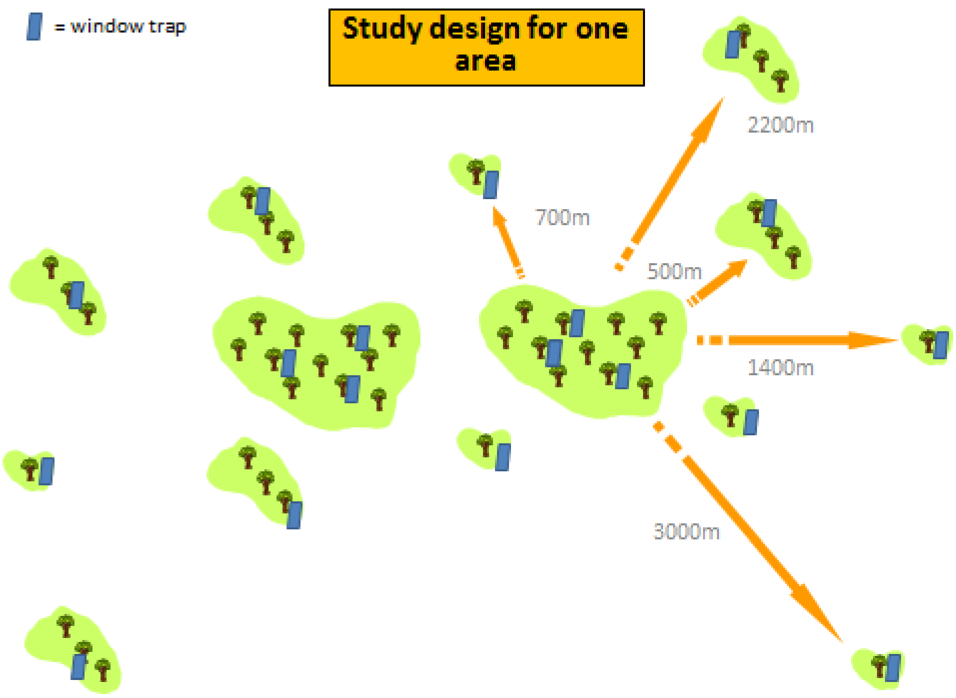

Fig.6. An illustration of how the survey site might look in terms of patches and distance between patches, as well as the location of traps.

Two alternatives are presented regarding the numbers of sites and number of traps. The first alternative is considered to provide a more robust statistical basis for analysis. It may however prove to be difficult to find adequate numbers of trees and patches for the numbers of traps proposed.

	Area 1	Area 2	Area 3	Area 4
Traps on trees in core patches (min 15 hollow trees with max 250 m distance between the trees)	7	7	7	7
Traps on trees in small groups of varying size (3-5, all not more than 250 m from one another) and at varying distances between 500 and 3000 m from the core patches	10	10	10	10
Traps on single trees at varying distances of between 500 and 3000 m from the core patch	10	10	10	10
Sum	27	27	27	27
Total				108

The second alternative involves fewer traps at each site, but more sites. Both options involve a total of 108 traps. This is considered to be a sensible number given the potential natural variation that is expected from the sites.

	Area 1	Area 2	Area 3	Area 4	Area 5	Area 6
Traps on trees in core patches (min 15 hollow trees with max 250 m distance between then trees)	6	6	6	6	6	6
Traps on trees in small groups of varying size (3-5, all not more than 250 m from one another) and at varying distances between 500 and 3000 m from the core patches	6	6	6	6	6	6
Traps on single trees at varying distances between 500 and 3000 m from the core patch	6	6	6	6	6	6
Sum	18	18	18	18	18	18
Total						**108**

The location of the traps in the core patches would be randomly selected, as will be the case in the small patches (3-5 trees).

6.4.1 Proposed study design 2

A key aspect for understanding species distribution is how they respond to habitat factors and different spatial scales. There are two key issues that we aim to find the answer to within this study:

1. Is there any difference in the saproxylic beetle communities between hollow oaks which are in concentrations (often in parks or wood pastures) and hollow oaks that are isolated in the agricultural landscape?
2. Do different species require different densities of oaks?

The first proposed study design was based on a theoretical model (prior to having the information about the actual site specific conditions) where the beetle fauna would be studied from hollow oaks at specific distances from the core area containing a concentration of hollow oaks. Following field visits - establishing the actual distribution of hollow oaks in the four study areas - a modification of the study design was required.

The modified design is more flexible and works better in landscapes with less hollow oaks or if the oaks are distributed in different ways in the different study areas, which more closely reflects reality. The modified design involves identifying 27 hollow oaks in each of the study sites, of which 7 are in the core concentration area (this is parkland in each of the four study sites identified) and 20 in the surrounding agricultural landscape (more isolated trees). This quantity of traps (as in the first proposal) provides a level which gives a robust statistical power for a reasonable amount of money and survey effort. The study will provide a gradient of oaks with varying distances of other hollow oaks around them. Ten traps is an adequate number to provide statistically robust answers regarding the species composition within the core area. The surrounding landscape is however geographically larger and thus more traps are required to help ensure that we take account of the fact that it may be more difficult to trap the species, the populations may be smaller and the gradient in terms of density of hollow oaks is more variable.

Another advantage with this design, in addition to the fact that it allows for the actual variation in the landscape, is that we will obtain results for both species richness and for single species. For each hollow oak, we will examine if it is possible to calculate how many other hollow oaks there are within various radii (50 m, 100 m, 250 m, 500 m up to 2 km – and ideally up to 3 km if feasible). In Sweden a similar study (Bergman et al 2012) showed that 2100 m was the distance at which the density of hollow oaks had the greatest explanatory effect on the species richness. This is why it is important to spread the traps on oaks in a gradient from isolated trees, to trees standing in a situation where there is a relatively high concentration of hollow oaks close by. The trees suitable for trapping within the core area will be selected based on suitability. In terms of the trees in the wider landscape, once again, they will primarily be selected based on suitability in terms of habitat quality, but also in terms of proximity of other hollow oaks, ensuring that there is a variation in the density in comparison with the core area. Ideally the trees identified for trapping would be randomly selected from all suitable trees but this will not be feasible with the identified study sites as insufficient information is currently available on the features of all of the trees present.

We will also need to measure a number of other factors regarding the individual hollow trees, which may help explain the reason for the variation in the species collected in the beetle sampling, such as girth, degree of openness, hollow stage and type of decay, the quantity of wood mould and where the beetle traps are located. This information is important for understanding how the species react in relation to the access to hollow oaks at different scales (temporal and geographical) and the conditions in and around the trees.

Following the identification of the beetle samples to species level and the number of individuals, several different types of statistical analyses will need to be carried out. This will include multivariate statistical analyses, such as DCA (detrended correspondence analysis) and PCA (principal component analysis) with the help of the programme CANOCO (to identify which parameters most significantly explain the presence of the species), but also so-called Wald-analyses. We will need to identify the distance (radii) at which the oak density has the greatest explanatory effect on the species richness and occurrence of each beetle species. For each beetle species we will, for each radii, run a simple binomial generalized linear model (logit-link; Statsoft 2007) to help predict the occurrence of the species by the density of hollow oaks at a given radius. Then we will plot the Wald-statistics obtained from the models against a given radii at which the oak density had been measured. The maximum Wald value will indicate the radius where the oak density explains most of the variation in the probability of finding the species. This value is called the characteristic scale for the species following Holland et al (2004). We will be dependent on the number of individuals collected for each species. This is why we need to use a large number of traps in different locations and different situations. It is likely however, even with large numbers of traps, that there will be too few individuals for the most uncommon species, in order to draw conclusions based on those. There are also likely to be species collected that have a characteristic habitat scale which is at a greater distance than the study area size included in this project. The results will provide important knowledge regarding how the current landscape with old oaks functions for the saproxylic fauna in the UK. This study may also in the future, be expanded to cover other species and aspects.

6.5 Experience from field visits to identify trees suitable for trapping

6.5.1 Knepp

The Knepp Castle Estate was subject to an extended field visit over 25th - 27th November 2014 as part of a field trial of study design 1 and led to the adoption of the modified study design 2. Trees of the wider estate were explored and 21 trees suitable for trapping were identified. A further ten trees within the formal parkland landscape were identified by the Estate itself on 27th January 2015, using a guidance sheet provided for the purpose.

Although the estate has been progressing with a detailed tree by tree survey as its contribution to the Ancient Tree Inventory, there is no mapping which distinguishes the areas already covered by that survey work from those areas as yet unsurveyed. Coverage of the estate is currently very incomplete. Areas with no mapped trees may either have no notable trees or may not have been investigated yet. The November visit therefore focused particularly on known concentrations of mapped trees, supported by discussion with the surveyors and the owner. From the new fieldwork, it quickly became clear that the ATI survey data was not sufficient for the purposes of the study; that assumptions about hollowing have been made from external features such as bracket fungi, lost crown, etc, rather than just documenting the presence of visible decay and cavities. None of the trees have been tagged by the estate.

The farmland has large numbers of hedgerow trees and this meant that a primary tree by tree survey was needed in order to provide the data required by the present study. About 12 hours were spent inspecting approximately 300 trees but locating just 21 trees suitable for trapping. The hedgerow trees were found to be mostly of very different form and age class to the core parkland trees.

Ironically, trees that have been crown lifted when intensive farming was being carried out are those most likely to show the signs of early hollowing - a lot of the cut scars seen have solid dry and seasoned heartwood exposed, with no obvious decay progressing, although there might have been decay within. But in a number of such cases heartwood decay was present in the cut limbs and so the old cuts had created open sockets in the tree trunk with visible hollowing and/or decay. A proportion of the hedgerow trees were found to be covered with ivy growth making identification of hollowing impossible.

6.5.2 Killerton

The Killerton Estate was subject to a day's field survey on 10th December 2014 and 8 trees suitable for trapping identified across Columbjohn Farm (Culm Valley, west of Killerton Park) and 11 across Ashclyst, Burrow, and Channons Farms (Clyst Valley, south of Ashclyst Forest). A further two trees were selected on Columbjohn Farm on 12th December and ten selected within the historic deer park area close to Killerton House.

The farmland trees had been subject to detailed mapping and recording by Mosaic Mapping for the Killerton Estate in the past, but the parkland trees appear not to have been mapped digitally by the Trust. Some of the trees have numbered tags relating to Tree Inspection Surveys, carried out for health and safety reasons (Ed Nicholson, pers. comm.). The estate also includes the extensive area of largely plantation woodland - Ashclyst Forest - which was planted on open heath pasture and agricultural fields from 1818 onwards. The veteran oaks engulfed within the forest also appear not to have been mapped digitally.

The older farmland and parkland trees are of a very comparable age and form and may be derived from a single wider landscape of such trees – see 6.3.6.2. The farm trees include free-standing examples as well as others deep within hedgerows. The latter category proved to be relatively difficult to gain access to for recording purposes due to multiple barbed-wire fencing, deep ditches and even some tree-planting strips. The presence of two surveyors working simultaneously on both sides of a hedgeline proved essential in order to pass tapes around the trunks for girthing and to adequately record the presence of cavities, etc. The farming practices appear to relate to modern industrialised agriculture, the tenancies mostly being intensive commercial dairy enterprises.

6.5.3 Stowe

Stowe was subject to a full day's field survey on 16th December 2014, a shorter visit on 6th January 2015 and another full day on 10th February. Seventeen trees suitable for trapping have been identified across the farmland to the north, together with seven in the Deer Park, two in the adjoining avenue on the west side and one in the Landscape Gardens. The last will enable a public information notice to be placed in the visitor hot-spot informing visitors about the project. Other suitable trees have been identified along the Water Stratford Avenue should further trees be required for trapping. Some of the farmland trees lie on land owned by Stowe School rather than the National Trust but permission had been given to include these areas for trapping. The third visit enabled both completion of the coverage of the NT land and an exploration of the 2km buffer zone (see 6.4.2) to identify any other hollowing oak outside of the Trust's ownership. One particularly notable ancient oak was found to the north-east of the NT land, measured at 8.83m girth. Two private areas were observed which contain veteran oak but which were not entered as the ownership was not known - around Boycott Manor and on the west side of Charmandean School, owned by Tile House Estate. The Boycott Manor area is best included within the defined core site as it is parkland and lies in an area with no identified trap trees nearby so the density of trees with cavities here is not relevant. The Tile House Estate oaks however are in an outlying area of farmland and so will need to be mapped either in advance of the trapping study or as part of that study.

A key feature of Stowe is that the farmland trees include ancient oaks whereas the parkland and landscape garden areas only have mature and veteran oaks. Historic trees have survived better in the farmed land than in the central areas most affected by 18th century landscape gardening.

6.5.4 Wimpole

The Wimpole Estate was initially explored on 7th January 2015. The National Trust's forester, Simon Damant, identified the required seventeen oaks within the farmed areas and guided the surveyors to their locations. The trees all lie within hedgerows or alongside field drains. One of the selected trees lies on a neighbour's land adjoining the estate. As with Stowe, these trees appear to be the oldest and most historic within this landscape, including ancient oak pollards. Ten trees have also been selected within the landscaped parkland, including one within the gardens, enabling local publicity about the project.

A return visit over 10th and 11th February 2015 completed coverage of both the parkland and the National Trust farmland as well as extending the exploration out to 2km from the external boundary of the core area. Three areas of neighbouring farmland were found to include small numbers of hedgerow oaks – South Sea Farm to the north, Low Barns Farm to the north-west, and Mill Farm, Arrington, on the west side. The Arrington area is notable for three ancient oak pollards along one particular hedge-line.

The outer 1 to 2 km of the buffer zone includes Eversden Wood. This is an ancient woodland site much discussed by Rackham (2003) and designated as an SSSI in 1954. The wood is known locally for its many pollards, an unusual feature in a coppice. The wood was in multiple ownership in the past, hence each compartment was managed by a different person - the pollards are mostly along boundary banks and there is also one compartment of former wood pasture. Rackham (loc cit) maps about 25 pollards but these do not include most of the ones seen there in the brief exploration in January 2015, so the total count is likely to be much more than the figure mapped. Some of the pollards are oak and have extensive development of red-rot visible. The northern shelterbelts of Wimpole Park were added to the SSSI by the last revision (2003) after a maternity roost of the rare Barbastelle bat had been discovered there, the designated site now being known as Eversden and Wimpole Woods SSSI. The site has subsequently been declared a Special Area for Conservation (SAC) for its Barbastelle roost.

6.5.5 General issues

6.5.5.1 Inadequacy of the current tree survey data

The priority for each site visit was to locate trap-suitable oak trees and to note down any other oak trees within the immediate area which could be seen to have heartwood decay and/or hollowing; tree species other than oak were not taken into consideration although these may of course be supporting comparable heartwood decay and hollowing assemblages (see next paragraph). Where previous tree mapping was available it mainly provided guidance on areas that might be worth inspecting – it was found to be inadequate for precision in tree selection. This means that none of the study sites have been subject to a full and detailed assessment of the non-woodland trees in terms of the project's requirements. The result is that **it will not be possible at this stage to calculate absolute distances of each identified trap-suitable tree from other trees with heartwood decay and/or hollowing, and hence to calculate local densities of such trees.** It will however be possible to compare the fauna of the parkland trees with that of the farmland trees, and to analyse species-richness in individual farmland trees in relation to distance from the outlying trees within the area of parkland.

6.5.5.2 Influence of other tree species

The focus of the field visits has been on identifying oaks with heartwood decay suitable for vane trapping, especially red-rot habitat. Some of the sites also contain other species of tree with veteran characteristics, including at least one example of a field maple exhibiting red-rotten heartwood. It was not possible to map these within the timescales of the winter 2014/15 fieldwork.

6.5.5.3 Ivy obscuring tree cavities

Ivy was found to be a serious problem with farmland trees, where lack of grazing has enabled ivy to expand across the tree trunks and may mask any cavities that might be present.

6.5.5.4 Potential conflicts between vane-trapping and other wildlife interests

The issue of running traps in the presence of barn owl was raised at Wimpole where one of the farmland oak pollards had an accumulation of owl pellets and faecal debris beneath. Wimpole also has a maternity roost of the rare Barbastelle bat, and all sites potentially have bat populations.

6.5.5.5 Impact of trapping on saproxylic beetle populations

Another important consideration is the potential impact of the proposed trapping on the saproxylic fauna (Alexander et al 2014). In many cases, the identified trap-suitable trees constitute the majority of the largest hollowing trees and the possibility must be considered that continuous all-season trapping has the potential to have a detrimental impact on the local populations of rare and threatened species. This impact could be reduced by applying an intermittent sampling protocol – see 6.6.1.6.

With increasing interest in vane trapping, it is perhaps time to consider developing some guidelines for their responsible use. There is presumed to be no real issue where only a small proportion of the veteran trees at a particular site are being studied, but there must increasingly be potential for damaging impacts on the local beetle populations where a site has relatively few veteran trees – a common situation across the English countryside - and where trapping involves an increasingly high proportion of the veteran trees. Tree selection for trapping will inevitably target the trees that have the most interesting looking cavities and heartwood decay.

6.5.5.6 Woodland as barriers to saproxylic mobility

It is thought that blocks of closed-canopy woodland may act as barriers to movement of saproxylic beetles (see 1.1). The presence of such blocks within the landscapes under study needs to be considered when analysing the data from the studies. With this issue in mind, no trees close to woodland were chosen for trapping, although hollowing trees were mapped where they lay close to trap trees. At Killerton Park Estate, for instance, Ashclyst Forest was given a relatively wide berth.

Parklands tend to have shelterbelts around their margins and this is very apparent around Wimpole for instance. Such relatively narrow belts of dense stands of high-forest-form trees might also act as barriers to movement for sun-loving insects.

6.5.5.7 How comparable are the four study sites?

The four sites were selected on the basis that these were the only areas where it was already documented that they were both foci for a relatively species rich assemblage of saproxylic beetles and held sufficient veteran oaks in the surrounding agricultural landscape. As the fieldwork progressed an appreciation of both the similarities and the dissimilarities between the sites also developed. What were initially perceived as strengths of the sites often began to be perceived as weaknesses – this is discussed in more detail below.

The location of Stowe on the southern edge of the former medieval Whittlewood Forest actually means that the defined study site may not be an isolated hot-spot within a wider landscape relatively devoid of veteran oaks, in contrast with Wimpole which clearly is a relatively isolated hot-spot of saproxylics. Whittlebury Park, for instance, is within 5 km to the north. This may suggest that the tree survey needs to expand out into a 5 km buffer zone rather than the 2 km zone adopted for the proposed project.

Killerton's apparent strength in being a large-scale hot-spot of veteran oaks means that the overall population size of veteran oaks locally is substantially greater than those of either Stowe or Wimpole. It is still an apparent hot-spot for veteran oaks within the local landscape but the scale is significantly different.

Knepp's apparent strength in being within the relatively well-wooded Weald means that the landscape surrounding the core is relatively rich in veteran oaks at the 5 km scale and beyond, unlike any of the other three sites; there remains the question however of to what extent the density of veteran oaks varies given that the surrounding landowners are said to have removed many of their hedgerow trees as a part of agricultural intensification whereas this did not happen at Knepp. A wider study of oaks in the landscape would be required in order to quantify the differences in oak density.

An implicit assumption of the project brief is that the area of defined parkland or wood-pasture - and which is believed to be notably rich in saproxylic fauna - has relatively high density of trees. An important feature of three, if not all four of the selected study sites, is the frequency of veteran trees in the surrounding landscape – this is largely why they were chosen of course. Killerton Park is an enclosure within a landscape of veteran oaks but does not have a notably high density of ancient oaks itself, although the density is relatively high in comparison with the surrounding farmland. There is also the complication presented by the large Ashclyst Forest which stands within the otherwise farmed part of the estate and contains old hedge banks with pollards. At Stowe it is the adjoining farmland that is notably rich in large old veteran oaks, with the parkland areas more characterised by younger veteran oaks. At Wimpole, like Stowe, it is the adjoining farmland that has a scatter of veteran oak pollards, whereas the parkland trees are generally of a younger generation of trees. Wimpole also has Eversden Wood - with its old internal pollards - within the farmland. Knepp is somewhat different in that it lacks older generation oaks, and so the veteran oaks across both the farmland and the parkland are of more comparable age structure, but the parkland oaks show increased levels of veteranisation. It could be argued that the study sites are not typical of the situation across England more generally, although this remains to be demonstrated; no other sites have been subject to such close scrutiny of the oaks.

6.5.5.8 Historical aspects

No analysis of historical tree distributions and densities has been attempted, e.g. using early Ordnance Survey mapping. This might provide important insights into the quality of the beetle fauna that will be detected once the vane-trapping exercise has been carried out. It is therefore recommended that consideration is given to commissioning a separate project to address this issue.

6.6 Methodological recommendations

6.6.1.1 Definition of core site

All four study sites comprise historic parkland and surrounding agricultural land. The English Heritage (EH) Register of Parks and Gardens in each case refers to a mapped extent of designed landscape. However, this may or may not coincide completely with the concentrations of old parkland trees which are the focus of the present project. It is therefore recommended that the project adopt the ecological boundaries of wood-pasture type habitat as the core site rather than the registered landscaped gardens:

- At Killerton Park, the recommended core site is the old deer park which lies to the north-west of Killerton House; the EH site is much more extensive and includes areas of 18th century landscape park and sections of farmland with trees planted strategically to enhance the views from the house and garden.
- At Knepp, the EH registered land is more or less coincident with the concentration of parkland trees, and is the recommended core site.
- At Stowe, the EH site covers a very extensive area of farmland as well as the more formal landscape, and it is recommended that the core site should be the Old Deer Park, the Landscape Gardens and the adjoining Water Stratford Avenue as these contain the concentration of parkland trees.
- At Wimpole Hall, the EH registered land is more or less coincident with the concentration of parkland trees, and is the recommended core site.

6.6.1.2 Identification of trees suitable for trapping

Ideally a full and targeted tree survey is needed in order to provide the required identification of trees which are suitable for vane trapping. Existing tree survey data, eg where available from surveys based on the Specialist Survey Methodology (SSM) which was developed from English Nature's Veteran Trees Initiative, or from the Woodland Trust's Ancient Tree Inventory, may help to identify areas of potential interest but neither provides a sufficiently detailed record of the extent of decay and/or hollowing nor on the precise position of the access points, nor on the suitability for placement of vane-traps. Indeed, some of the trees selected for trapping for the present project would not necessarily have featured from either methodology as cavity formation is possible in relatively small girth trees which would not have been mapped as veterans or notable trees. In some survey methodologies these would have been classified as mature trees with veteran features (MV) as opposed to veteran trees.

No central repository is currently available for tree survey data. This makes access to such data for studies such as the current one problematic. Even where the data is held by a national organisation such as the National Trust, site records may be held nationally, regionally, or at the property concerned, depending on how and by whom they were commissioned. The officer responsible will change over time and the software packages available for managing the data will also change over time. There is a clear need for national guidance on the management and maintenance of such data; otherwise it will gradually become degraded and then lost.

A survey aimed specifically at the requirements of the current project needs to:

- Map and document all trees with suitable habitat, using a shortened and more targeted version of the Specialist Survey Methodology of English Nature's Veteran Tree Initiative, and in particular:
    - identify which exhibit visible heartwood decay and/or hollowing
- note the situation of the tree in terms of vegetation and proximity of other trees and shrubs
- record the detail of the above, especially position of access points to cavities, and
- decide on their suitability for vane trapping, eg height of cavities, public access, livestock issues, etc.

This would enable random selection of trees to be trapped, to strengthen the statistical basis for analysis of the trapping results. Again, ideally, the mapped trees should be entered onto the Ancient Tree Inventory database – using if necessary the category MV - to ensure that the record remains in the public domain, for future studies.

An important consideration when planning survey work in farmland is the need to survey hedgerows from both sides as access to the trees can be problematic. Two surveyors were found to be needed at Killerton and Knepp in particular, so that any trees identified could be adequately documented and their girths recorded. Killerton is very much a modern intensive agricultural estate: the hedges tend to have barbed wire fences either side of the bank and ditch, and in some cases parallel strips of new tree planting.

A decision was taken to exclude trees as trap-suitable where the only suggestion of hollowing was the presence of one or more woodpecker holes. While these do suggest internal decay, the extent of that decay is not normally discernible and the hole(s) may be being used by birds or bats, thus rendering them unsuitable for trap placement.

6.6.1.3 Map digitising

The digitisation of the tree data was determined partly based on previous survey experience and partly on the requirements of the proposed study. The following describes the practices adopted and it is recommended that this should be the standard for similar work in the future.

Trees with hollowing visible from ground inspection were categorised as either ‘trap suitable’ or ‘other trees’. The latter category refers to trees which appeared less suitable for trapping owing to a variety of considerations – i) the degree of hollowing may not have been great, ii) any cavities were high in the crown and out of easy reach, iii) the best position for trapping would make the traps too vulnerable to vandalism or damage from livestock.

Trap trees were located by handheld GPS equipment (global positioning satellite) and the locations adjusted when this data was superimposed with air imagery; an extra set of “adjusted” eastings and northings is shown in the far right of the spreadsheet, indicating that the position has been adjusted using the air imagery. In one or two instances, it may be that the location is further refined by those setting the traps in place. Note that where a trap tree coincides with an ATI tree record, the precise locations are often different, as the ATI tree locations do not always appear to have been referenced against air imagery.

Our “other” trees are located manually with reference to printed maps and aerial photography – when digitising their locations it is not always possible to determine exactly which tree on the imagery they are –in a hedgerow or spinney they could be out by one or two trees in any direction – but this should be evident on the ground.

6.6.1.4 Categorisation of degree of apparent hollowing

It is important to record the hollowing characteristics of the oak trees when surveyed. This will allow easier identification of suitable trees for traps. Jansson & Antonsson (1994) devised a hollow scale of 1 to 4 regarding the size and degree of hollowing under a height of 5m (allowing access for trapping), see illustration below.

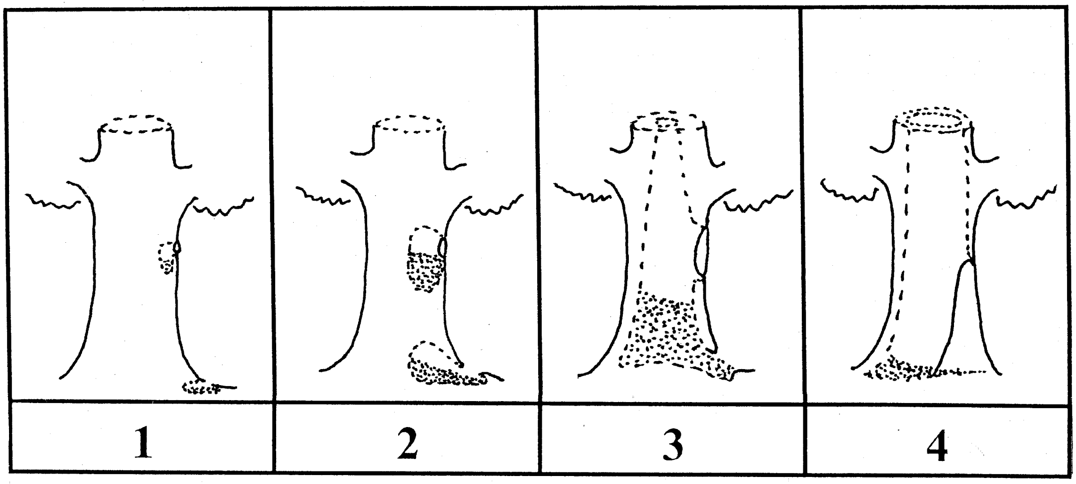

Figure 7: categorisation of degree of apparent hollowing

This does not however cover situations where a large branch has broken away from the trunk and resulted in a tear which has created a large exposure of heartwood decay. Also the internal decay illustrated is indicative and does not imply that decay and hollowing necessarily follow these patterns. A modified categorisation is proposed but based on the same four stages.

This can be described as follows:

1. A small cavity high on the trunk with decay and/or hollowing evident within
2. A medium-sized cavity high on the trunk with decay and/or hollowing evident within
3. A large scar/tear to the main trunk exposing substantial decaying heartwood within
4. A completely hollow trunk

Stage 1 can be difficult to discern in the case of trees affected by crown-lifting, whereby lower lateral branches have been sawn off, for a variety of reasons. The saw-cut heartwood may appear undecayed from the vantage point on the ground below but the heartwood behind may be decaying. The surrounding sapwood may also have decayed around the undecayed heartwood resulting in small slit-like cavities which may or may not provide access to heartwood decay within. The type of cavity caused by crown-lifting, and where decay and hollowing is apparent, has been referred to as a 'socket' for the purposes of the present study. Where only the cut end of solid heartwood is visible from the ground then the tree is not assessed as hollowing, although there can be problems with visibility for higher cuts.

6.6.1.5 Categorisation of degree of visible heartwood decay

A parallel numbering scheme has been developed for the purposes of the present project by which the quantity of heartwood decay that is apparent is scored on a 1 to 4 scale. Again, this is based on the decayed wood that is visible from the ground, with no assumptions made about what may be happening in the interior of the tree. The typical socket type of decay is scored 1, for example. It is important to appreciate that a completely hollowed tree – scoring 4 for hollowing – may actually contain very little heartwood decay. Such trees are also scored 1 for decay. The two categories together therefore help to describe the visible features – the hollow trunk has 4 for hollowing and 1 for decay, whereas a crown-lift socket would have 1 for hollowing and 1 for decay.

Both of the categories may be modified as a result of the trap-setting exercise, when use of a ladder will provide improved access to the cavity and decay. A ladder is not recommended for the initial tree survey as it tends to slow things down.

6.6.1.6 Proposed trapping programme

Before deciding on the optimal time of year for trapping it is instructive to examine the results of other published studies from Britain. The Hatfield Forest study (Drane & Warrington, 2010) used five trapping periods of 14-16 days each across the field season:

- 17th April to 1st May
- 20th May to 5th June
- 23rd June to 7th July
- 20th August to 3rd September
- 15th September to 1st October

The trapping period was broken up in order to reduce the quantity of material that would need to be identified (S. Warrington, pers. comm.).

May to July is often regarded as the key period for saproxylics but significant species were found in each period, including important species developing in decaying heartwood (see table below). Their results might suggest that ideally, flight trapping should cover the spring flight period of click beetles as well as the high summer period for red-rotters such as *Euglenes oculatus*.

Table 1: Notable species found by trapping period, Hatfield Forest study 2008
(Bold denotes significant heartwood decay fauna)

Trapping season	Total catch of notable species	Notable species only trapped in this period
April/May	5	***Aderus populneus***, *Pediacus dermestoides*, ***Ischnodes sanguinicollis***
May/June	7	*Hedobia imperialis, Tillus elongatus,* ***Procraerus tibialis,*** *Ischnomera cyanea, Conopalpus testaceus,* ***Mycetochara humeralis, Prionychus ater, Pseudocistela ceramboides***
June/July	13	*Xyleborus dispar, Taphrorychus bicolor, Plegaderus dissectus, Lymexylon navale, Prionocyphon serricornis, Anaspis thoracica*
August/Sept	6	***Euglenes oculatus***, *Cicones variegatus, Synchita humeralis, Triphyllus bicolor*
Sept/Oct	1	

Many of the key click beetles are active fliers in May and June, eg *Ampedus cardinalis, A. elongatulus,* and - despite the Hatfield Forest result - even *Ischnodes* *sanguinicollis. Aderus populneus* is also known to fly in the same period. Although *Euglenes oculatus* is regarded as a high summer species, adults have been found active from May through to late July; again, the Hatfield Forest experience appears somewhat anomalous and may reflect a late season that year.

The Essex study ran from late June, but acknowledged that an earlier start would have been better. The delay had been due to the time taken to make and position the traps. They used three trapping periods:

- 20 June to 4 July
- 18 July to 1 August
- 13 to 26 September

The detail of their results is not currently available.

The initial proposal for this Natural England project was that the traps be put up around 1st May, emptied around the 10th June and then taken down and emptied around 20th July. This would involve three visits, which keeps costs down, but allows for the majority of the key flying season to be covered. However, the concern that continuous trapping has the potential to be damaging to rare and threatened invertebrates – especially in sites with relatively few old hollow trees - suggests that the Hatfield Forest and Essex approaches of intermittent trapping might be advisable. The proposal has therefore been revised to trapping periods of approximately two weeks duration followed by two weeks without trapping:

- Mid May to early June
- Late June to early July
- Late July to early August

The traps may be left in situ during the rest period with just the collecting bottle removed, so that all trapped insects pass through the traps unharmed. Although this would involve six visits, the middle four are less time demanding. If local trap operators can be found then the costs should not be prohibitive.

The trapping programme also needs to be flexible, to allow for unusually dry or wet or windy seasons; the programme of visits may need to be adjusted to allow for seasonal variation, although this may be difficult to arrange in practice. In addition, we need to be sure that trapping at all sites is managed in the same way, so as to avoid too much variation in the trapping times, which would undermine any statistics. Additional visits may be required to check for damage and to adjust traps, as necessary, rather than risk a whole run being lost. Local operation of the traps would make this more feasible and cost-effective.

6.6.1.7 A protocol for trapping practice on veteran trees

One of the outcomes from this study design process has been the concern that large-scale trapping has the potential to be damaging to the invertebrate populations under investigation. It is tempting to place traps on each on the trees which appear to be the richest in habitat. But such an approach is likely to have the greatest impact on invertebrate populations breeding in veteran trees. The following guidelines are therefore proposed (these have been discussed with two active European saproxylic beetle workers: Marcos Mendez (Universidad Rey Juan Carlos, Madrid) and Dmitry

Telnov (Riga Museum, Latvia), and posted on the European saproxylic e-group for wider debate):

When planning a large-scale study of the saproxylic invertebrates of a particular area:

- If trees with cavities and signs of internal heartwood decay are abundant across the proposed study area then trapping may be assumed not to pose a significant risk to population viability of the target invertebrates;
- If trap-suitable trees are scarce, then first map all of the trees which appear suitable for trapping, and make a random selection of trap trees rather than rely on personal preference;
- Place traps on no more than 50% of the identified trap-suitable trees;
- Consider adopting an intermittent trapping programme in preference to continuous trapping across the field season, eg two weeks on, two weeks off.

6.6.1.8 Local trap operation

With the four study sites being well dispersed across southern England, central operation of the trapping does not seem sensible. Ideally local people should be recruited to set up and operate the traps. These might be sub-contractors and/or volunteers, depending on the skills available locally. If this is adopted then clear instruction will be needed to ensure standardisation across sites. A training session may be required – this could best be achieved at the time when the traps were being placed on the trees at the start of the field project.

6.6.1.9 Trap production

Ideally a set of standardised vane traps should be made up specifically for this project but it may prove feasible to re-use existing traps where these are in storage. Natural England currently hold 30-40 cross-vane vane traps which are not in use (J. Webb, pers. comm.), the veteranisation project has about 84 single-plane window traps in storage (V. Bengtsson, pers. comm..) and other cross-vane traps may also be available (M. Telfer, pers. comm.). The Royal Parks Agency has current plans for the use of their stock so these will not be available for use in 2015 (G. Jonusas, pers. comm.). Combinations of these traps could only be used for the current Natural England study where the traps have been made up to the same specification.

6.6.1.10 Breaking down the beetle catches into taxonomic and functional groups

Although the focus of the study design has been on heartwood-decay specialist beetles, and red-rot in particular, the trap catches will include other saproxylic invertebrates. It is recommended that analysis of the catches should consider as broad a range of attributes as possible. This includes taxonomically - by species and family, and ecologically – bark assemblages as well as heartwood assemblages, predator guilds as well as fungivore guilds, etc.

6.6.1.11 Inclusion of other sampling methodologies

The study brief included a question about whether or not other sampling should take place in parallel to the main trapping project, eg hand-collecting. However, the focus of the project development has been on focusing on the core project and keeping costs down. Any additional recording would add to the time required per site and would produce unstructured data that could not be used in the analysis. It is perhaps best avoided as an unnecessary complication.

7 Analyses of tree data from the four sites – Knepp, Stowe, Killerton and Wimpole

7.1 Introduction to the approach taken

Data was collated using existing data combined, where possible, with data collected from field visits by John Smith and Keith Alexander (see 6.5). Supplementary field work was carried out at Stowe and Wimpole as a part of an extension to this contract, and further work is in hand at Knepp.

Three different analyses were carried out for each site to try and understand the density of trees with suitable habitat in the landscape, the distances between these trees, and the distances of these trees from the core parkland areas. They are also intended as a tool to help direct further field work which may be required.

1) *Kernel density analysis*
   This is a geographical tool, which is often used in an ecological context, where an overview of the density of a specific factor or quality in relation to the surrounding landscape is useful: in this case veteran oaks with saproxylic habitat features. It provides a smooth picture moving from individual features (trees in this case) out to a specified radius (in this case 1000 m). In other words the picture it creates for this project is the density of suitable habitat trees per square kilometre. The overview provides the opportunity to identify connectivity in the landscape as well as gaps, which is why it was considered a useful tool in the context of this project. In all maps, the redder the colour the greater the density of oak trees with suitable habitat.

2) *Buffer tool analysis*
   This is a different geographical tool, which allows the creation of real buffers around points or polygons at a specified radius. This tool has been used in two different ways for this project. Firstly it has been used in relation to the historic park boundary highlighting a buffer of 100 m, 250 m, 500 m, 1000 m and 2000 m. These buffers help us to identify where in the surrounding landscape the trees are, as well as what areas we may need to undertake further survey work. This also helps to identify the distance gradient from the core parkland and out into the wider (generally agricultural landscape).

   Secondly this tool has been used to help identify clusters of trees which are within varying distances from one another. This is carried out by first creating buffers around each tree (at distances/radii of 100 m, 250 m, 500 m and 1000 m). Where these buffers then overlap, they are joined together to create a “site”. The “site” in this sense shows groups or clusters of trees where they are no further than 200 m, 500 m, 1000 m or 2000 m (2 x radii) from one another.

This tool is useful because it helps to see at what distances, the trees become a connected “site”. This is a key issue for this project in terms of identifying isolated trees from clusters. It is also a useful tool in terms of understanding how the landscape looks for species with different dispersal abilities.

7.2 Wimpole

7.2.1 Kernel Density map.

This map shows two centres where there are habitat trees at a reasonably high density (more than 9 per km2). The areas between have now been surveyed including the historic park. This means that this gives a relatively true picture of the density of suitable habitat trees. The green dots are trees with habitat suitable for trapping and the yellow triangles are trees with habitat but not suitable for trapping. The redder the colour the greater the density of trees. The white boundary is the historic park boundary.

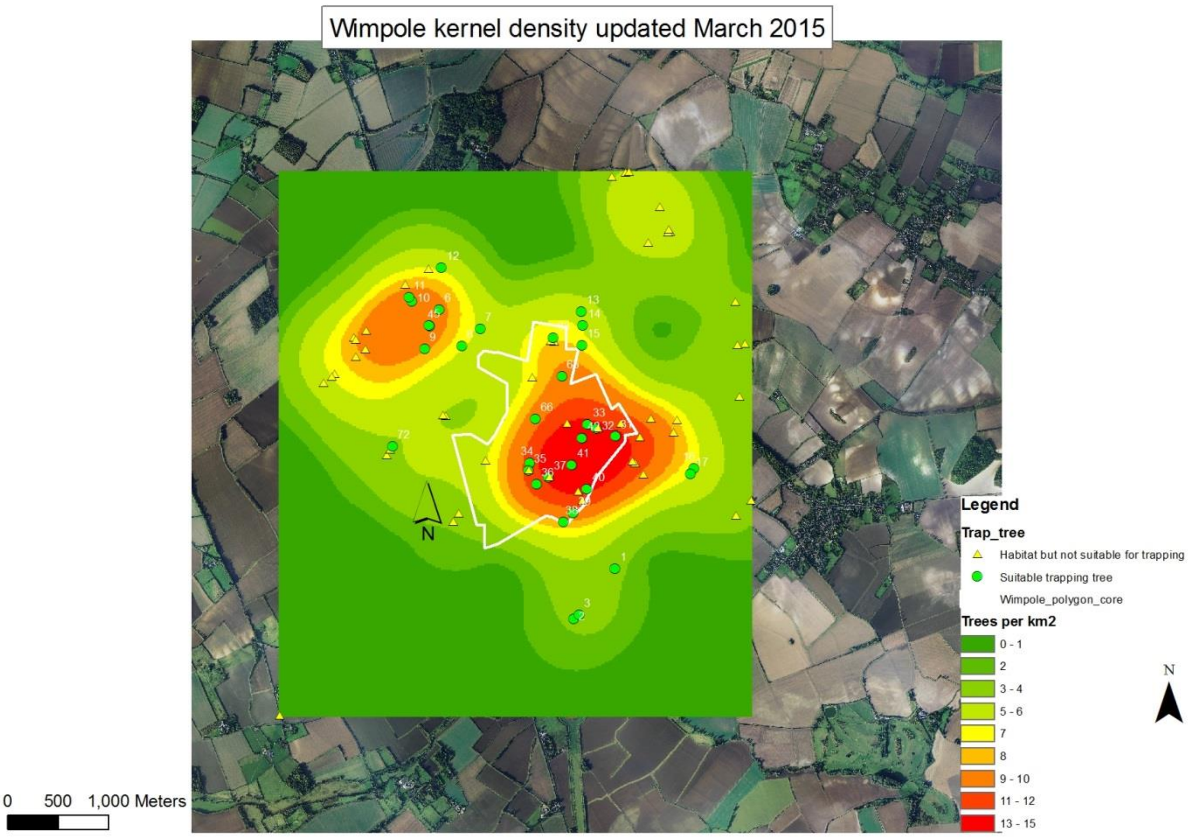

Fig. 8 Wimpole kernel density map

7.2.2 Buffer from core parkland

This map shows the zones out from the core parkland and where the trees are located up to a distance of 2 km from the edge of the parkland boundary. It would be important to be sure that all the suitable habitat trees have been identified within this 2 km boundary. According to the extended survey work (Feb 2015), there are 26 habitat trees in the core parkland, 2 more in the area 100 m out, an additional 11 in the 100 – 250 m ring, an additional 3 in the 250-500 m ring and 16 trees in the 500 m to 1000 m ring, and an additional 23 in the outermost ring and one more tree outside of the 2 km ring. This provides a useful gradient in terms of density of suitable habitat trees, in particular a comparison between the core parkland and those trees up to 2 km from the core area in a north-westerly and south-easterly direction. There are 81 trees with potentially suitable habitat within the 2 km ring.

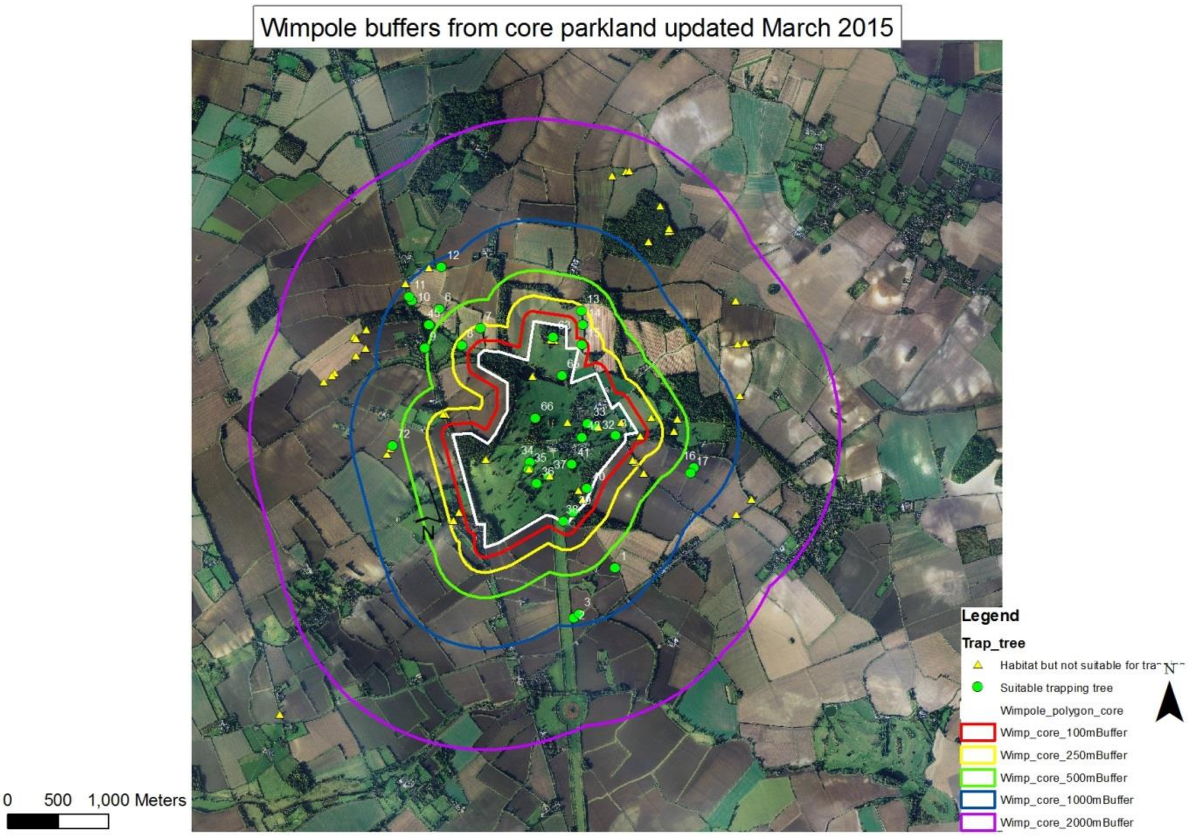

Fig. 9 Wimpole buffers from core parkland map

7.2.3 Tree buffers

This map shows buffers that are joined together based on the clustering of the trees. The numbers on the map indicate the number of suitable habitat trees within the "sites" created using the 100 m radius buffer, which means these trees are not more than 200 m from one another within these clusters. The buffer which was created using a radius of 1000 m (i.e. two trees can be up to 2000 m from on another) contains all of the trees surveyed, apart from one, which provides a useful, totally isolated tree. Once again this map shows where the trees suitable for trapping are as well as the other trees with habitat.

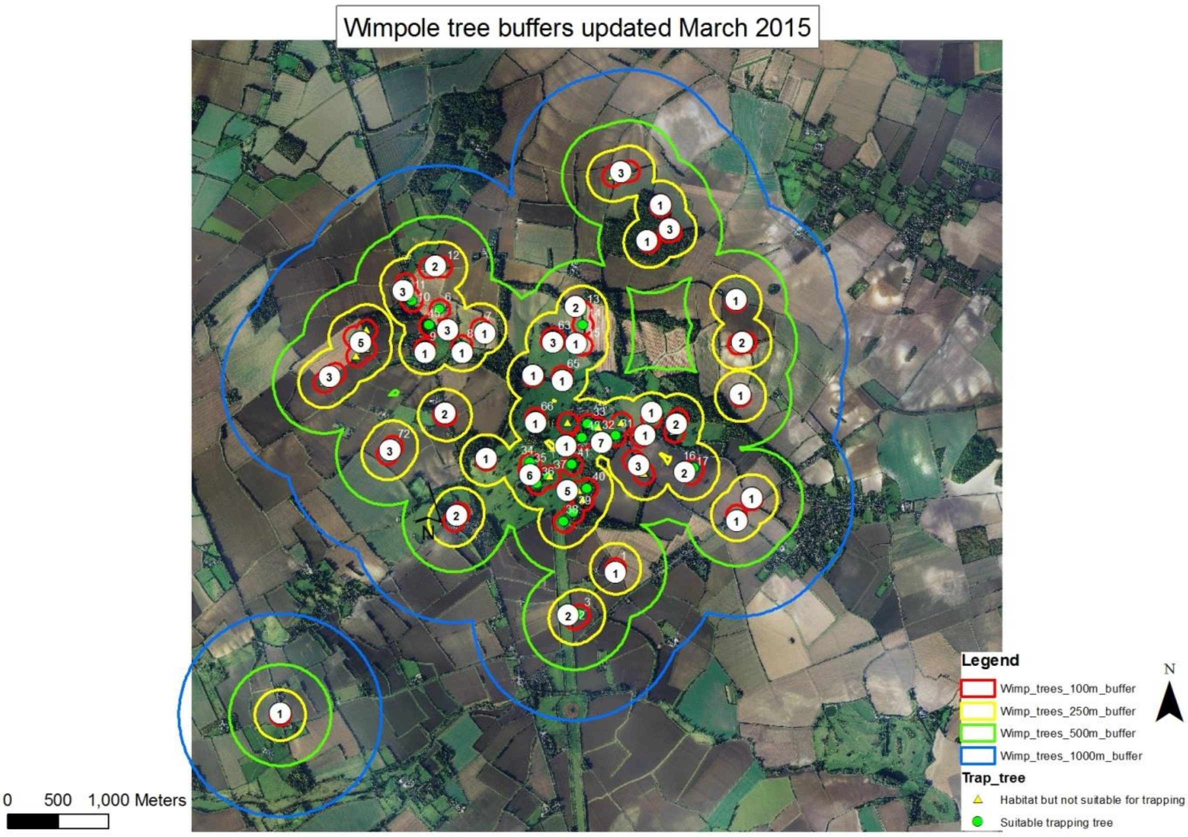

Fig. 10 Wimpole tree buffers map

7.3 Stowe

7.3.1 Kernel Density map

This map shows that there is much greater connectivity in this landscape and is now based on more complete survey data in terms of trees with suitable habitat. The avenue in the southwest provides a potential cluster separated from the other areas. The green dots are trees with habitat suitable for trapping and the yellow triangles are trees with habitat but not suitable for trapping. The redder the colour the greater the density of trees. The white boundary indicates the historic park.

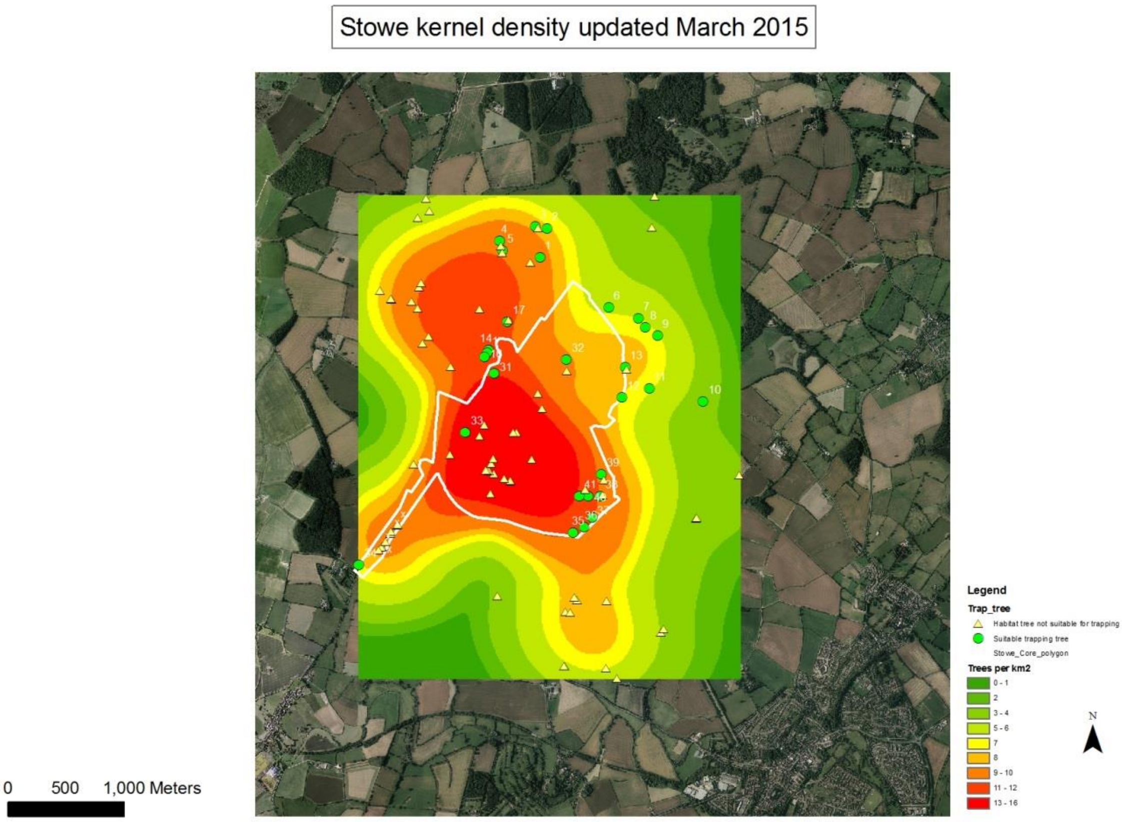

Fig. 11 Stowe kernel density map

7.3.2 Buffer from core parkland

This map shows the zones out from the core parkland and where the trees are located up to a distance of 2 km from the edge of the parkland boundary. The majority of the area within the 2 km zone has now been surveyed - only a privately-owned area of wood pasture remains to be surveyed in the outer buffer zone. According to the updated survey work, there are 41 habitat trees in the core parkland, 8 more in the area 100 m out, an additional 6 in the 100 – 250 m ring, an additional 7 in the 250-500 m ring and 22 trees in the 500 m to 1000 m ring, and an additional 12 in the outermost ring. This provides a smooth gradient in terms of density of suitable habitat trees, in particular a comparison between the core parkland and those trees up to 2 km from the core area. In total there are 96 trees with suitable habitat that have been recorded from the area.

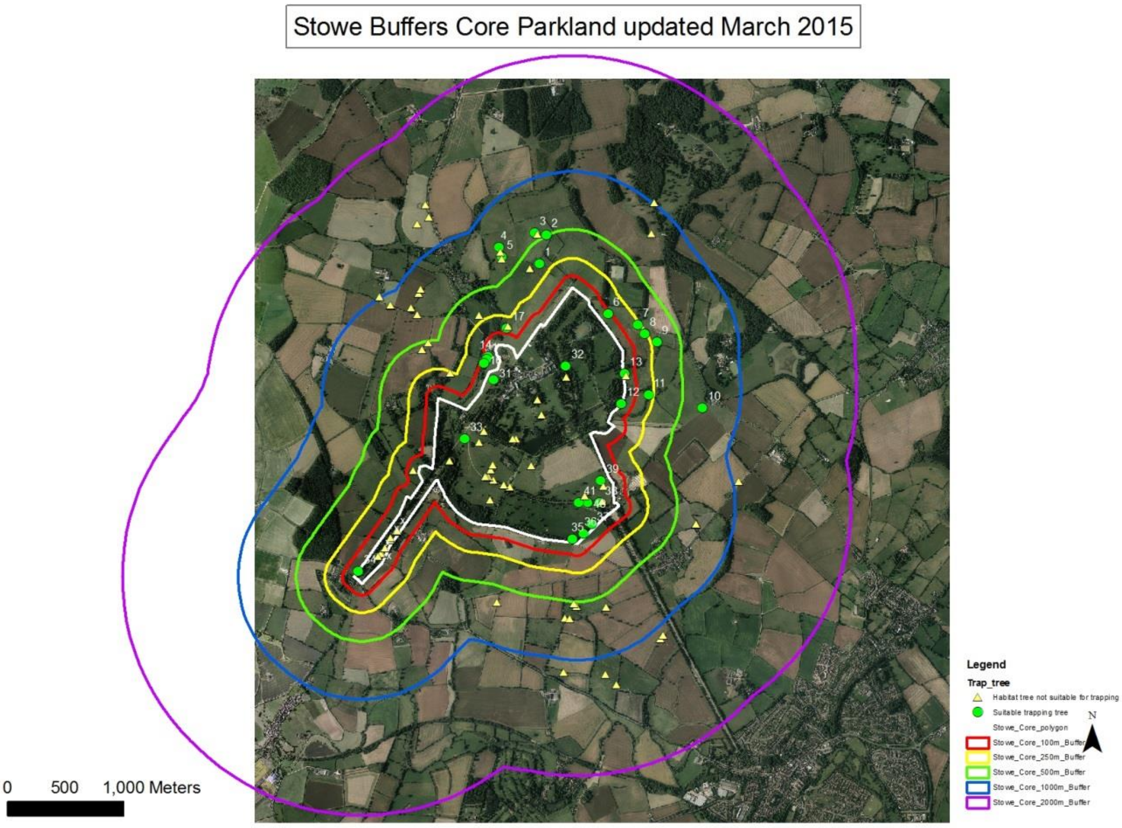

Fig. 12 Stowe buffer from core parkland map

7.3.3 Tree buffers

This map shows buffers that are joined together based on the clustering of the trees. The numbers on the map indicate the number of suitable habitat trees within the "sites" created using the 100 m radius buffer, which means these trees are not more than 200 m from one another within these clusters. The buffer which was created using a radius of 1000 m (i.e. two trees can be up to 2000 m from on another) contains all of the trees surveyed. Once again this map shows where the trees suitable for trapping are as well as the other trees with habitat. There is a good range showing clusters with 10 trees down to individual trees.

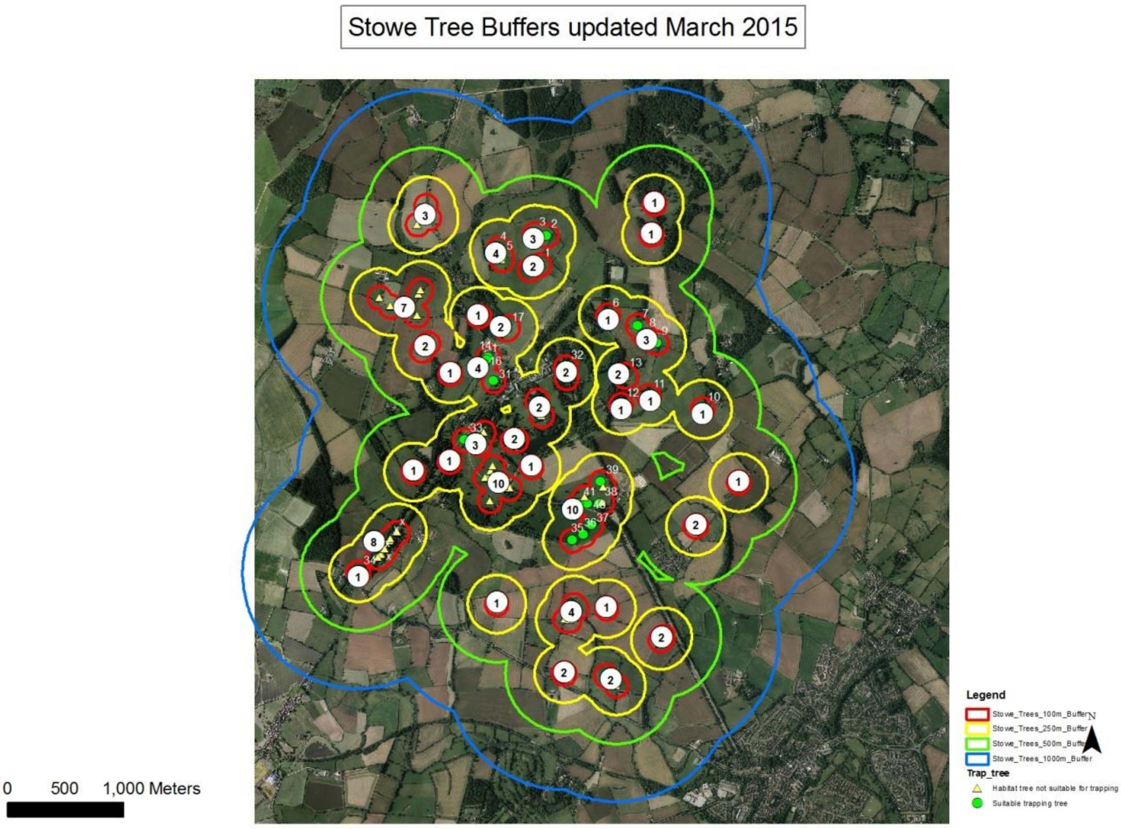

Fig. 13 Stowe tree buffers map

7.4 Knepp

7.4.1 Kernel Density map

This map shows that there is reasonable connectivity in this landscape, with three hot spots. The green dots are trees with habitat suitable for trapping and the yellow triangles are trees with habitat but not suitable for trapping. The redder the colour the greater the density of trees. The white boundary indicates the historic park. Knepp has the potential for being a good site due to the clustering and potential isolation of other pockets of suitable habitat trees; however we would need to understand what trees there are in between the clusters.

Fig. 14 Knepp kernel density map

7.4.2 Buffer from core parkland

This map shows the zones out from the core parkland and where the trees are located up to a distance of 2 km from the edge of the parkland boundary. It would be important to be sure that all the suitable habitat trees have been identified within this 2 km boundary. According to the current survey work, there are 13 habitat trees in the core parkland, 0 in the area 100 m out, 0 in the 100 – 250 m ring, an additional 7 in the 250-500 m ring and 10 trees in the 500 m to 1000 m ring, there are a further 13 in the outermost ring. This provides a useful gradient with gaps between the clusters of the trees and would potentially provide the opportunity to study trees in the parkland compare with trees further out in the agricultural landscape, but we would need to definitely establish the actual degree of isolation with further study.

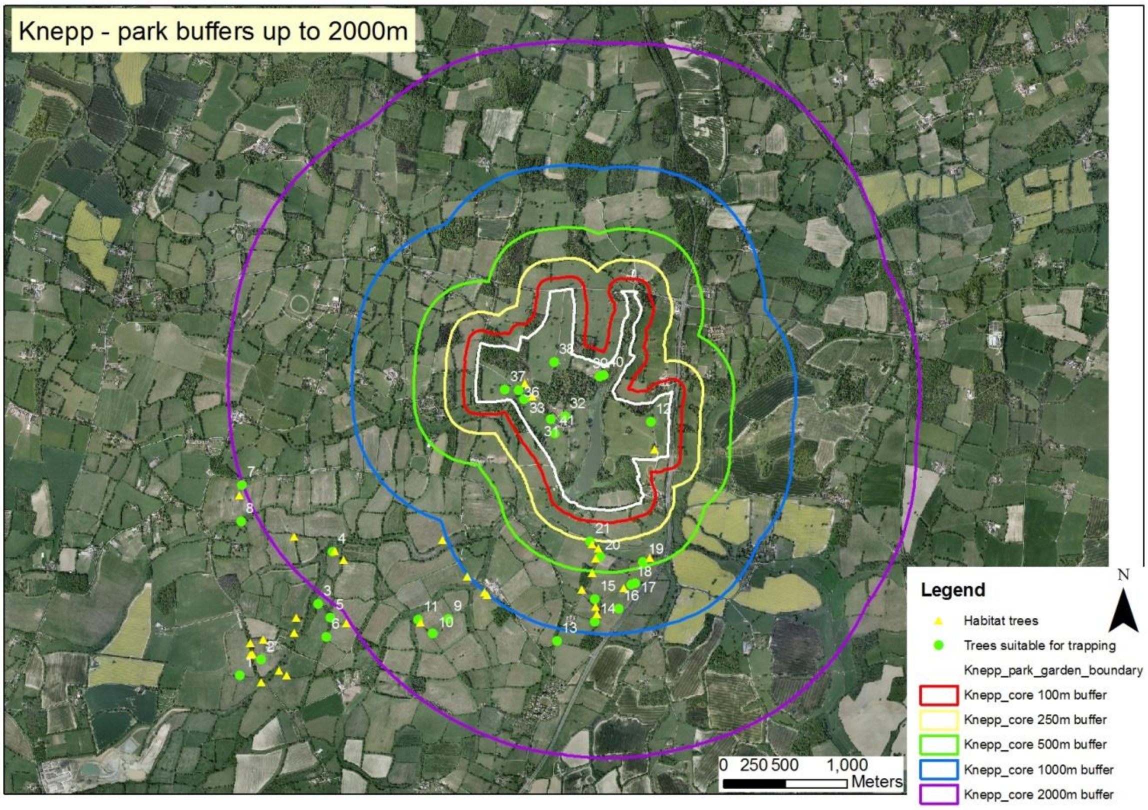

Fig. 15 Knepp buffers from core parkland map

7.4.3 Tree buffers

This map shows buffers that are joined together based on the clustering of the trees. The numbers on the map indicate the number of suitable habitat trees within the "sites" created using the 100 m radius buffer, which means these trees are not more than 200 m from one another within these clusters. The buffer which was created using a radius of 1000 m (i.e. two trees can be up to 2000 m from on another) contains all of the trees surveyed. Once again this map shows where the trees suitable for trapping are as well as the other trees with habitat. This map shows more clearly where there are individual trees and clusters with varying gradients.

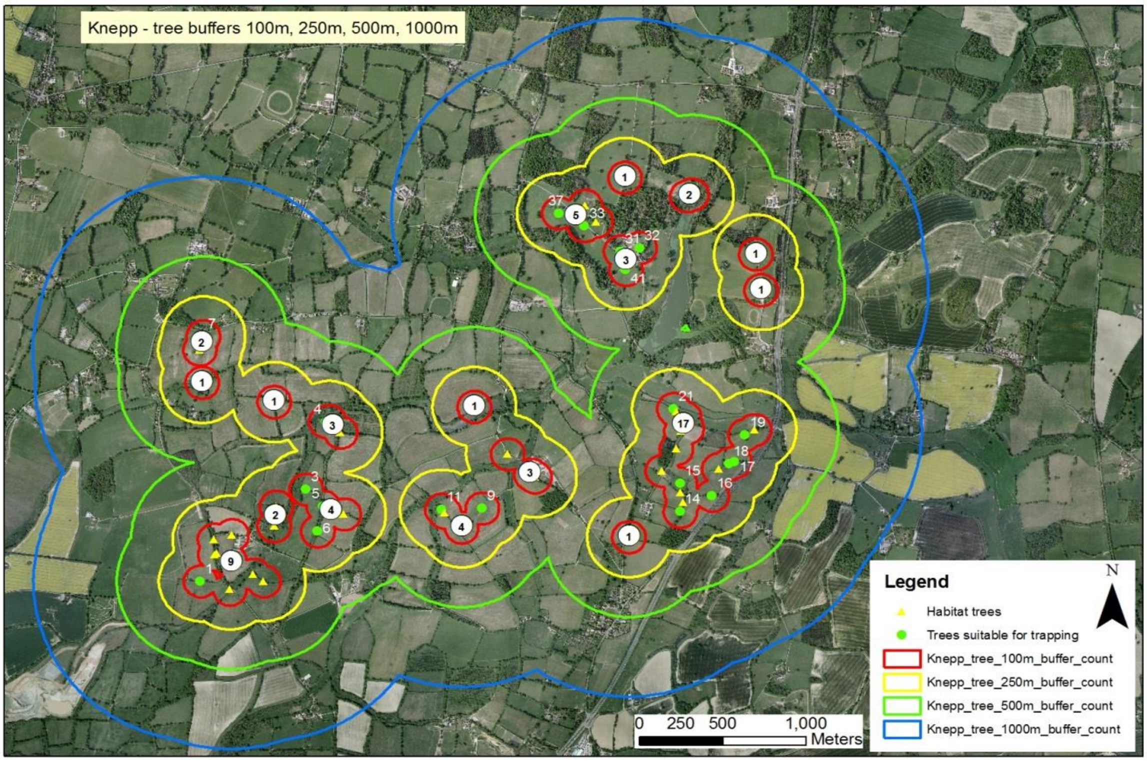

Fig. 16 Knepp tree buffers map

7.5 Killerton

Whilst we have more data for Killerton than the other sites, the data was not collected with a view to this project and is thus much less clear cut. In addition we are lacking data for the core parkland. This means that the data which the analyses are based on has had to be interpreted, and not based on new field work, in order to be able to use it. The trees that have been checked in the field are identified and confirmed however. We do also know that there are groups of trees that have been identified, but where no further information has been collected. Transforming this data into something that we can analyse or use in the field is very difficult and would require significantly more field work and a lot of data management. The landscape of trees in this area means that it will be difficult to find the isolated patches that we need, without field work over a much larger area.

7.5.1 Kernel Density map

This map shows that there is much greater connectivity in this landscape and that the density of trees is greater in the hotspots. The green dots are trees with habitat suitable for trapping (that have been verified in the field) and the yellow triangles are trees with habitat but not suitable for trapping (some of which have been verified in the field). The redder the colour the greater the density of trees. The white boundary indicates the historic park.

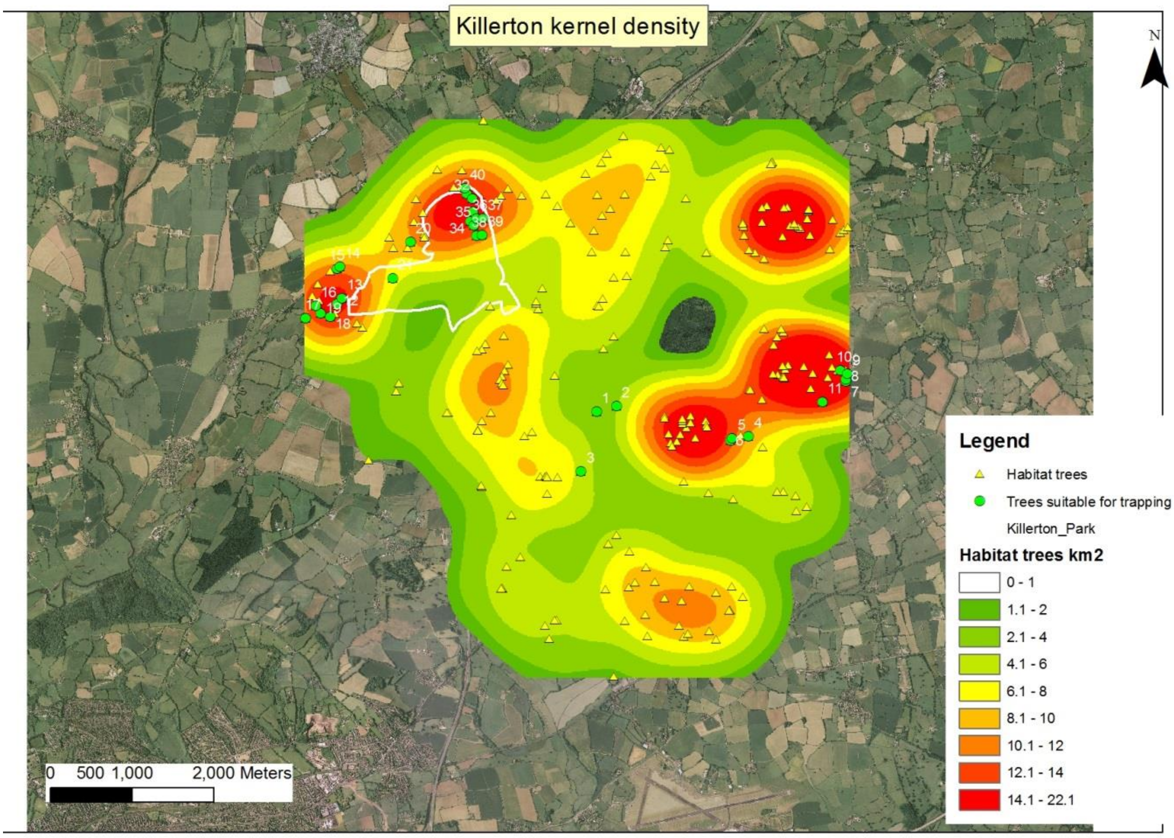

Fig. 17 Killerton kernel density map

7.5.2 Buffer from core parkland

This map shows the zones out from the core parkland and where the trees are located up to a distance of 2 km from the edge of the parkland boundary. It would be important to be sure that all the suitable habitat trees have been identified within this 2 km boundary. According to the current survey work, there are 11 habitat trees in the core parkland (but we know there are more trees, but have no survey data), 8 more in the area 100 m out, an additional 19 in the 100 – 250 m ring, an additional 17 in the 250-500 m ring, 19 additional trees in the 500 m to 1000 m ring and 29 additional trees in the outermost ring. This provides a smooth gradient in terms of density of suitable habitat trees, and also gives us greater concentrations of trees in each band. It may however be difficult to find trees that are properly isolated.

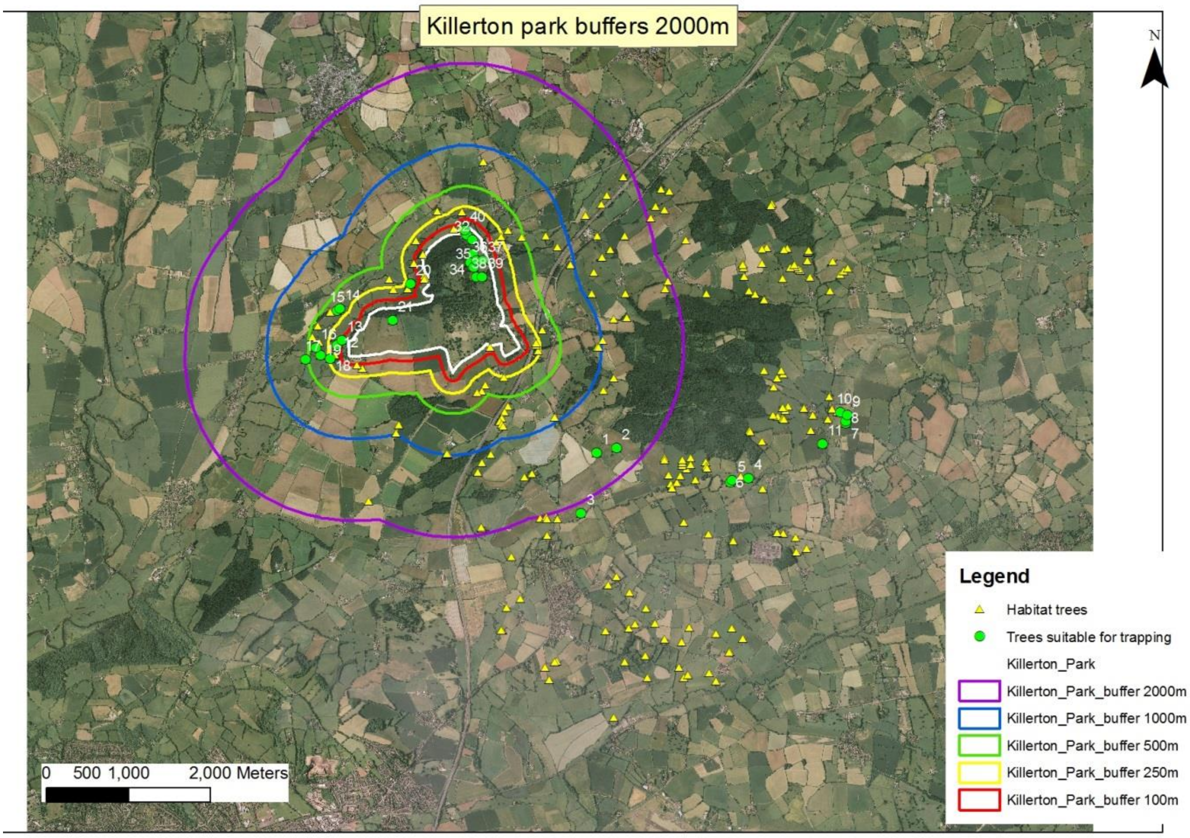

Fig. 18 Killerton buffers from core parkland map.

7.5.3 Tree buffers

This map shows buffers that are joined together based on the clustering of the trees. The numbers on the map indicate the number of suitable habitat trees within the “sites” created using the 100 m radius buffer, which means these trees are not more than 200 m from one another within these clusters. The buffer which was created using a radius of 1000 m (i.e. two trees can be up to 2000 m from on another) contains all of the trees surveyed. Once again this map shows where the trees suitable for trapping are as well as the other trees with habitat.

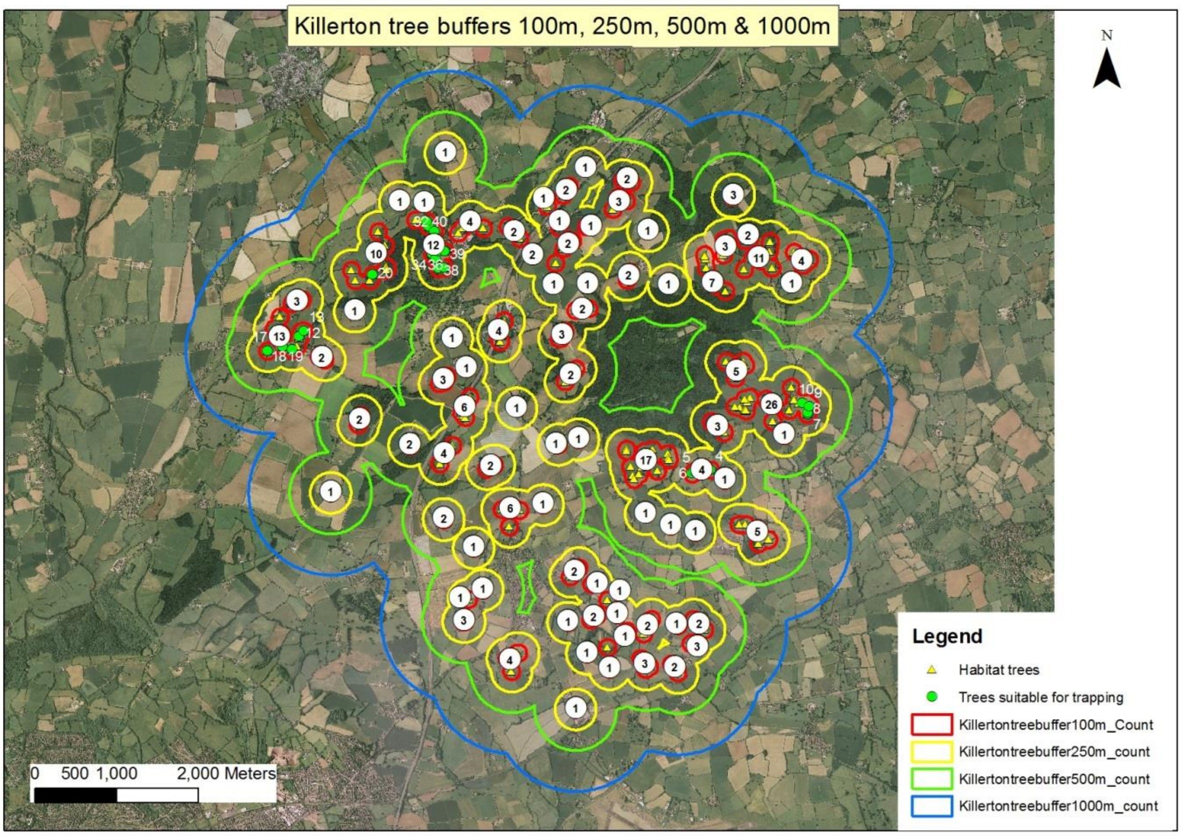

Fig. 19 Killerton tree buffers map

8 Costing for next stage in project

8.1 Outline costing for fieldwork

Sixty traps were constructed for Natural England in 2013, using 3 mm poly-carbonate at 450 mm vane height and with a spare set of collection bottles, at a cost of £2000. This covered the sourcing of the materials as well as construction and delivery (S. Perry, pers. comm.). This is equivalent to a cost £33 per trap. The basic units can be produced relatively quickly – the 60 traps were supplied within one calendar month of ordering.

The proposed design requires a minimum of 108 vane traps, so a budget of £4000 would enable sufficient plus a few spares to be supplied. There would be additional costs for the ties, trap preservative mixture, and laboratory consumables.

A minimum of two people will be required to set up the trap networks, both for logistical and 'health & safety' reasons. These would comprise one person from the national project team and one person from the local operating team, to ensure that common standards are maintained. With 27 traps per site, it is estimated that four days would need to be allocated for setting up at each site. Emptying and re-setting the traps periodically (4 visits) should be quicker, say taking two days each. The final collection and removal of the traps may take somewhere between the two time estimates, say 3 days. The total person days required to operate the trap networks comes to 30 person days' work. There will also be travel costs involved, with the national project team person probably having to stay locally for the three nights of the first visit.

The samples may be identified locally if a suitable expert is available, or via the national project team. The time requirement for identification of the samples is estimated at 10 days work. It is important that sample sorting is carried out by an expert, to ensure that no material is lost, eg fragments of elytra, etc, which may become separated from the beetles.

Data analysis and report construction may involve another 10 days work. Ideally this should include correlation with existing data on the fauna of the study sites, where available.

Cost items	**Daily rate**	**Total cost per item**
Vane traps		£4000
Ties & preservative		£250
Laboratory consumables		£250
Fee for trap operation	30 days @ £300	£9000
Expenses for trap operation		£1000
Fee for sample identification	10 days @ £300	£3000
Fee for analysis and reporting	10 days @ £300	£3000
Estimated total cost for trap operation project		**£20 500**

8.2 Alternative options as backup to shortage of funds

The study design has focused on a minimum of work needed to produce sufficiently robust data for statistical analysis. Any reduction in the numbers of traps, number of study sites, and extent of seasonal coverage of the trapping are considered likely to undermine this basic requirement.

However, one option might be to develop a pilot project at one or more of the proposed study sites in order to try out the practicalities of the proposed study design and provide both practical feedback on the methodology and some preliminary data.

If funding becomes available late in the field season – eg underspend money – this would best be used to expand the baseline tree survey data at selected sites. The first priority would be the four study sites already identified as these are closest to a complete dataset. The second priority would be add more study sites, eg Needwood and Grimsthorpe.

8.3 Health & safety aspects

The use of a ladder will be required at each site.

Preservatives are to be used at each site and during the sample sorting and identification. COSHH Guidance should be followed. The same chemicals should be used consistently across the four study sites.

Potential for problems with visitors interfering with traps at study trees.

It is recommended that each site produce some form of publicity information about the project to inform local visitors and also that each trap or trap tree is clearly labelled with local contact details.

9 Recommendations for next stages of the project

9.1 Current project

Stowe and Wimpole are now ready for a vane trapping study to proceed – using a 2 km buffer - although there is one private area in the outer buffer zone at Stowe which merits some further tree recording once permission can be obtained from the owner, Tile House Estate. It is recommended that these two sites be used if possible as a pilot study to test the method and to analyse the results. A first step here would be to ensure that the survey work has been completed so that distance measurements can be provided for each of the trap trees to the next suitable habitat tree.

Knepp is expected to reach this stage within the current study; additional fieldwork is in-hand and will be reported as a supplement to the current document.

Killerton requires a considerable amount of work to more fully investigate the suitability of the farmland trees within the buffer zones, and to complete the mapping of the trees in the parkland and within Ashclyst Forest. Until this is done it will not be possible to carry out the analysis of the densities of hollowing oak trees across the estate.

The priority actions are as follows, depending on the level of funding that may become available:

- Carry out field trial of the methodology at Stowe and/or Wimpole;
- Complete tree survey at Knepp, and then consider whether or not to conduct a field trial there too;
- Complete tree survey at Killerton.

9.2 Extending the range of sites

Preparation of the tree survey data at selected other sites will be required in order to expand the study. Grimsthorpe and Needwood are the best options for extension, with Moccas Park another possibility. Mapping and documentation of oak trees in the surrounding farmland trees is thought to be the main requirement at these sites, but given our experience from existing data covering the sites reported in this document, it may also be necessary to revisit the surveyed trees to assess them from the objectives of this study.

Veteran oak within woodland situations could also be included in future sites, eg oak pollards on boundary banks within ancient woodland (eg Eversden Wood SSSI), within secondary woodland, and within plantations (eg in Sherwood Forest). These three situations have considerable potential to inform conservation management. All three situations historically held old oaks growing in open situations, although the ancient woodland example would have gone through fluctuations in canopy density according to coppice regimes. Sites such as these have considerable potential to study the impacts of restoration on the saproxylic fauna.

The priority actions are as follows, depending on the level of funding that may become available:

- ensure tree survey data is available for the surrounding landscapes at Grimsthorpe, Needwood and Moccas, with 2 m buffers around the main concentrations of old oaks;
- explore the potential to include further parkland sites, as well as consider expansion to include overgrown veteran oaks currently within woodland situations.

9.3 Linking sites

The current project team has focused on core sites with concentrations of old oaks and where there are more old oaks in the surrounding farmland within a 2 km buffer zone out from the core parkland area. What would be an interesting and useful adjunct to this project would be to go further out and perhaps link up with another core site, forming transects of farmland trees between the parkland and wood pasture hot-spots, and to compare the old forest landscapes – such as Kesteven (Grimsthorpe), Needwood and Whittlebury (Stowe) - with non-forest landscapes such as Killerton and Wimpole.

9.4 Expanding saproxylic content

The development of wood mould boxes (see 4.8) offers the potential to study the saproxylic beetle fauna in a much more controlled experimental way. Boxes can be placed on posts set at intervals across the landscape and their colonisation by beetles can be analysed in relation to proximity of suitable host trees - regular grids or transects of boxes imposed on the natural treescape. However, they attract late successional and white-rot associated species, but not red-rot species. They are clearly not suitable for the present study but provide options for expanding the study beyond oaks and red-rot.

9.5 Involving the local biological recording community and students

The project brief included a request for consideration of the potential to develop suitable identification skills of a future generation of field surveyors and in particular a role for students. The lead contractor has been involved in coaching field workers through two Field Studies Council projects:

- Biodiversity Training, 2007
- Biodiversity Fellows, 2013 (funded by Natural England)

Both involved coaching people in saproxylic ecology in a historic parkland, Attingham Park SSSI. The British Entomological and Natural History Society have recently initiated a group structure and this already has support from two universities – Bath and Sussex. A new saproxylic group has been proposed and will be launched at the AGM of the Society on 21st March 2015. The aim will be improve understanding and knowledge of saproxylic habitats and the invertebrates which are associated, combining coaching with recording at a series of field sites, with the potential for being involved in vane-trapping studies. It is possible that logistical support for the present project and proposed study might be provided through this initiative, with students learning about saproxylic ecology, species identification skills, and scientific methodology for studying saproxylic invertebrates.

10 Acknowledgements

The Natural England Project Officers for this contract were Suzanne Perry and Jon Webb, with landscape ecology support from Nick Macgregor. Thanks especially to Professor Per Milberg for helpful discussions about the proposed study design; Max Blake (Aberystwyth University) for discussion of genetic aspects; Marcos Mendez (Universidad Rey Juan Carlos, Madrid) and Dmitry Telnov (Riga Museum) for discussion of the potential impacts of trapping on beetle populations and help with developing a new protocol. Jill Butler (Woodland Trust) provided access to data held by the Ancient Tree Inventory project.

At Killerton Park Estate, thanks to Ed Nicholson (Lead Ranger), Daniel Fields (Rural Surveyor), Phillip Smart (General Manager) and Jerry Baker (Outdoors Manager); also to Janet Lister (Wildlife & Countryside Adviser, South West).

At Knepp Castle Estate special thanks to Sir Charles Burrell for his enthusiastic support for the use of his Knepp Castle Estate; also to Ted Green and Jill Butler for help with locating suitable trees for trapping; and Penny Green and Graeme Lyons for carrying out a search of the park trees for suitable trees for suitable trap locations.

At Wimpole, Stuart Warrington (Wildlife & Countryside Adviser, East Anglia) provided useful discussion of the suitability of NT parklands locally and facilitated access to Wimpole Hall Estate; Simon Damant (Estate Forester, Wimpole Hall) saved the project considerable time by showing the surveyors exactly where suitable trees might be and how to reach them. Pete Kirby provided valuable information from his 2001-2 invertebrate survey of Wimpole Park.

At Stowe, Jo Hodgkins (Wildlife & Countryside Adviser, London & South East) facilitated access on both the National Trust and Stowe School land.

Acknowledgement also needs to be made to the members of the Ancient Tree Forum who have freely discussed many of the topics covered in this report and provided many facts and insights, notably Ted Green, Bill Cathcart and Jill Butler.

11 References

ALEXANDER, K.N.A. 1991. *Aderus populneus* (Creutzer) (Coleoptera: Aderidae) and other deadwood beetles from Stowe Park, Buckinghamshire. *British Journal of Entomology & Natural History* **4**: 83-84.

ALEXANDER, K.N.A. 1993. The deadwood fauna of Cornwall. *British Journal of Entomology & Natural History* **6**: 97-101.

ALEXANDER, K.N. A. 1994. The use of freshly-downed timber by insects following the 1987 storm. Pp134-150, in: Kirby, K.J. & Buckley, G.P. (eds) Ecological responses to the 1987 Great Storm in the woods of south-east England. *English Nature Science* No. **23**.

ALEXANDER, K.N.A. 1996. The links between forest history and biodiversity: the invertebrate fauna of ancient pasture-woodlands in Britain and its conservation. Ch 7: 73-80, in Kirby, K.J. & Watkins, C. (eds) *The Ecological History of European Forests.* Wallingford: CAB International.

ALEXANDER, K.N.A. 2002a. *The invertebrates of living & decaying timber in Britain and Ireland – a provisional annotated checklist*. English Nature Research Report No. 467.

ALEXANDER, K.N.A. 2002b. Forthampton Oaks, Gloucestershire: a site of major importance for saproxylic invertebrates. *British Journal of Entomology & Natural History* **15**: 63-64.

ALEXANDER, K.N.A. 2003a. *Gastrallus immarginatus* (Muller) (Anobiidae) at Hatfield Forest, Essex. *The Coleopterist* **12**: 23.

ALEXANDER, K.N.A. 2003b. *Globicornis rufitarsis* (Panzer) (Dermestidae) at Blenheim Park, Oxfordshire. *The Coleopterist* **12**: 96

ALEXANDER, K.N.A. 2004. Revision of the Index of Ecological Continuity as used for saproxylic beetles. *English Nature Research Report* **574**

ALEXANDER, K.N.A. 2005. Tree age and form in relation to colonisation by *Phloiophilus edwardsi* Stephens (Phloiophilidae). *The Coleopterist* **14**: 85-88.

ALEXANDER, K.N.A. 2008 Wood-decay beetles of Ashclyst Forest and Killerton Park, S.E. Devon, including four new county records. *The Coleopterist* **17**: 121-123.

ALEXANDER, K.N.A. 2009a. Saproxylic Coleoptera from Belton Park, Lincolnshire, including eight species new to the county list. *The Coleopterist* **18**: 73-74.

ALEXANDER, K.N.A. 2009b. The wood-decay invertebrates of the Lanhydrock Estate, East Cornwall: a site of high nature conservation value but with no legal protection. *British Journal of Entomology & Natural History* **22**: 61-70.

ALEXANDER, K.N.A. 2010a Rare old growth Diptera (Clusiidae, Milichidae, Mycetophilidae, Sciaridae, Tipulidae) from Dunham Park, Cheshire. *Dipterists Digest* **17**: 140.

ALEXANDER, K.N.A. 2010b. A remarkable wood-decay beetle fauna from a group of traditional orchards at Colwall, Herefordshire. *The Coleopterist* **19**: 11-14.

ALEXANDER, K.N.A. 2011. A review of the saproxylic invertebrate assemblages at Birklands and Bilhaugh Sites of Special Scientific Interest. Sherwood Forest, Nottinghamshire. *Natural England Commissioned Report* **NECR 072**: 176 pp.

ALEXANDER, K.N.A. 2012 *Vaillantodes miksici* (Krek) (Diptera, Psychodidae) new to Wales. *Dipterists Digest* **19**: 128.

ALEXANDER, K.N.A. 2013. A surpisingly rich saproxylic beetle fauna from an Isle of Wight woodland complex. *The Coleopterist* **20**: 77-80.

ALEXANDER, K.N.A. & ABRAHAMS, D. 2006. Saproxylic invertebrate survey, assessment and management recommendations of Calke Park, Derbyshire. *English Nature Research Report* **691**.

ALEXANDER, K.N.A., BOWER, L. & GREEN, G. H. 2014. A remarkable saproxylic insect fauna from a traditional orchard in Worcestershire – but are the species resident or transient? *British Journal of Entomology & Natural History* **27**: 221-229.

ALEXANDER, K.N.A., BUTLER, J.E., & GREEN, E.E. 2006. The value of different tree and shrub species to wildlife. *British Wildlife* **18**: 18-28.

ALEXANDER, K.N.A. & CHANDLER, P.J. 2010 Rare fungus gnats (Diptera, Mycetophilidae) from a Herefordshire cherry orchard. *Dipterists Digest* **17**: 25-26.

ALEXANDER, K.N.A. & CHANDLER, P.J. 2011. A notable assemblage of fungus gnats (Diptera, Sciaroidea) from St John's Wood, County Roscommon, Ireland. *Dipterists Digest* **18**: 27-42.

ALEXANDER, K.N.A & LOTT, D. 1992. The dead-wood beetles of Attingham Park. *The Coleopterist* **1**: 9-16.

ALEXANDER, K.N.A. & PERRY, I. 2013. The distribution and ecology of the freeloader fly *Madiza britannica* Hennig (Diptera, Milichiidae). *Dipterists Digest* **20**: 202-204.

ANDERSSON, M., MILBERG, P. & BERGMAN, K.-O. 2011. Low pre-death growth rates of oak (*Quercus robur* L.) – is oak death a long-term process induced by dry years? *Ann. For. Sci.* **68**: 159-168.

BARBALAT, S. 2009. Methodology for a field work-based saproxylic beetle red list in Switzerland: trapping or direct collection? In: BUSE, J., ALEXANDER, K.N.A., RANIUS, T. & ASSMANN, T. *Saproxylic Beetle – Their role and diversity in European woodland and tree habitats.* Proceedings of the 5th Symposium and Workshop on the Conservation of Saproxylic Beetles, pp209-218. Sofia: Pensoft.

BERGMAN, K.-O., JANSSON, N., CLAESSON, K., PALMER, M.W. & MILBERG, P. 2012 How much and at what scale? Multiscale analyses as decision support for conservation of saproxylic oak beetles. *For. Ecol. Manage.* **265**: 133-141.

BJORKMAN, A.D. & VELLEND, M. 2010. Defining historical baselines for conservation: ecological changes since European settlement on Vancouver Island, *Can. Conserv. Biol*. **24**: 1559-1568.

BLAKE, M., MCKEOWN N.J. & SHAW, P.W. 2015. DNA isolation from single pieces of beetle frass: a resource for conservation genetic studies of *Gnorimus nobilis*. *Antenna ECE Special Edition* **2015**: 65-66.

BODDY, L. 1984. Microcliimate and moisture dynamics of wood decomposing in terrestrial ecosystems. *Soil Biology & Biochemistry* **15**: 149-157.

BODDY, L. 1994. Wood decomposition and the role of fungi: implications for woodland conservation and amenity tree management. Pp7-29, in: Spencer, J. & Feest, A. (eds). *The rehabilitation of storm damaged woods*. University of Bristol.

BOUGET, C., BRUSTEL, H., BRIN, A., & NOBLECOURT, T. 2008, Sampling saproxylic beetles with window flight traps: methodological insights. Pp 21-32. In: VIGNON, V. & ASMODÉ, J.-F. (eds) Proceedings of the 4th Symposium and workshop on the conservation of saproxylic beetles, held in Vivoin, Sarthe Department, France, 27-29 June 2006. *Revue D' Écologie (Terre et Vie), Supplément* **10**.

BOUGET, C., LARRIEU, L. & BRIN, A. 2014. Key features for saproxylic beetle diversity derived from rapid habitat assessment in temperate forests. *Ecol. Indic.* **36**: 656-664.

BRATTON, J. & ANDREWS, J. 1991. Invertebrate conservation – principles and their application to broad-leaved woodland. *British Wildlife* **2** (6): 335-344.

BRAWN, J.D. 2006. Effects of restoring oak savannas on bird communities and populations. *Conservation Biology* **20**: 460-469.

BROWN, N. & FISHER, R. 2009. *Trees Outside Woods*. A report to the Woodland Trust. Department of Plant Sciences, University of Oxford.

BRUNET, J. & ISACSSON, G. 2009. Restoration of beech forest for saproxylic beetles – effects of habitat fragmentation and substrate density on species diversity and distribution. *Biodiversity and Conservation* **18**: 2387-2404.

BRUSTEL, H. 2004. Coléoptères saproxyliques et valeur biologique des fôrets françaises. *Office National des Fôrets: Les Dossiers Forestiers* No. **13**.

BRUSTEL, H. 2004. "Polytrap" a window flight trap for saproxylic beetles. Poster: 3rd Symposium and Workshop on the Conservation of Saproxylic Beetles. Riga/Latvia, 7th - 11th July, 2004.

BRUSTEL, H. 2012. Polytrap2010: new "soft design" window flight trap for saproxylic beetles. pp91-92, in: JURC, M. (ed.) Saproxylic beetles in Europe: monitoring, biology and conservation. Ljubljana: Slovenian Forestry Institute, Silva Slovenica. *Studia Forestalia Slovenica, Professional and Scientific Works,* **137**.

BURNS, M., HANCOCK, E.G., ROBINSON, J., CORNFORTH, I. & BLAKE, S. 2014. Two novel flight-interception trap deisgns for low-cost forest insect surveys. *British Journal of Entomology & Natural History* **27**: 155-162.

BUSE, J. 2008. An endangered longhorn beetle associated with old oaks and its possible role as an ecosystem engineer. *Conservation Biology* doi: 10.111/j.1523-1739.2007.00880.x

BUSE, J., LEVANONY, T., TIMM, A., DAYAN, T. & ASSMANN, T. 2010. Saproxylic beetle assemblages in the Mediterranean region: impact of forest management on richness and structure. For. Ecol. Manage. 259: 1376-1384.

BUSE, J., ASSMANN, T., FRIEDMAN, A.-L.-L., RITTNER, O., PAVLICEK, T.R., LEATHER, S. & RIBERA, I. 2013. Wood-inhabiting beetles (Coleoptera) associated with oaks in a global biodiversity hotspot: a case study and checklist for Israel. *Insect Conservation & Diversity* **6**: 687-703.

BUßLER , H., MŰLLER, J. & SIMON, U. 2004. Erfassung xylobionter Käfer in Waldökosystemen – Ein methodenvergleich unter besonderer Berücksichtigung der Kronenfauna. *Naturschutz und Landschaftsplanung* **36**, Nr 7: 197-201.

CARREL, J.E. 2002. A novel aerial-interception trap for arthropod sampling. *Florida Entomologist* **85** (4): 656-657.

CHANDLER, P.J. 1998. Checklists of Insects of the British Isles (New Series) Part 1: Diptera. *Handbooks for the Identification of British Insects* **12**: 234 pp

CHANDLER, P.J. (ed) 2010 A Dipterist's Handbook (2nd Edition). *The Amateur Entomologist* **15**: 1-525.

CHAPMAN, J.A. & KINGHORN, J.M. 1955. Window flight traps for insects. *Canadian Entomologist* **87**: 46-47.

CLIFTON, S. 2012. Classic Wildlife Sites: Sherwood Forest National Nature Reserve, Nottinghamshire. *British Wildlife* 409-418.

CROWSON, R.A. & HUNTER, F.A. 1964. *Entomologist's Monthly Magazine* **100**: 198-200.

DAMANT, S. & KIRBY, P. 2005. Oasis in an arable desert: the rich saproxylic Coleoptera fauna of Wimpole Park, Cambridgeshire. *The Coleopterist* **14**: 51-63.

DAVIES, Z.G., TYLER, C., STEWART, G.B. & PULLIN, A.S. 2008. Are current management recommendations for saproxylic invertebrates effective? A systematic review. *Biodiversity Conservation* **17**: 209-234.

DEFRA BD2111. 2009. *Trends, long term survival and ecological values of hedgerow trees: development of population models to inform strategy*. Forest Research report to DEFRA.

DRAKE, C.M., LOTT, D.A., ALEXANDER, K.N.A. & WEBB, J. 2007. Surveying terrestrial and freshwater invertebrates for conservation evaluation. *Natural England Research Report* **NERR005**.

DRANE, A.B. 1982. *Ptinus subpilosus* Sturm (Col., Ptinidae) in Northants. *Entomologist's Monthly Magazine* **118**: 162.

DRANE, A.B. 1984. *Ernoporus caucasicus* (Col., Scolytidae) and other beetles associated with mature timber at Rockingham Castle Park, Northamptonshire. *The Coleopterists's Newsletter* **15**: 4-6.

DRANE, A. & WARRINGTON, S. 2010. Canopy interception trapping for beetles in mature and veteran trees at Hatfield Forest, Essex, in 2008. *The Coleopterist* **19**: 75-82.

DUFF, A.G. (Ed.) 2012. *Checklist of Beetles of the British Isles*. 2nd Edition. Iver: Pemberley Books.

ELOY, C. 2011. Leonardo's rule, self-similarity and wind-induced stresses in trees. *Physical Review Letters* **107**: 258101.

ELTON, C.S. 1966. *The Pattern of Animal Communities*. Methuen & Co.

ENGEN, S., SÆTHER, B-E., SVERDRUP-THYGESON, A., GRØTAN, V., & ØDEGAARD, F. 2008. Assessment of species diversity from species abundance distributions at different localities. *Oikos* **117**: 738-748.

FAGER, E.W. 1955. *A study of invertebrate populations in decaying wood*. Unpubl. D.Phil. Thesis Oxford University.

FAGER, E.W. 1968. The community of invertebrates in decaying oak wood. *Journal of Animal Ecology* **37**: 21-142.

FISCHER, J., STOTT, J. & LAW, B.S. 2010. The disproportionate value of scattered trees. *Biological Conservation* **143**: 1564-1567.

FRANC, N., GŐTTMARK, F., ØKLAND, B., NORDÉN, B. & PALTTO, H. 2007. Factors and scales potentially important for saproxylic beetles in temperate mixed oak forest. *Biological Conservation* **135**: 86-98.

GARDENFORS, U, & BARANOWSKI, R. 1992. Beetles living in open deciduous forests prefer different tree species than those living in dense forests. *Entomologisk Tidskrift 113*: 1-11.

GARLAND, S.P. 1983. Beetles as primary woodland indicators. *Sorby Record* **21**: 3-38.

GIBB, H., PETTERSSON, R.B., HJÄLTÉN, J., HILSZCZŃSKI, J., BALL, J.P., JOHANSSON, T., ALTEGRIM, O., & DANELL, K. 2006. Conservation-oriented forestry and early successional saproxylic beetles: responses of functional groups to manipulated dead wood substrates. *Biological Conservation* **129**: 437-450.

GIBBONS, P., LINDENMAYER, D.B, FISCHER, J., MANNING, A.D., WEINBERG, A., SEDDON, J., RYAN, P. & BARRETT, G. 2008. The future of scattered trees in agricultural landscapes. *Conservation Biology* **22**: 1309-1319.

GOUGH, L.A., BIRKEMOE, T. & SVERDRUP-THYGESON, A. 2014. Reactive forest management can also be proactive for wood-living beetles in hollow oak trees. *Biological Conservation* **180**: 75-83.

GOUIX, N., ZAGATTI, P. & BRUSTEL, H. 2009. Emergence of beetles from hollow trees – habitat requirements for Limoniscus violaceus (P.W.J. Müller, 1821) (Elateridae). In: BUSE, J., ALEXANDER, K.N.A., RANIUS, T. & ASSMANN, T. *Saproxylic Beetle – Their role and diversity in European woodland and tree habitats.* Proceedings of the 5th Symposium and Workshop on the Conservation of Saproxylic Beetles, pp133-148. Sofia: Pensoft.

GOUIX, N. & BRUSTEL, H. 2011. Emergence trap, a new method to survey Limoniscus violaceus (Coleoptera: Elateridae) from hollow trees. Biodiversity and Conservation (published on-line DOI 10.1007/s10531-011-0190-1)

GREEN, E.E. 1995. Creating decaying trees. *British Wildlife* **6**: 310-311.

GREEN, E.E. 2010. The importance of open-grown trees; from acorn to ancient. *British Wildlife* **21**: 334-338.

HALL, S.J.G. & BUNCE, R.G.H. 2011. Mature trees as keystone structures in Holarctic ecosystems – a quantitative species comparison in a northern English park. *Plant Ecology & Diversity* 4: 243-250.

HAMMOND, P.M. & HARDING, P.T. 1981. Saproxylic invertebrate assemblages in British woodlands: their conservation significance and evaluation. pp30-41, in: READ, H.J. (ed) *Pollard and veteran tree management*. Corporation of London.

HARDING, P.T. 1977. Fauna of the Mature Timber Habitat. London: Nature Conservancy Council: *CST Report* **103**.

HARDING, P.T. & WALL, T. (eds) 2000. Moccas: an English deer park. The history, wildlife and management of the first parkland National Nature Reserve.

HARDING, P. & ROSE, F. 1986. *Pasture-Woodlands in Lowland Britain; a review of their importance for wildlife conservation*. Huntingdon: Institute of Terrestrial Ecology.

HILSZCZAŃSKI, J., JAWORSKI, T., PLEWA, R., & JANSSON, N. 2014. Surrogate tree cavities: boxes with artifical substrate can serve as temporary habitat for *Osmoderma barnabita* (Motsch.) (Coleoptera, Cetoniinae). *Journal of Insect Conservation* **18**: 855-861.

HINES, J.W. & HEIKKENEN, H.J. 1977. Beetles attracted to severed Virginia pine (*Pinus virginiana* Mill.) *Environmental Entomology* **6**: 123-127

HOLLAND, J.D., BERT, D.G., & FARIGH, L. 2004. Determining the spatial scale of species response to habitat. *Bioscience* **54**, 229-235.

HORAK, J. & REBL, K. 2013. The species richness of click beetles in ancient pasture woodland benefits from a high level of sun exposure. *Journal of Insect Conservation* **17**: 307-318.

HORAK, J., VODKA, S., KOUT, J., HALDA, J.P., BOGUSCH, P. & PECH, P. 2014. Biodiversity of most dead wood-dependent organisms in thermophilic temperate oak woodlands thrives on diversity of open landscape structures. *Forest Ecology and Management* **315**: 80-85.

HUNTER, F.A. & JOHNSON, C. 1966. *Entomologist's Monthly Magazine* **102**: 284.

HYVARINEN, E., KOUKI, J & MARTIKAINEN, P. 2006. A comparison of three sampling methods used to survey forest-dwelling Coleoptera. *European Journal of Entomology* **103**: 397-407.

IRMLER, U., ARP, H., & NŐTZOLD, R. 2010. Species richness of saproxylic beetles in woodland sis affected by dispersion ability of species, age and stand size. *Journal of Insect Conservation* **14**: 227-235.

JANSSON, N. & ANTONSSON, K. 1994. Eklandskapet som miljöövervakningsobjekt. Metodutveckling på uppdrag av SNV. Länsstyrelsen i Östergötland. (*Monitoring of the Oak Landscape*. Method Development on behalf of the Swedish Environmental Protection Agency).

JANSSON, N. & ANTONSSON, K. 2003. The work with old trees and saproxylic beetles in Őstergötland Sweden. In: BOWEN, C.P. (ed) *Proceedings of the second pan-European conference on Saproxylic Beetles,* pp41-43. London: People's Trust for Endangered Species.

JANSSON, N. & LUNDBERG, S. 2000. Beetles in hollow broadleaved deciduous trees – two species new to Sweden and the staphylinid beetles (Coleoptera: Staphylinidae) *Hypnogyra glabra* and *Meliceria tragardhi* found again in Sweden. *Entomologisk Tidskrift* **121**: 93-97.

JANSSON, N., BERGMAN, K-O., JONSELL, M. & MILBERG, P. 2009a. An indicator system for identification of sites of high conservation value for saproxylic oak (*Quercus* spp.) beetles in southern Sweden. *Journal of Insect Conservation* **13**: 399-412.

JANSSON, N., RANIUS, T., LARSSON, A. & MILBERG, P. 2009b. Boxes mimicking tree hollows can help conservation of saproxylic beetles. *Biodiversity and Conservation* **18**: 3891-3908.

JOHNSON, C. 2011. Saproxylic Coleoptera from Calke, Chatsworth, Hardwick and Kedleston Parks, Derbyshire, 1881-1999. *The Coleopterist* **17**: 23-41.

JONSELL, M. WESLIEN, J. & EHNSTRŐM, B. 1998. Substrate requirements of red-listed saproxylic invertebrates in Sweden. *Biodiversity and Conservation* **7**: 749-764.

JONSELL, M., NORLANDER, G. & JONSSON, M. 1999. Colonization patterns of insects breeding in wood-decaying fungi. *Journal of Insect Conservation* **3**: 145-161.

JONSELL, M., SCHROEDER, M. & LARSSON, T. 2003. The saproxylic beetle *Bolitophagus reticulatus*: its frequency in managed forests, attraction to volatiles and flight period. *Ecography* **26**: 421-428.

KAPPES, H. & TOPP, W. 2004. Emergence of Coleoptera from deadwood in managed broadleaved forest in central Europe. *Biodiversity and Conservation* **13**: 1905-1924.

KIRBY, P. 2002. *Wimpole Park - Saproxylic Beetle Survey 2001*. Unpublished contract report to The National Trust, Wimpole Hall Estate.

KŐHLER, F. 2000. Totholzkäfer in Naturwaldzellen des Nördlichen Rheinlandes. Vergleichende studien zur Totholzkäferfauna Deutshlands und Deutschen Naturwaldforschung. Schriftenreihe LŐBF/LAfAO NRW 18. Recklinghausen. 351 pp. [referred to in Vandekerkhove et al, 2011]

LARKIN, P.A. & ELBOURN, C.A. 1964. Some observations on the fauna of dead wood in live oak trees. *Oikos* **15**: 79-92.

LARSSON, M.C., HARVEY, D., BURMAN, J., SVENSSON, G.P., WINDE, I., NYABUGA, F.N., ANDERSSON, K., MUSA, N., FORSMARK, B., JANSSON, N., WETSERBERG, L., ANDERSSON, F., HEDENSTRÖM, E., BERMAN, K.-O. & MILBERG, P. 2015. Pheromone-based monitoring: a game changer for saproxylic insect conservation. *Antenna ECE Special Edition* **2015**: 68-69.

LARSSON, M.C. & SVENSSON, G.P. 2009. Pheromone monitoring of rare and threatened insects: exploiting a pheromone-kairomone system to estimate prey and predator abundance. *Conservation Biology* **23**: 1516-1525.

LARSSON, M.C. & SVENSSON, G.P. 2011. Monitoring spatiotemporal variation in abundance and dispersal by a pheromone-kairomone system in the threatened saproxylic beetles *Osmoderma eremita* and *Elater ferrugineus*. *Journal of Insect Conservation* **15**: 891 ff.

LAWTON, J.H., BROTHERTON, P.N.M., BROWN, V.K., ELPHICK, C., FITTER, A.H., FORSHAW, J., HADDOW, R.W., HILBORNE, S., LEAFE, R.N., MACE, G.M., SOUTHGATE, M.P., SUTHERLAND, W.J., TEW, T.E., VARLEY, J., & WYNNE, G.R. (2010) Making Space for Nature: a review of England's wildlife sites and ecological network. Report to Defra. http://archive.defra.gov.uk/environment/biodiversity/documents/201009space-for-nature.pdf

LINDENMAYER, D.B., LAURENCE, W.F., FRANKLIN, J.F., LIKENS, G.E., BANKS, S.C., BLANCHARD, W., GIBBONS, P., IKIN, K., BLAIR, D., MCBURNEY, L., MANNING, A.D., & STEIN, J.A.R. 2014. New policies for old trees: averting a global crisis in a keystone ecological structure. *Conservation Letters* **7**: 61-69.

LONSDALE, D. (ed) 2013. *Ancient and other Veteran Trees: further guidance on management*. Ancient Tree Forum.

LOTT, D.A., ALEXANDER, K.N.A., DRANE, A.B. & FOSTER, A.P. 1999. The dead-wood beetles of Croome Park, Worcestershire. *The Coleopterist* **8**: 79-87.

LUSH, M., ROBERTSON, H.J., ALEXANDER, K.N.A., GIAVARINI, V., HEWINS, E., MELLINGS, J., STEVENSON, C.R., STOREY, M., & WHITEHEAD, P.F. 2007. Biodiversity studies of six traditional orchards in England. *Natural England Research Report* **NERR025**: 250pp.

MALAISE, R. 1937. A new insect trap. *Entomologisk Tidskrift* **58**: 148-160.

MANNING, A.D, FISCHER, J. & LINDENMAYER, D.B. 2006. Scattered trees are keystone structures – implications for conservation. *Biological Conservation* **132**: 311-321.

MARTIKAINEN, P. & KOUKI, J. 2003. Sampling the rarest: threatened beetles in boreal forest diversity inventories. *Biodiversity and Conservation* **12**: 1815-1831.

MARTIKAINEN, P. & KAILA, L. 2004. Sampling saproxylic beetles: lessons from a 10-year monitoring study. *Biological Conservation* **120**: 171-181.

MERIGUET, B. 2007. Modèle de piège d'interception ultra-léger. *L'Entomologiste* **63** (4): 215-219.

MERIGUET, B., SERRES, E., RENAULT, O & ZAGATTI, P. 2009. From microhabitat to landscape: analysis of structuring factors for the saproxylic beetle (Coleoptera) communities, an ongoing approach. In: BUSE, J., ALEXANDER, K.N.A., RANIUS, T. & ASSMANN, T. *Saproxylic Beetle – Their role and diversity in European woodland and tree habitats.* Proceedings of the 5th Symposium and Workshop on the Conservation of Saproxylic Beetles, pp233-235. Sofia: Pensoft.

MICÓ, E., GARCÍA-LÓPEZ, A., SÁNCHEZ, A., JUÁREZ, M. & GALANTE, E. 2015. What can physical, biotic and chemical features of a tree hollow tell us about their associated diversity? *Journal of Insect Conservation* DOI 10.1007/s10841-015-9754-9.

MILBERG, P., BERGMAN, K.-O., JOHANSSON, H., JANSSON, N. 2014. Low host-tree preferences among saproxylic beetles: a comparison of four deciduous species. *Insect Conservation and Diversity* **7**: 508-522.

MORETTI, M. & BARBALAT, S. 2004. The effect of wildfire on wood eating beetles in deciduous forests on the southern slope of the Swiss Alps. *Forest Ecology and Management* **187**: 85-103.

MUIRHEAD-THOMSON, R.C. 1991. *Trap responses of flying insects. The influence of trap design on capture efficiency*. Academic Press.

MŰLLER, J., BUßLER, H., BENSE, U., BRUSTEL, H., FLECHTNER, G., FOWLES, A., KAHLEN, M., MÖLLER, G., MŰHLE, H., SCHMIDL, J., & ZABRANSKY, P. 2005. Urwald relict species – saproxylic beetles indicating structural qualities and habitat tradition. *Waldökologie online* **2**: 106-113.

MŰLLER, J., JARZABEK- MŰLLER, A., BUSSLER, H. & GOSSNER, M.M. 2013. Hollow beech trees identified as keystone structures for saproxylic beetles by analyses of functional and phylogenetic diversity. Animal Conservation. Print ISSN 1367-9430.

MUSA, N., ANDERSSON, K., BURMAN, J., ANDERSSON, F., HEDENSTRŐM, E., JANSSON, N., PALTTO, H., WESTERBERG, L., WINDE, I., LARSSON, M.C., BERGMAN, K-O, & MILBERG, P. 2013. Using sex pheromone and a multi-scale approach to predict the distribution of a arre saproxylic beetle. *PLOS ONE* **8** (6)

NIETO, A. & ALEXANDER K.N.A. 2010. *European Red List of Saproxylic Beetles*. Luxembourg: Publications Office of the European Union.

NILSSON, S.G. & BARANOWSKI, R. 1997. Habitat predictability and the occurrence of wood beetles in old-growth beech forests. *Ecography* **20**: 491-498.

ØKLAND, B., GŐTMARK, F., NORDÉN, B., FRANC, N. KURINA, O. & POLEVOI, A. 2005. Regional diversity of mycetophilids (Diptera: Sciaroidea) in Scandinavia oak-dominated forests. *Biological Conservation* **121**: 9-20.

OLEKSA, A., CHYBICKI, I.J., GAWRONSKI, R., SVENSSON, G.P. & BURCZYK, J. 2013. Isolation by distance in saproxylic beetles may increase with niche specialization. *Journal of Insect Conservation* **17**: 219-233.

OWEN, J.A. 1989a. The 1987 Presidential Address - Part 2 A preliminary account of the beetles of the RSPB Loch Garten Reserve. *British Journal of Entomology & Natural History* **2**: 17-28.

OWEN, J.A. 1989b. An emergence trap for insects breeding in dead wood. *British Journal of Entomology & Natural History* **2**: 65-67.

OWEN, J.A. 1992a. Catching beetles with a simple flight-interception trap. *Coleopterist* **1**(2): 22-26.

OWEN, J.A. 1992b. Experience with an emergence trap for insects breeding in dead wood. *British Journal of Entomology & Natural History* **5**: 17-20.

PAILLET, Y., BERGES, L., HJALTEN, J., ODOR, P., AVON, C., BERNHARDT-ROMERMANN, M., BIJLSMA, R.J., DE BRUYN, L., FUHR, M., GRANDIN, U., KANKA, R., LUNDIN, L., LUQUE, S., MAGURA, T., MATESANZ, S., MESZAROS, I., SEBASTIA, M.T., SCHMIDT, W., STANDOVAR, T., TOTHMERESZ, UOTILA. A., VALLADARES, F., VELLAK, K. & VIRTANEN, R. 2010. Biodiversity differences between managed and unmanaged forests: meta-analysis of species richness in Europe. *Conservation Biology* **24**: 101-112.

PALM, T. 1959. Die Holz- und Rindenkäfer der Sud- und Mittelschwedischen Laubbäume. *Opusc. Entomol. Suppl*. **16**, 1-374.

PALTTO, H., NORDÉN, B, GÖTMARK, F & FRANC, N. 2006. At which spatial and temporal scales does landscape context affect local density of Red Data Book and Indicator species? *Biological Conservation* **133**: 442-454.

PALTTO, H. THOMASSON, I & NORDÉN, B. 2010. Mulstispecies and multiscale conservation planning: setting quantitative targets for red-listed lichens on ancient oaks. *Conservation Biology* **24**(3): 758-68.

PETERKEN, G.F. 1974. A method for assessing woodland flora for conservation using indicator species. *Biological Conservation* **6**: 239-245.

PETERKEN, G.F. 1981. *Woodland Conservation and Management*. London: Chapman & Hall.

QUINTO, J., MARCOS-GARCÍA, M. de los A., BRUSTEL, H., GALANTE, E. & MICÓ, S. 2013. Effectiveness of three sampling methods to survey saproxylic beetle assemblages in Mediterranean woodland. *Journal of Insect Conservation* **17**: 765-776.

QUINTO, J., MICÓ, S., MARTINÉZ-FALCÓN, A.P., GALANTE, E., MARCOS-GARCÍA, M.d.l.A. 2014. Influence of tree hollow characteristics on the diversity of saproxylic insect guilds in Iberian Mediterranean woodlands. *Journal of Insect Conservation* **18**: 981-992.

RACKHAM, O. 2003. *Ancient Woodland; its history, vegetation and uses in England*. New Edition. Dalbeattie: Castlepoint Press.

RACKHAM, O. 2004. Pre-existing trees and woods in country-house parks. *Landscapes* **2**: 1-16.

RAMÍREZ-HERNÁNDEZ, A., MICÓ, E. & GALANTE, E. 2014. Temporal variation in saproxylic beetle assemblages in a Mediterranean ecosystem. *Journal of Insect Conservation* **18**: 993-1007.

RANIUS, T. 2000. Minimum viable metapopulation size of a beetle, *Osmoderma eremita*, living in tree hollows. *Animal Conservation* **3**: 37-43.

RANIUS, T. 2002. Influence of stand size and quality of tree hollows on saproxylic beetles in Sweden. *Biological Conservation* **103**:85-91.

RANIUS, T., AGUADO, L.O., ANTONSSON, K., AUDISIO, P., BALLERIO, A., CAMPANETO, G.M., CHOBOT, K., GJURASEN, B., HANSSEN, O.,

HUIJBREGTS, H., LAKATOS, F., MARTIN, O., NECULISEUANU, Z., NIKITSKY, N.B, PAILL, W.,PIRNAT, A., RIZUN, V.,RUICANESCU, A., STEGNER, J., SUDA, I., SZWALKO, P., TAMUTIS, V., TELNOV, D., TSINKEVICH, V., VERSTEIRT, V., VIGNON, V., VOGELI, M., & ZACH, P. 2005. *Osmoderma eremita* (Coleoptera, Scarabaeidae, Cetoniinae) in Europe. *Animal Biodiversity and Conservation* **28**: 1-44.

RANIUS, T. & HEDIN, H. 2004. Hermit beetle (*Osmoderma eremita*) in a fragmented landscape, p. 162-170, *In*: AKÇAKAYA, H.R., BURGMAN, M.A., KINDVALL, O., WOOD, C.C., SJÖGREN-GULVE, P., HATFIELD, J.S. AND MCCARTHY, M.A. (Eds). *Species conservation and management*. Oxford University Press.

RANIUS, T. & HEDIN, J. 2001. The dispersal rate of a beetle *Osmoderma eremita* living in tree hollows. *Oecologia* **126**: 363-370.

RANIUS, T. & JANSSON, N. 2000. Influence of forest regrowth, original canopy cover and tree size on saproxylic beetles associated with old oaks. *Biological Conservation* **95**: 85-94.

RANIUS, T. & JANSSON, N. 2002. A comparison of three methods to survey saproxylic beetles in hollow oaks. *Biodiversity and Conservation* **11**: 1759-1771.

RANIUS, T., JOHANSSON, V. & FAHRIG, L. 2011. Predicting spatial occurrence of beetles and pseudoscorpions in hollow oaks in southeastern Sweden. *Biodiversity & Conservation* **20**: 2027-2040.

RANIUS, T., NIKLASSON, M. & BERG, N. 2009a. Development of tree hollows in pedunculate oak (*Quercus robur*). *Forest Ecology and Management* **257**: 303-310.

RANIUS, T., SVENSSON, G.P., BERG, N., NIKLASSON, M & LARSSON, M.C. 2009b. The successional change of hollow oaks affects the suitability for an inhabiting beetle, *Osmoderma eremita*. *Annales Zoologica Fennici* **46**: 205-216.

RAPPORT, D.J., COSTANZA, R. & MCMICHAEL, A.J. 1998. Assessing ecosystem health. *TREE* **13**: 397-402.

RAYNER, A.D.M. & BODDY, L. 1988. *Fungal decomposition of wood. Its biology and ecology*. Chichester: Wiley.

READ, H. 2000. *Veteran trees: a guide to good management*. English Nature.

READ, H., FORFANG, A.S., MARCIAU, R., PALTTO, H., ANDERSSON, L., & TARDY, B. 2003. *Tools for preserving woodland biodiversity*. NACONEX Textbook 2. Töreboda Tryckeri AB, Sweden, 95.

RUKKE, B.A. & MIDTGAARD, F. 1998. The importance of scale and spatial variable for the fungivorous beetle *Bolitophagus reticulatus* (Coleoptera: Tenebrionidae) in a fragmented forest landscape. *Ecography* **21**: 561-572.

SCHLAGHAMERSKÝ, J., 2005. Saproxylic beetles of a hardwood floodplain forest canopy. Pp85-92. In: BARCLAY, M.V.L. & TELNOV, D. (eds). Proceedings of the 3rd Symposium and Workshop on the Conservation of Saproxylic Beetles, Riga, Latvia, 7th – 11th July, 2004. *Latvijas entomologs*, Supplementum VI.

SCHULTEN, B., ISMAY, J.W. & MANN, D.J. 2005. A new design of flight interception trap intended to collect Coleoptera and Diptera. *British Journal of Entomology & Natural History* **18**: 200-201.

SEBEK, P., BARNOUIN, T., BRIN, A., BRUSTEL, H., DUFRENE, M., GOSSELIN, F., MERIGUET, B., MICAS, L., NOBLECOURT, T., ROSE, O., VELLE, L. & BOUGET, C. 2012. A test for assessment of saproxylic beetle biodiversity using subsets of "monitoring species". *Ecological Indicators* **20**: 304-315.

SEBEK, P., CIZEK, L. HAUCK, D. & SCHLAGHAMERSKÝ, J. 2012. Saproxylic beetles in an isolated pollard willow stand and their association with *Osmoderma barnabita* (Coleoptera: Scarabaeidae). pp67-72, in: JURC, M. (ed.) *Saproxylic beetles in Europe: monitoring, biology and conservation*. Ljubljana: Slovenian Forestry Institute, Silva Slovenica. Studia Forestalia Slovenica, Professional and Scientific Works, 137.

SIITONEN, J. 2012. Microhabitats. In: STOKLAND, J.N., SIITONEN, J. & JONSSON, B.G. *Biodiversity in Dead Wood*. Cambridge University Press, pp 150-182.

SIRAMI, C., JAY-ROBERT, P., BRUSTEL, H., VALLADARES, L., LE GUILLOUX, S. & MARTIN, J.-L. 2008. Saproxylic beetle assemblages of old holm-oak trees in the Mediterranean region: role of a keystone structure in a changing heterogeneous landscape. Pp101-114, in: VIGNON, V. & ASMODÉ, J.-F. (eds) Proceedings of the 4th Symposium and workshop on the conservation of saproxylic beetles, held in Vivoin, Sarthe Department, France, 27-29 June 2006. *Revue D' Écologie (Terre et Vie), Supplément* **10**.

SOUTHWOOD, T.R.E. 1978. *Ecological Methods, with particular reference to the study of insect populations.* London: Chapman & Hall. 2nd edition.

SPECTOR, T. & PUTZ, F.E. 2006. Crown retreat of open-grown Southern live oaks (*Quercus virginiana*) due to canopy encroachment in Florida, U.S.A. *Forest Ecology and Management* **228**: 168-176.

SPEIGHT, M.C.D. 1989. Saproxylic invertebrates and their conservation. *Nature and Environment Series* No. **42**. Council of Europe, Strasbourg.

STATSOFT, INC., 2007. STATISTICA, version 8.0. www.statsoft.com

STOKLAND, J.N. & SIITONEN, J. 2012. Mortality Factors and Decay Succession. In: STOKLAND, J.N., SIITONEN, J. & JONSSON, B.G. 2012. *Biodiversity in Dead Wood*. Cambridge University Press, pp 110-149.

STOKLAND, J.N., SIITONEN, J. & JONSSON, B.G. 2012. *Biodiversity in Dead Wood*. Cambridge University Press.

STUBBS, A.E. 1982. Hoverflies as primary woodland indicators with reference to Wharncliffe Wood. *Sorby Record* **20**: 62-67.

SVENSSON, G.P., LARSSON, M.C. & HEDIN, J. 2004. Attraction of the larval predator *Elater ferrugineus* to the sex pheromone of its prey *Osmoderma eremita* and its implications for conservation biology. *Journal of Chemical Ecology* **30**: 353-363.

SVERDRUP-THYGESON, A. 2009. Oaks in Norway: Hotspots for red-listed beetles (Coleoptera). In: BUSE, J., ALEXANDER, K.N.A., RANIUS, T. & ASSMANN, T. *Saproxylic Beetle – Their role and diversity in European woodland and tree habitats.* Proceedings of the 5th Symposium and Workshop on the Conservation of Saproxylic Beetles, pp13-26. Sofia: Pensoft.

SVERDRUP-THYGESON, A. & BIRKEMOE, T. 2009. What window traps can tell us: effect of placement, forest openness and beetle reproduction in retention trees. *Journal of Insect Conservation* **13**: 183-191.

SVERDRUP-THYGESON, A., & MIDTGAARD, F. 1998. Fungus infected trees as islands in boreal forests: spatial distribution of the Fungivorous beetle *Bolitophagus reticulatus* (Coleoptera: Tenebrionidae). *Écoscience* **5**: 486-493.

TOLASCH, T., VON FRAGSTEIN, M. & STEIDLE, J.L.M. 2007. Sex pheromone of *Elater ferrugineus* L., (Coleoptera: Elateridae). Journal of Chemical Ecology 33: 2156-2166.

VANDEKERKHOVE, K., DE KEERSMAEKER, L., WALLEYN, R., KŐHLER, F., CREVECOEUR, L., GOVAERE, L. THOMAES, A. & VERHEYEN, K. 2011. Reappearance of old-growth elements in lowland woodlands in northern Belgium: do the associated species follow? Silva Fennica 45 (5): 909-935.

VODKA, S., KONVICKA, M. & CIZEK, L. 2009. Habitat preferences of oak-feeding xylophagous beetles in a temperate woodland: implications for forest history and management. *Journal of Insect Conservation* **13**: 553-562.

VERA, F.W.M. 2000. *Grazing Ecology and Forest History*. CABI Publishing.

WARREN, M.S. & KEY, R.S. 1991. Woodlands: past, present and potential for insects. In: Collins NM & Thomas JA (eds) *The Conservation of Insects and their Habitats*. Ch 8: 155-211. London: Academic Press.

WEBB, J. & PERRY, S. 2014. Saproxylic Coleoptera of Grimsthorpe Park, South Lincolnshire. *The Coleopterist* **23**: 116-127.

WEISS, J. & KŐHLER, F. 2005. Erfolgskontrolle von maßnahmen des totholzschutzes im wald. Einzelbaumschutz oder Baumgruppenerhaltung? LŐBF-Mitteilungen 3: 26-29. [referred to i Vandekerkhove et al, 2011]

WHITEHEAD, P.F. 2009. *NE Bredon LV Bin Report*. Unpublished report to People's Trust for Endangered Species.

WIDERBERG, M.K., RANIUS, T., DROBYSHEV, I., NILSSON, U., & LINDBLADH, M. 2012. Increased openness around retained oaks increases species richness of saproxylic beetles. *Biodiversity and Conservation* **21**: 3035-3059.

WIKARS, L.O., SAHLIN, E., & RANIUS, T. 2005. A comparison of three methods to estimate species richness of saproxylic beetles (Coleoptera) in logs and high stumps of Norway spruce. *Canadian Entomologist* **137**: 304-324.

WILDE, I., 2005a. The shadier side of Epping Forest: saproxylic Coleoptera research. Pp124-125. In: BARCLAY, M.V.L. & TELNOV, D. (eds). Proceedings of the 3rd Symposium and Workshop on the Conservation of Saproxylic Beetles, Riga, Latvia, 7th – 11th July, 2004. *Latvijas entomologs*, Supplementum VI.

WILDE, I. 2005b. *Kept in the dark: the shady secrets of the saproxylic Coleoptera of ancient oak pollards in Epping Forest*. MSc Thesis, University of London, Birkbeck.

ZAULI, A., CHIARI, S., HEDENSTRŐM, E., SVENSSON, G.P. & CARPANETO, G.M. 2014. Using odour traps for population monitoring and dispersal analysis of the threatened saproxylic beetles *Osmoderma eremita* and *Elater ferrugineus* in central Italy. *Journal of Insect Conservation* **18**: 801-813.

APPENDIX 1: GLOSSARY

This Appendix aims to briefly discuss some of the issues involved in the use of particular terms and expressions. Webster's Dictionary has been used to provide a 'layman's view'.

Ancient tree:

- A tree that has passed beyond maturity and is old, or aged, in comparison with other trees of the same species (*Ancient Tree Guide No. 4*, The Woodland Trust);
- Read (2000) used the term 'veteran' as interchangeable with 'ancient' and therefore her definition relates to what is now specifically referred to as an ancient tree: The term veteran is one that is not capable of precise definition but it encompasses trees defined by three guiding principles:
    - Trees of interest biologically, aesthetically or culturally because of their age;
    - Trees in the ancient stage of their life;
    - Trees that are old relative to others of the same species;
- Note that all ancient trees fall within the current definition of veteran tree – see below.

Forest:

- The term 'forest' has many different usages in Britain, as clearly outlined in Webster's Dictionary:
    - A tract of more or less wooded land formerly set apart primarily for the keeping and hunting of game;
    - A dense growth of trees and underbrush covering a large tract of land;
    - An extensive plant community of shrubs and trees in all stages of growth and decay with a closed canopy;
- It is important therefore to be clear about the context whenever the word is used;
- The Food and Agriculture Organisation of the United Nations defines forest, in its global forest resource assessment, as "land spanning more than 0.5ha with trees higher than 5m and a canopy cover of more than 10%, or trees able to reach these thresholds in situ" (taken from Brown & Fisher 2009); this is the definition used by the Convention on Biological Diversity.

Forest ecosystem:

- A forest ecosystem can be defined at a range of scales. It is a dynamic complex of plant, animal and micro-organism communities and their abiotic environment interacting as a functional unit, where trees are a key component of the system. Humans, with their cultural, economic and environmental needs are an integral part of many forest ecosystems. (from the Convention on Biological Diversity)

Habitat

- "the place or type of site where an organism or population naturally occurs" (Article 2 of the Convention on Biological Diversity). Note that plant assemblages are not the same thing as 'habitat'; the EU Habitats Directive is mistaken in assuming the two are the same thing. Veteran trees (small scale) and old growth (large scale) can be regarded as habitat for saproxylic beetles but a woodland plant assemblage has no real meaning in this respect *per se*.

Health, in context of invertebrate populations:

- Ecological health is about stress and dysfunction (eg Rapport et al 1998);
- The notion of health has generally been used to denote the vitality of populations, etc;
- An unhealthy invertebrate population is one which is becoming unsustainable due to changes in habitat availability and suitability within its environs; it can be assessed using measures of resilience, vigour and organisation;
- Vigour is measured in terms of activity, metabolism or primary productivity; an example of reduced vigour is the decline in abundance of a species and lack of suitable habitat within the local environment;
- Organisation can be assessed as the diversity and number of interactions between system components, eg imbalance in the habitat requirements of the larvae in relation to those of the adults;
- Resilience (counteractive capacity) is measured in terms of a system's capacity to maintain structure and function in the presence of stress, eg the populations capacity to exploit alternative resources if the favoured resources decline.

Open-grown tree:

- A tree that has developed without competition from neighbouring trees, such that crown development results in a form that is a compromise between optimising the light-gathering potential and resisting damage from winds;
- Trunks are relatively short and squat, and have spreading lateral branches;
- See also Green (2010) and Eloy (2011).

Saproxylic:

- Any species that depends, during some part of its life cycle, upon wounded or decaying woody material from living, weakened or dead trees (Stokland et al 2012).

Veteran tree:

- A tree with markedly ancient characteristics irrespective of chronological age (Lonsdale 2013), i.e. this is about **condition** not age per se;
- Effectively a tree with significant amounts of dead and decaying woody tissues, resulting from physical damage and/or age.

Woodland:

- The term 'woodland' is widely used but rarely explained or defined;
- The vernacular usage generally refers to 'land covered with woody vegetation' (Webster's Dictionary), and so may or may not include well-spaced open-grown trees;
- Brown & Fisher (2009) identify three criteria as important: woodland area, tree cover and tree height; they go on to refer to "core woodland habitat with its characteristic microclimate"
- 'Ecosystems that contain widely spaced trees with their crowns not touching' (Lindenmayer et al 2014);
- The Forestry Commission website gives the definition of 'woodland' in United Kingdom forestry statistics as land under stands of trees with a canopy cover of at least 20% (or having the potential to achieve this), including integral open space, and including felled areas that are awaiting restocking. There is no minimum height for trees to form a woodland at maturity, so the definition includes woodland scrub but not areas of gorse, Rhododendron, etc., outside woodland.

- Like ‘forest’ it is important therefore to be clear about the context whenever the word is used.

Wood-pasture:

- Areas of land which have been used for the dual purpose of growing trees and grazing deer and livestock (Harding & Rose 1986);
- Peterken (1981) described pasture woodlands in terms of ‘underwood virtually eliminated and most of trees mature or over-mature; field layer generally dominated by heathland and grassland communities’; he effectively viewed wood pasture - from a forestry background - as degraded woodland rather than as a sustainable land-use in parallel to managed, enclosed and ungrazed, woodland;
- The criterion used for Natural England’s wood pasture and parkland inventory is three trees within 250m of each other;
- Best thought of as trees within pasture, or pasture-trees, since the characteristic features of conventional ‘woodland’ are very often missing, eg shade-tolerant ground vegetation and a shrub layer.

APPENDIX 2: RECORD SHEETS FOR PROJECT STUDY SITES

<table>
<tr><td colspan="5">Inventory of Parkland & Wood Pasture Sites</td></tr>
<tr><td colspan="3">Site name: Killerton Park</td><td colspan="2">Owner/Manager:
National Trust South West Region</td></tr>
<tr><td>Parish:
Broadclyst</td><td>LA:
East Devon</td><td>Size:
135 acres</td><td>Type:
Parkland</td><td>Grid Ref:
SX9897</td></tr>
<tr><td>EH Register: Killerton House is Grade II* but park not listed</td><td>CL: N/A</td><td></td><td colspan="2">LCZ:</td></tr>
<tr><td colspan="3">Designations: Killerton Park SSSI (geological)</td><td colspan="2">Agri-environment scheme status: information not yet sought</td></tr>
</table>

Summary of available data:

Historical record (habitat continuity)	• 1242 Manor of Killerton dates back to 1242 when owned by Kildrington family; • no known documentation for a medieval deer park; • Elizabethan mansion built by Edward Drewe who acquired land through marriage; • no deer park shown by Saxton; • Bought by John Acland of Columbjohn at end of 16C; house destroyed in Civil War; • Park pale to deer park on east side of Dolbury; structure suggests 16C or 17C • 1756 estate map shows deer park of 135a north of mansion • 1770s c 500a of farmland around Dolbury enclosed to form large landscape park and the current house built somewhat later; park design by John Veitch; • deer park belonging to Sir Thomas Ackland, Bart. (Lyson's *Devonshire*, 1822): • existing deer park of Sir Thomas D Acland, Bart. (1867); • 1922 deer herd disbanded; • 1944 acquired by National Trust from Trustees of Sir Richard Acland Bt.
Tree population (assess by tree size classes, species, form, situation)	Ancient oak pollards (at least 10 of c 6m gbh) > 400 years age within old deer park enclosure; ancient sweet chestnut; veteran oaks much more numerous and over a larger extent of the 18C parkland
Deadwood detail	Limited fallen. Plentiful aerial.
Field layer & scrub	Pasture recovering from intensive agricultural use; some bramble patches have developed at fringes of old deer park area, etc.
Fungi	An Initial Fungus Survey (2001): very rare (pRDB)

	heartwood decay fungus *Aurantioporus fissilis* (beech); also uncommon saprotrophs eg *Inonotus cuticularis* (on beech) & mycorrhizals; Casual records include Oak Polypore *Piptoporus quercinus* (BAP Priority Species)
Inverts	Limited knowledge. • Late 19C records for important saproxylic beetles listed in Victoria County History. • 1990 NT Bio Survey identified as regionally important site for sapro beetles, key species include *Prionychus ater*. • NCC Invertebrate Site Register: Killerton (under-worked). • 2001 NT Invertebrate Survey (J Denton) additional key species *Abdera biflexuosa* • 2003 casual recording as part of Spalding Associates survey report (see below) additional key species *Stenagostus rhombeus* • 2010 *Dorcatoma substriata*, *Eledona agricola* & *Enicmus brevicornis* noted by Devonshire Association (Entomological Section)
Epiphytes	No data
Other wildlife interest	2003 Nature Conservation Assessment of the Killerton Estate Farmland (Spalding Associates)
Wider landscape of trees (core area +)	Ancient oak pollards extend into surrounding landscape; also woodland on Dolbury and trees along River Culm; Estate includes Ashclyst Forest, with further veteran trees along old field banks within the secondary plantation woodland
Management agreements,etc	Not collated.

Assessments of specific ecological interests

Veteran trees	**Fungi**	**Invertebrates**	**Epiphytic lichens**
No of veterans:	Two beech quality indicators; one oak	IEC = 11: Regional significance	
No of ancients:			
No >1.5m dbh:			
Full data not available	**County importance**	**Regional importance**	

Overall assessment

Recommended site quality	**Site condition**	**Land management issues**
Regional importance		

Saproxylic Site Register

Site name: Knepp Castle Estate		Owner/Manager: Sir Charles Burrell Bt.	
County: West Sussex	VC: 13	Grid Ref: TQ1521	Size: 1416ha
Parish: Shipley	LA:	Alt Range: 8-10m	
HS Register: Grade II park and garden	CL: n/a	Landscape Character Zone: • Low Weald Natural Area • Upper catchment of River Adur	
Designations:		Agri-environment scheme status:	

Summary of available data:

Historical record (habitat continuity)	• Forest of Anderida • Late 12C deer park around motte & bailey Norman castle of William de Brewes, Lord of the Rape of Bramber • 1209 King John seized Knepp Castle from de Broase family • 1215 Knepp restored to Broase family; land surrounded by forest at that time • Late 14C onwards decline & deterioration • Speed's Tudor map shows no deer park • 16C land used for iron working – Kneppmill Pond is an old hammer pond constructed prior to 1568 • 1787 estate acquired by Sir Charles Raymond; his dau Sophia married Sir William Burrell • 1802 Knepp Castle built for Burrell family by John Nash & park landscaped by Humphrey Repton • Shirley: no mention of deer park in 1867 • 1985 Sir Charles Burrell took over estate • 2001 Knepp Wildland Project began with restoration of 202ha deer park • 2004 deer park extended to 283ha • 2005 second park created north of A272 • 2009 extended to c 1000ha
Tree population (assess by tree size classes, species, form, situation)	• Very few large old trees remain in landscape due to ironworking • Estate unusually rich in hedgerow trees as were not grubbed out in mid 20C, unlike practice of all the neighbours
Deadwood detail	Not documented
Field layer & scrub	Not documented
Fungi	Very notable: *Phellinus robustus, Podoscypha multizonata, Phellinus populicola*

Inverts	Not documented
Epiphytes	Not documented
Other wildlife interest	Not documented
Wider landscape of trees (core area +)	Weald; West Grinstead Park adjoins other side of A24
Management	

Assessments of specific ecological interests

Veteran trees	**Fungi**	**Invertebrates**	**Epiphytic lichens**
No of veterans:			
No of ancients:			
No >1.5m dbh:			
Significance:	National		

Overall assessment

Recommended site quality	**Site condition**	**Land management issues**
National significance for fungi		

Saproxylic Site Register

Site name: Stowe Park Estate		Owner/Manager: National Trust	
County: Buckinghamshire	VC: 24	Grid Ref: SP675370	Size:
Parish:	LA: Aylesbury Vale	Alt Range:	
HS Register: Grade I Landscape Garden	CL: n/a	Landscape Character Zone:	
Designations:		Agri-environment scheme status:	

Summary of available data:

Historical record (habitat continuity)	• Whittlewood Forest • 1257 deer park of Sir John Chastillon • 1574 no deer park shown on Saxton's map • Late C16 bought by Temple family • 1677 mansion built for Sir Richard Temple, 3rd Bt • 1714 4th Bt became Lord Cobham • 1717-34 Bridgeman landscaping • Early 1730s William Kent employed • 1741-50 Capability Brown employed • 1749 Cobham died, inherited by Richard Grenville, Earl Temple (d 1779) • Inherited by Marquess of Buckingham & later Dukes of Buckingham • 1921 estate sold and house later became a school • Former home of Baroness Kinloss; no deer since school started • 1990 NT acquired landscaped gardens; 1992 Castle Fields; 1995 Home Farm
Tree population (assess by tree size classes, species, form, situation)	• Buckingham Avenue elms & beeches, felled & replanted following DED
Deadwood detail	Not documented
Field layer & scrub	Not documented
Fungi	Not documented
Inverts	• NT Bio Survey identified *Dorcatoma flavicornis, Bitoma crenata*, *Ischnomera cyanea*, *Aderus populneus* and *Xyloborus dryographus* in 1990; *Xestobium rufovillosum* in 1995; *Anitys rubens, Silvanus unidentatus, Biphyllus lunatus, Mycetophagus piceus, Prionychus ater* and *Phymatodes testaceus* in 2000
Epiphytes	• Lichen indicator species 2 + 4 extinct (H Bowen data)
Other wildlife interest	Not documented

Wider landscape of trees (core area +)	Whittlewood Forest area to north includes historic parklands and other veteran trees
Management	

Assessments of specific ecological interests

Veteran trees	**Fungi**	**Invertebrates**	**Epiphytic lichens**
No of veterans:		IEC = 14	
No of ancients:			
No >1.5m dbh:			
Significance:		Regional significance	Local or county interest

Overall assessment

Recommended site quality	**Site condition**	**Land management issues**
Regional significance		

Saproxylic Site Register

<table>
<tr><td colspan="2">Site name: Wimpole Hall Estate</td><td colspan="2">Owner/Manager: National Trust</td></tr>
<tr><td>County: Cambridgeshire</td><td>VC: 29</td><td>Grid Ref: TL336510</td><td>Size: 600a</td></tr>
<tr><td>Parish: Wimpole</td><td>LA: South Cambs District</td><td>Alt Range: 37-47m</td><td></td></tr>
<tr><td>HS Register:
Grade I Hall
Grade I Landscape park</td><td>CL: none</td><td colspan="2">Landscape Character Zone:
West Anglian Plain Natural Area
Boulder clay and Chalk marl</td></tr>
<tr><td colspan="2">Designations: Eversden & Wimpole Woods SSSI/SAC</td><td colspan="2">Agri-environment scheme status:</td></tr>
</table>

Summary of available data:

<table>
<tr><td>Historical record (habitat continuity)</td><td>
1302 first record of deer park at Wimpole (Reaney’s Place Names of Cambridgeshire)
1390s owned by Sir William de Staundon
1428 widow left manor to Henry Chicheley, Archbishop of Canterbury
1638 Benjamin Hare’s map shows park of c 40a to north of moated manor house; open fields shown to south where parkland today (British History Online)
House demolished & new hall built c 1640 by Sir Thomas Chicheley, & park expanded to 200a in formal continental manner
1686 sold to Sir Thomas Cutler
1693 his son-in-law inherited, Charles Robartes, 2nd Earl of Radnor; park expanded again & planted tree belts
1710 sold to John Holles, 3rd Duke of Newcastle; estate passed to dau who m
1713 Edward Harley, 2nd Earl of Oxford inherited estate & park again expanded
1740 sold to Philip Yorke, later 1st Earl of Hardwicke & park remodelled
Geometrical design probably of London & Wise; further developed by Bridgeman; converted into a serpentine design by Brown; Repton produced further proposals which were never implemented - 1801 Repton’s Red Book for Wimpole
250a deer park according to Shirley’s review
1976 acquired by NT under will of Elsie Bambridge, dau Rudyard Kipling
1981 Bridgeman’s South Avenue acquired by NT
</td></tr>
<tr><td>Tree population (assess by tree size classes, species, form,</td><td>Venerable elms mentioned; all now gone. Parkland 2015 dominated by horse chestnut and common lime, but with areas of oak, including Turkey oak; no ancient trees</td></tr>
</table>

situation)	Group of 3 large veteran oak by Wimpole Ruins, to north of main park The Great Avenue was planted in 1718 with *Ulmus minor* and a *procera* clone, but Dutch Elm Disease appeared in 1972 and began to kill them; they were eventually clear-felled and removed (Rackham 2003 see p258 and Fig 16.2).
Deadwood detail	Plentiful January 2015, with many trees crown-reduced and cut material left beneath; natural collapses left largely in situ
Field layer & scrub	Grassland pasture dominates, with some thorn scrub developing locally; steeper banks unimproved or reverting. Much of park on open-field ridge and furrow
Fungi	Typical brackets: *Fistulina, Laetiporus, I dryadeus, G australe; Hericium erinaceum* reported by Simon Damant
Inverts	First surveyed by Pete Kirby over 2001/2002; rarities include *Aeletes atomarius, Ischnodes sanguinicollis, Elater ferrugineus, Laemophloeus monilis, Pseudocistela ceramboides, Mycetochara humeralis, Ischnomera cinerescens, Phloeophagus truncorum* & *Ernoporus caucasicus* *Callicera spinolae* & 8 other RDB Diptera (Damant & Kirby 2005) Very much a notably rich white-rot assemblage; red-rot may be of interest in farmland oak pollards
Epiphytes	
Other wildlife interest	Barbastelle maternity roost in northern shelterbelts
Wider landscape of trees (core area +)	Repton: 'Wimpole is like a flower in the desert' Surrounding farmland includes ancient boundary oak pollards; Arrington valley has elm, ash, maple pollards
Management	Home Farm is a working farm with rare breeds of livestock; 988.7 ha

Assessments of specific ecological interests

Veteran trees	**Fungi**	**Invertebrates**	**Epiphytic lichens**
No of veterans:		IEC=81 (2015)	
No of ancients:		SQI=569 (PK)	
No >1.5m dbh:			
Significance: County	County	European Significance	

Overall assessment

Recommended site quality	**Site condition**	**Land management issues**
European significance	Favourable	None, other than need to continue much as at present