The extent and severity of *Cameraria ohridella* and *Pseudomonas syringae* on *Aesculus* species, and the success of management techniques used to mitigate these problems in the United Kingdom.

Rupert Ellingham

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"The Horse chestnut is at once the best known and the most beautiful of flowering trees of the largest size. The stately, spreading form of fully-grown trees is appropriately accompanied by noble proportions and handsome shape of leaf, and by large, striking flower clusters. An English park can afford no finer sight than a group of Horse chestnuts towards the end of May, when every branchlet carries its erect cone of white flowers." (Bean, 1970)

Abstract

The primary purpose of the research project was to establish the extent and severity of *Cameraria ohridella* (Horse chestnut leaf miner) and *Pseudomonas syringae* (Horse chestnut bleeding canker) on *Aesculus* species (Horse chestnuts and Buckeyes), and to ascertain the success of various management techniques being used to mitigate these problems in the United Kingdom.

In order to extrapolate the information required the research directly targeted 577 professionals in all areas of the arboricultural industry, including contractors, consultants, researchers, lecturers and tree officers for surveying by e-mail. In addition 5000 people were indirectly targeted through Arbtalk, an internet discussion forum (Arbtalk, 2009a).

The results established that *C. ohridella* and *P. syringae* are prevalent throughout the UK, and that many *Aesculus* species are being removed unduly, before the long-term impacts are fully understood. This is predominantly due to the lack of information on the success of management techniques for *C. ohridella* and *P. syringae*, the cost of such management techniques, and an over emphasis on sanitation felling and health and safety (Anderson, 2006).

Where management techniques had been used there was a general consensus that it was too early to evaluate the results. However, a small percentage of respondents reported some success, suggesting that management techniques can be effective in mitigating *C. ohridella* and *P. syringae*.

The research highlighted the need for further research, in the form of field trials, to be undertaken in order to develop, refine and evaluate management techniques for *C. ohridella* and *P. syringae*.

It is hoped that the report will increase understanding of the present threat to *Aesculus* species, provide guidance on how to actively manage *C. ohridella* and *P. syringae* and emphasise the need for further research to be undertaken.

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Chapter 1: Introduction

1.1 Background

In the last ten to fifteen years there has been an unprecedented increase in the numbers of pests and diseases attacking trees throughout the world (Green *et al.*, 2009). Many of the causal organisms have been inadvertently introduced into new ecosystems through increased international trade of live plants, soil and poorly treated timber products (Brasier, 2008).

Aesculus (Horse chestnuts and Buckeyes), an important amenity tree species throughout much of the United Kingdom [UK] and northern Europe, are suffering from two major problems of recent introduction into the continent: *Cameraria ohridella* (Horse chestnut leaf miner) and *Pseudomonas syringae* (Horse chestnut bleeding canker). Both *C. ohridella* and *P. syringae* have rapidly established and become widespread throughout the UK over the last eight years and are having a devastating effect on *Aesculus* species.

Management techniques for *C. ohridella* and *P. syringae* are still very limited with the main emphasis on hygiene, principally through the destruction of infested or infected plant material, and tree health, primarily through the provision of a healthy environment for tree roots to thrive. Natural and chemical treatments are also being trialled with varying success, to directly treat the causal organisms. However, there is little evidence that any of these management techniques are sufficiently successful to warrant the capital expenditure.

1.2 Developing the Research Question

The research question was developed in response to the author's involvement in remedial work and the removal of structurally unsound, failed and dead *Aesculus* species as a result of *P. syringae*, along with a growing interest in preventative measures from clients of the authors employer to alleviate premature leaf drop caused

by *C. ohridella*. After initial background research and much deliberation, it was decided both *C. ohridella* and *P. syringae* would be studied, as they are equally current and prominent issues affecting *Aesculus* species. The aim of the research was to establish the extent and severity of *C. ohridella* and *P. syringae* on *Aesculus* species, and the success of management techniques used to mitigate these problems in the UK. The objectives of the research were to:

- Establish the extent and severity of *C. ohridella* and *P. syringae* on *Aesculus* species in the UK.
- Determine the number of *Aesculus* species being removed as a result of *C. ohridella* and *P. syringae* in the UK and whether they are being removed unduly.
- Ascertain the success of management techniques used to mitigate *C. ohridella* and *P. syringae* in the UK and establish how widely they are used.
- Identify other biotic and abiotic factors affecting *Aesculus* species in the UK.
- Establish what is being planted in place of removed *Aesculus* species in the UK.
- Ascertain whether a non-native tree species, such as *Aesculus*, should be safeguarded in the UK.

The report endeavours to produce a rigorous overview of the current situation by collating existing information and research through the literature review (secondary research) and gathering and analysing the opinions of arboriculturalists through a well-designed questionnaire (primary research). The primary research provides a combination of quantitative and qualitative data, most of which is substantiated by the secondary data. Quantitative data has been plotted in tables, graphs and charts to make the research clearer and more accessible to a wider audience. Qualitative analysis was undertaken on the comments provided within the questionnaire.

The report has been e-mailed to 120 questionnaire respondents who requested it through the questionnaire. It has also been made available on Arbtalk, an internet discussion forum for people with an interest in trees and the arboricultural and forestry industries (Arbtalk, 2009a). It is hoped that this will increase understanding of the present threat to *Aesculus* species, provide guidance on how to actively manage *C. ohridella* and *P. syringae* and highlight the need for further research to be undertaken. The findings also provide a reference point for further research.

Chapter 2: Literature Review

2.1 *Aesculus*

The *Aesculus* genus originated around 65 million years ago in East Asia, spreading into North America and South East Europe, becoming erratically distributed due to geological and climatic changes (Xiang *et al.*, 1998). Today the genus comprises of between 13 and 19 species of woody deciduous trees and shrubs (Bean, 1970; Daniels, 1984; Xiang *et al.*, 1998; Huxley, 1999). They are native to the temperate northern hemisphere and can be found in all three northern continents (Bean, 1970). One in South East Europe, five to eleven in East Asia and India, and seven in North America plus a number of hybrids (Daniels, 1984). There is uncertainty about six species in China as they are nearly indistinguishable from previously described species and their recognition remains tentative (Xiang *et al.*, 1998). The Eurasian species are known as Horse chestnuts and the North American species as Buckeyes. Carl Linnaeus named the genus after the Latin name for oak with edible acorns (Huxley, 1999). The *Aesculus* genus has traditionally been part of the *Hippocastanaceae* family. However, recent phylogenetic analysis of morphological (Judd *et al.*, 1994) and molecular data (Harrington *et al.*, 2005) has led to this family being included in the *Sapindaceae* family.

The most common *Aesculus* species found in the UK today are *A. hippocastanum* (Common Horse chestnut) and *A. x carnea* (Red Horse chestnut). Less common ones include *A. flava* (Yellow Buckeye), *A. indica* (Indian Horse chestnut) and *A. parviflora* (Bottlebrush Buckeye). *A. hippocastanum* is indigenous to the central Balkan Peninsula in South East Europe deep in the remote Pindus Mountains of Northern Greece and Southern Albania (Bean, 1970; Phillips, 1978; Anderson, 2006). It was introduced to Vienna, Austria via Constantinople, Turkey in 1576 by Karl Clusius and reached Britain in 1616 (Bean, 1970). It is the only *Aesculus* native to Europe and is the most familiar member of the genus worldwide. *A. x carnea* is a natural hybrid of *A. hippocastanum* and *A. pavia* (Red Buckeye) (Bean, 1970; Daniels, 1984; Huxley, 1999), a small shrub from southern North America (Daniels, 1984). It was first discovered in early 19th century Germany and distributed around

1818 from budding or grafting to the rootstock of *A. hippocastanum* (Bean, 1970). Despite being a hybrid it is rather fertile and breeds true from seed (Daniels, 1984).

Aesculus species, notably *A. hippocastanum*, have been extensively planted in the UK over the last four centuries as highly visible amenity trees along streets, on village greens, country lawns, in city parks, private gardens and in grand avenues (Anderson, 2006) (Plate 1). They were favoured by many landscape architects including Sir Christopher Wren (Miles, 1999) and Lancelot 'Capability' Brown, and peaked in popularity during the Edwardian era (Wilkinson, 1981). They are also common ornamental trees in many European cities in the northern temperate zone (Wilkinson, 1981; Steadman and Pritchard, 2003). One of the most famous is the Anne Frank tree in Amsterdam, Netherlands.

Plate 1: A majestic *Aesculus hippocastanum* set in open parkland (Allicin Tree Care, No date).

The National Inventory of Woodland and Trees conducted by the Forestry Commission in 2001 and 2002, estimated that there were 473,000 *Aesculus* trees in the UK: 432,000 in England, 29,900 in Scotland and 11,100 in Wales (Smith and Gilbert, 2001a, b, 2002). The majority of these are situated in non-woodland situations along streets, in parks and gardens. The planted and self-sown individuals also flourish along roadsides, in hedges, woodlands, copses, shelterbelts and other landscape feature groups across the UK.

Aesculus species are widely cultivated as amenity trees throughout the temperate northern hemisphere but have very few viable commercial uses. The timber is lightweight and not very strong, lacking both tannin and resin (Wilkinson, 1981), and consequently has little economic value (Mitchell, 1985). It is popular for turning and carving as it is nearly white in colour, and smooth and soft in texture (Mitchell, 1985) making it easy to work with. It is often used for children's toys and kitchen utensils that do not require much strength. It also has absorbent properties that make it ideal for fruit racks and storage trays, as it keeps the fruit dry and so prevents rotting (Readers Digest, 2002). As a fuel, it needs to be thoroughly dried and is still only mediocre to burn as it produces small flames, low heat and is prone to shoot embers (Wilkinson, 1981). Extracts from *A. hippocastanum* have important pharmaceutical uses. The extracted active ingredients Aesculin and Aescin are widely used for medicinal as well as cosmetic preparations and are marketed as herbal remedies because of their anti-inflammatory properties (Plant Poisons, No date). The saponin Aescin also forms a soapy lather when mixed and agitated with water so can be used as an alternative to soap (Wilkinson, 1981).

This non-native species has been naturalizing itself in the UK for a number of centuries and is now an integral part of the landscape (Anderson, 2006). They are a familiar feature in many designed historic landscapes and hold a special place in the hearts of the nation because of their fruit, the conker. *Aesculus* species have ecological value as many insects and animals have come to rely on it. The fruits are sought by cattle, deer and squirrels (Wilkinson, 1981), while the flowers provide pollen for insects, notably bees.

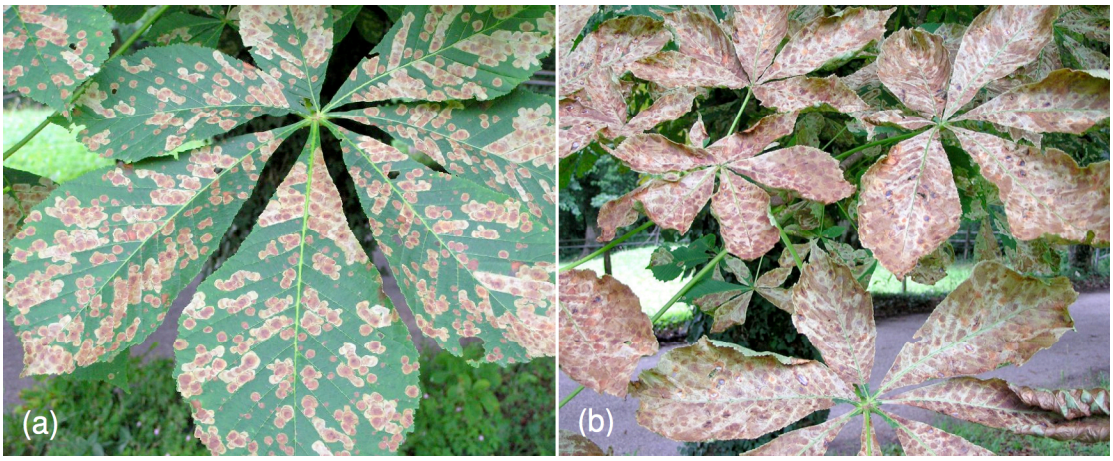
2.2 *Cameraria ohridella*

Cameraria ohridella Deschka and Dimic (Horse chestnut leaf miner) is a small but highly debilitating leaf mining moth from the l*epidopteran* family *Gracillariidae* (Pavan *et al.*, 2003). It was first discovered in Macedonia, Northern Greece in 1984, and described as a new species by Deschka and Dimic in 1986 (CONROCAM, 2004). Its precise geographical origin is unknown, but it is thought that it may have originated from North America or East Asia, namely China (Gilbert *et al.*, 2003). Since then it has spread rapidly across Central and Western Europe resulting in premature defoliation of many *Aesculus* species, notably *A. hippocastanum* (Tilbury and Evans, 2002).

C. ohridella was first found established in the UK in the London borough of Wimbledon in July 2002 (Londsdale, 2001; Pepper, 2003). High densities of leaf mines were found, which suggested that the first moths arrived in 2000 or 2001, but had remained undetected (Tilbury *et al.*, 2004). From this initial area of infestation, the moth has spread rapidly, and it is now present across most of Southern and Central England (Tilbury *et al.*, 2004; Gilbert *et al.*, 2005; Straw and Tilbury, 2006; Forestry Commission, 2009a).

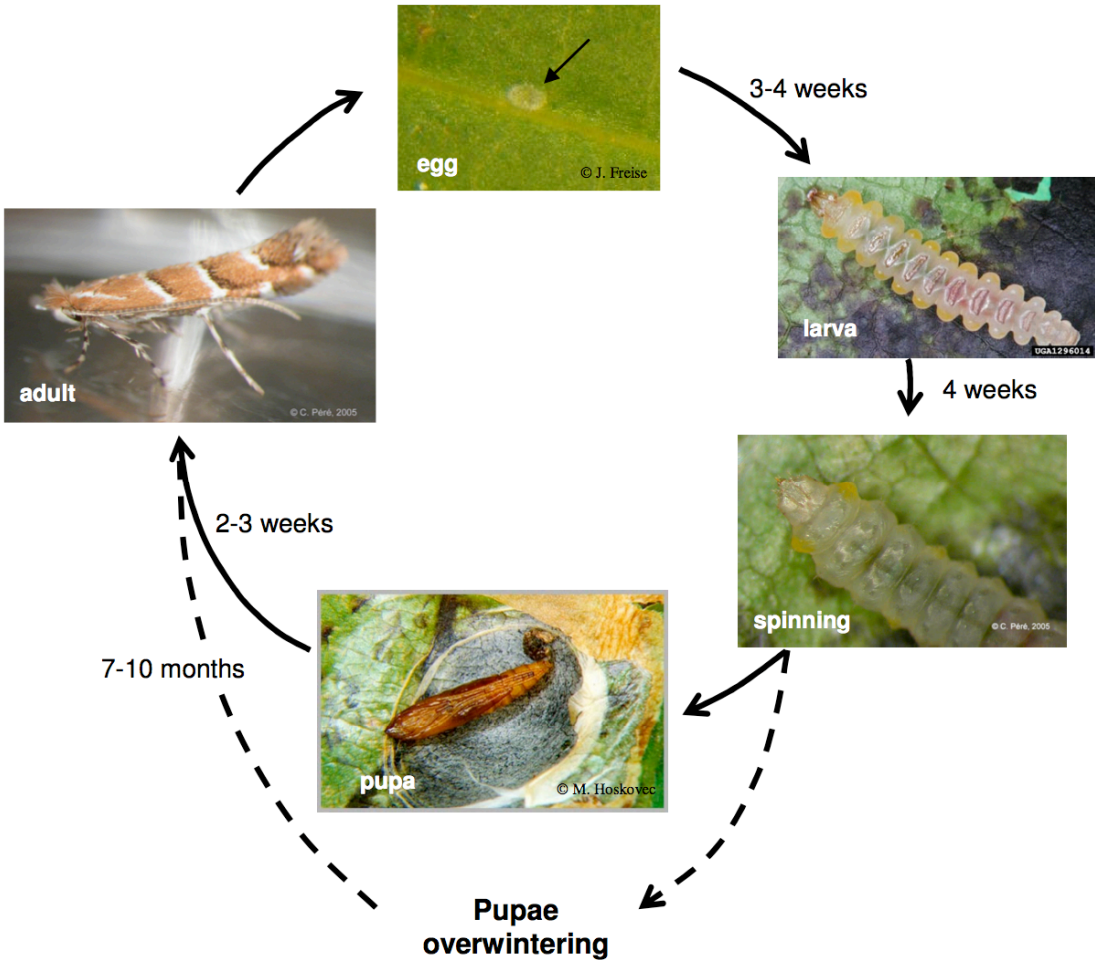
The highly visible leaf damage is caused by the larvae of *C. ohridella*, which drills into the leaf palisade and feeds on the sap and then the parenchyma between the upper and lower epidermis layers (Kehrli and Bacher, 2003; Raimondo *et al.*, 2003; Thalmann *et al.*, 2003). The resultant three to four centimetre long serpentine mines (CONROCAM, 2004) often merge together leading to browning and drying of the leaves (Plate 2), which eventually fall prematurely (Tilbury and Evans, 2002; Salleo *et al.*, 2003).

Plate 2: Leaves of *Aesculus hippocastanum* infested with *Cameraria ohridella* in mid-June (a) and mid-August (b) (Pere, 2009).



C. ohridella produces two to four generations per year in the UK, depending on climatic conditions, and can rapidly reach large population densities within one or two years (Thalmann *et al.*, 2003) (Figure 1). Once established, the moth maintains exceptionally high rates of infestation (up to 700 mines per leaf) without any evidence of decline (CONROCAM, 2004). The first generation emerges in spring and feeds mainly in the lower crown, while the subsequent generations feed predominantly in the upper crown (Tomiczek and Krehan, 1998). Infested trees suffer severe defoliation during late summer, after the second generation occurs (Salleo *et al.*, 2003), causing premature defoliation before normal leaf fall in autumn (Freise and Heitland, 1999). In many areas where *C. ohridella* is established, trees can be completely defoliated in summer (Thalmann *et al.*, 2003). This greatly reduces the trees visual appearance, photosynthetic performance (by 30 to 40 percent) and contribution to a balanced urban microclimate (Kehrli and Bacher, 2003; Thalmann *et al.*, 2003; Nardini *et al.*, 2004). Reduced photosynthetic performance depletes starch reserves (Tomiczek and Krehan, 1998; Salleo *et al.*, 2003) and reduces the trees productivity and vigour (Gross, 1999) increasing the predisposition to other harmful environmental influences, pests and diseases (Tomiczek and Krehan, 1998) and can be a contributory factor in further tree decline.

Figure 1: Life cycle of *Cameraria ohridella* (Pere, 2009).



Although *A. hippocastanum* is the principal host of *C. ohridella* in Europe, many other *Aesculus* species are also susceptible. *A. turbinata* (Japanese Horse chestnut) is highly susceptible, and species from North America, such as *A. californica* (California Buckeye), *A. flava*, *A. glabra* (Ohio Buckeye), *A. parviflora, A. pavia* (Red Buckeye), *and A. sylvatica* (Painted Buckeye) are moderately susceptible (Freies *et al.*, 2004). In contrast, other species from Asia, such as *A. assamica* (East Himalayan Horse chestnut), *A. chinensis* (Chinese Horse chestnut) and *A. indica,* are generally resistant (Straw and Tilbury, 2006). *A. x carnea* is highly resistant to *C. ohridella*, killing the larvae in the first or second instar (Freies *et al.*, 2004). The majority of other *Aesculus* hybrids are derived from crosses between *A. flava*, *A. glabra*, *A. pavia* and *A. sylvatica* (Bean, 1970; Daniels, 1984; Huxley, 1999). Susceptibility to *C. ohridella* varies from moderately susceptible in *A. x bushii* to highly resistant in *A. x neglecta* (Straw and Tilbury, 2006). *C. ohridella* has also been reported to damage *Acer*

platanoides (Norway maple) and *Acer pseudoplatanus* (Sycamore) (Gregor *et al.*, 1998; Straw and Tilbury, 2006). This host range expansion is expected to increase further, threatening many other trees (CONROCAM, 2004).

C. ohridella has no known natural parasitoids or predators and few proven methods of control (Tilbury and Evans, 2002; Straw and Bellett-Travers, 2004). Removal and destruction of fallen leaves to prevent the pupa over-wintering is the most common and effective short-term control method (Gilbert *et al.*, 2003; Pavan *et al.*, 2003). Commercial composting at high temperatures or burning the leaves destroys the pupae and eliminates the first generation of moths in the spring, reducing infestation at the start of the growing season (Kehrli and Bacher, 2004). This is when trees are growing most strongly and when any reduction in damage is of the greatest benefit. Trees become re-infested later in the summer, as moths fly in from the surrounding area, assisted by the wind, and through the passive transport of adult moths or infested leaves in or on vehicles (Tilbury and Evans 2002; Tilbury *et al.*, 2006). In the long-term, leaf removal and destruction could decrease the numbers of natural control agents that over-winter in the leaves. Pheromone and sticky traps can capture hundreds of moths in a day and are therefore useful aids for monitoring *C. ohridella* populations. However, it is questionable that they can reduce the damage at locations with high population densities as multiple, overlapping generations at all developmental stages result in rapid reproduction and infestation (Tilbury and Evans, 2002). Encouraging possible opportunistic predators, such as birds, bats, spiders, ants, earwigs and grasshoppers could be beneficial, however there is little evidence that any species regularly feeds on the moth (Grabenweger *et al.*, 2005).

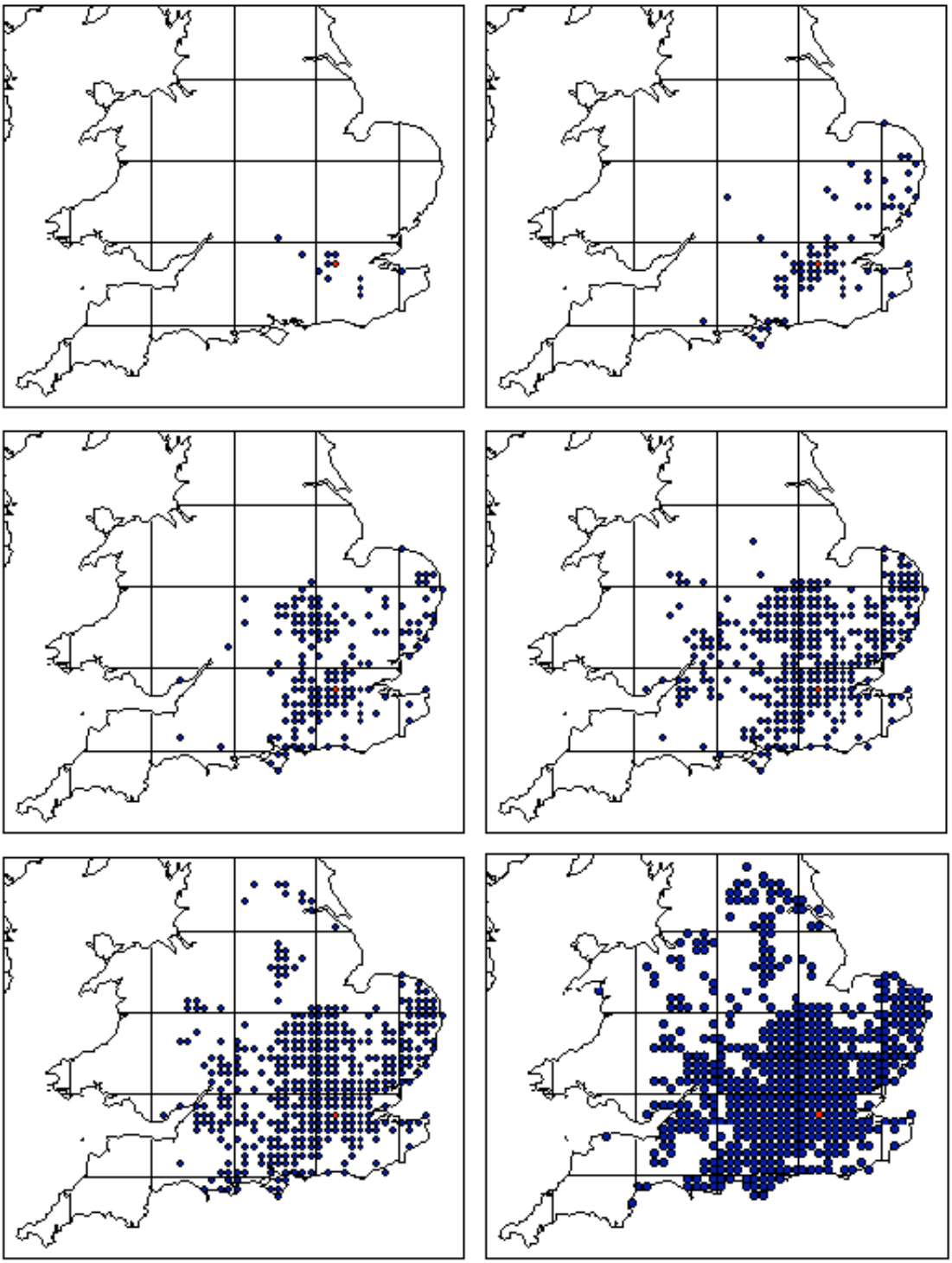
A variety of chemical insecticides, including diflubenzuron, imidacloprid and abamectin, have been shown to be effective in controlling *C. ohridella* and preventing leaf damage (Baraniak *et al.*, 2005). Systemic insecticides applied as root drenches or injected into the stem cambium or soil preclude many of the hazards and objections associated with the use of sprays, powder and dust formulations, particularly to large urban trees (Arboricultural Association Newsletter, 2008). Alternatively, recent developments in natural insect repellents, notably allicin manufactured from *Allium sativum* (Garlic), have shown promising results in controlling *C. ohridella* and preventing leaf damage (JCA Limited, 2009). Allicin was initially developed to treat

Pseudomonas syringae (Horse chestnut bleeding canker). It is injected into the stem cambium like a systemic insecticide and translocated throughout the tree via the vascular system by root pressure and capillary action, tainting the foliage and deterring *C. ohridella* (JCA Limited, 2009). However, both chemical insecticides and natural insect repellents are expensive, and are only effective for one, sometimes two, growing seasons, therefore needing to be applied almost every year in order to maintain low rates of infestation (CONROCAM, 2004).

Aesculus species and their hybrids with proven resistantance to *C. ohridella*, such as *A. assamica*, *A. chinensis*, *A. indica*, *A. x carnea* and *A. x neglecta*, currently seem most appropriate for new plantings. In the long-term, a permanent reduction in *C. ohridella* populations is only likely to be achieved by natural enemies, such as native parasitoid wasps adapting to the moth and causing greater mortality, or by the introduction of specific parasitoids as part of a biological control programme.

Figure 2: The distribution of *Cameraria ohridella* in the United Kingdom from 2002 to 2008 (Forestry Commission, 2009a).

The red dot indicates the location of the original infestation in Wimbledon, London in 2002. The blue dots indicate the spread of subsequent infestations from 2003 to 2008.



2.3 *Pseudomonas syringae*

Pseudomonas syringae pathovar *aesculi* (Horse chestnut bleeding canker) is a virulent pathogenic bacterium from the family *Pseudomonadaceae*. It is one of at least fifty closely related pathovars of the species *P. syringae* which can be distinguished by host range, and which infect a wide range of herbaceous and woody plants (Green *et al.*, 2009). *P. syringae* pv. *aesculi* was originally isolated from leaf lesions on *A. indica* in the North West Himalaya in the 1970's (Durgapal and Singh, 1980; Schmidt *et al.*, 2008; Webber *et al.*, 2008). Little is known about the infection processes of this pathogen, or the genetic and physiological factors, which cause it to be so highly damaging (Green *et al.*, 2009). Most of the research on this pathogen and the disease is limited to macroscopic description of the symptoms and epidemiological studies. However, it was most probably introduced to Europe via imported infected nursery stock (Brasier, 2008) becoming considerably more aggressive due to milder, wetter winters and different host plants (Green *et al.*, 2009). All *Aesculus* species in Europe are susceptible to *P. syringae*, notably *A. hippocastanum* and *A. x carnea*.

Previous episodes of horse chestnut bleeding canker in the UK date back to the 1970's but were attributed to *Phytophthora citricola* and *cactorum* (Brasier and Strouts, 1976). Both are considered uncommon and restricted to the South of England, accounting for five to ten percent of bleeding cankers on *Aesculus* species in the UK (Strouts and Winter, 2000; Webber and Thorpe, 2004). *P. syringae* was first noted in 2000 affecting *A. hippocastanum* in the South East of England. Since 2003 there has been a marked increase in the prevalence of the disease across England, Scotland and Wales and it is now also widespread in Western Europe, notably Belgium, France, Germany and the Netherlands (Webber *et al.*, 2008).

P. syringae infects and disseminates in *Aesculus* species in Europe through the vascular system, killing the cambium, phloem and bark (Royal Horticultural Society, 2009). It causes lesions on the stem and scaffold branches to bleed as a tree exudates flow from infected sites (Plate 3). The rusty-red, yellow-brown or black gummy liquid oozing from patches of dying bark is greatest in spring and autumn (Webber and Thorpe, 2004), which suggests that the pathogen activity is greatest under moist, mild

conditions. Depending on the extent of the bleeding, the liquid either runs down the tree, staining the bark, or dries near the lesions to form crusty resin like deposits (Anderson, 2006). The dying cambium causes the bark to crack and eventually fall away revealing necrotic or dead phloem, with a mottled or zoned orange-brown colour (Plant Clinic News, 2008; Webber *et al.*, 2008). Underneath this the wood may be stained blue-black (Anderson, 2006). Cracks and absence of bark increase the predisposition to other harmful environmental influences, pests and diseases, notably wood-rotting fungi, causing further tree decline (Anderson, 2006). Necrosis of the cambium and phloem causes disruption to water and nutrient transport (Royal Horticultural Society, 2009) resulting in foliage chlorosis, reduction in leaf size, crown thinning and premature leaf drop (Plant Clinic News, 2008). As infection spreads and becomes more extensive it can coalesce and eventually girdle the entire stem or branch, causing crown die back, limb drop, structural failure and tree mortality (Plant Clinic News, 2008; Webber *et al.*, 2008).

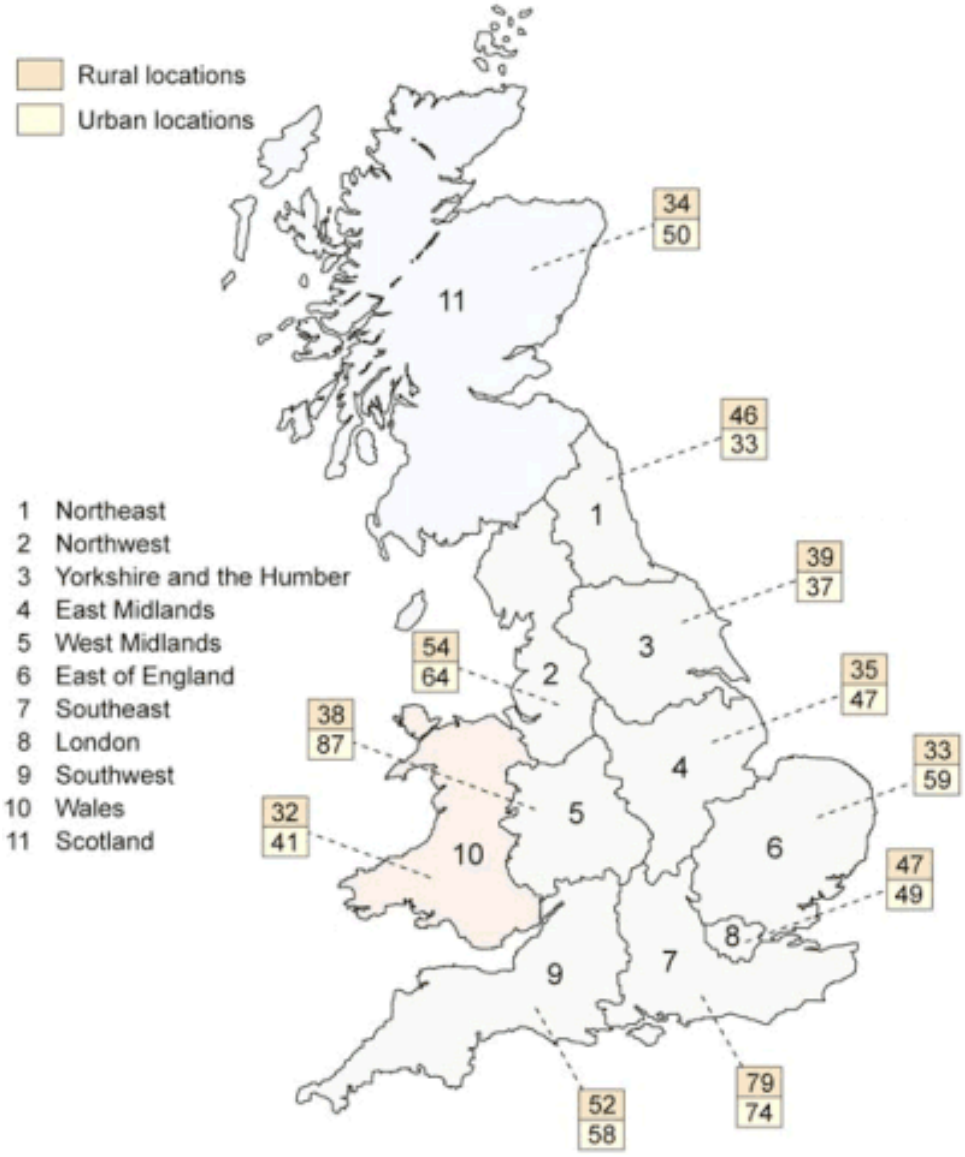
Plate 3: Stem and scaffold braches of *Aesculus hippocastanum* exhibiting bleeding and bark cracking caused by *Pseudomonas syringae* (Forestry Commission, 2009b).

Badly infected trees can die within two to four years, younger trees succumbing more quickly (Anderson, 2006; Webber *et al.*, 2008). Some trees have to be felled for public safety reasons when the condition weakens the trunk or branches until they are in danger of falling. The particularly weak *Aesculus* branches become even more brittle and susceptible to sudden fracture and drop as the infected dead wood dries out. However, in some infected trees the disease progression can be very slow, or even cease, with trees showing signs of recovery as vigorous callus development occurs at the edge of wounds created when bark has been killed by *P. syringae* (Anderson, 2006).

P. syringae is highly mobile, being disseminated through spores found in environmental substrates, such as soil, water and infected tree debris (Green *et al.*, 2009). Generally it spreads through groundwater from tree to tree and is translocated through the cambium within trees (JCA Limited, 2009). There are hypothesis that the spores may be transported by the hydrological cycle (Green *et al.*, 2009) and sap-sucking insects, such as *C. ohridella* (Horse chestnut leaf miner).

The Forestry Commissions national survey in 2007 found that 49 percent of *A. hippocastanum* inspected exhibited symptoms of *P. syringae* (Forestry Commission, 2008a). The South East of England had the highest levels of symptomatic trees (76 percent) but no region had less than 30 percent (Figure 3). This represents a significant threat to the tree population, especially when considering that Forest Research scientists estimate that a few thousand have probably already been felled as a result of the disease.

Figure 3: The percentage of *Aesculus hippocastanum* surveyed in Great Britain exhibiting symptoms of *Pseudomonas syringae* in 2007 (Forestry Commission, 2008b).



There are no chemical treatments currently available to cure or arrest the development of *P. syringae*. However, ensuring trees are healthy and vigorous can reduce susceptibility to infection and facilitate recovery. As more than 80 percent of urban tree disorders are caused by problems below ground (Patterson *et al.*, 1980) it is paramount to create a healthy environment for tree roots to thrive. The most common problems include nutrient deficiencies, drought and soil compaction. Nutrient deficiencies can be identified through soil samples and remediated through the

incorporation of organic mater and fertilizers with the soil or by injecting them under pressure directly into the tree's root system. Drought and soil compaction are often linked and can be rectified by breaking up the surface soil with an air spade and injecting high-pressure nitrogen gas and mycorrhizal fungi into the trees root system (deep root aeration) and back filling the holes with sea weed, organic mulch, grit or gravel to allow air and water movement into the soil. Applying a thick layer of organic mulch helps to retain soil moisture, while mycorrhizal inoculation can improve water and nutrient uptake. Irrigation can also be of benefit throughout prolonged periods of drought, particularly if a tree has recently been transplanted.

Recent developments in natural anti fungal, anti bacterial and anti viral agents, notably allicin, have shown promising results in controlling *P. syringae* (JCA Limited, 2009). It is injected and translocated in the same way as treating *C. ohridella*, described in section 2.2. However, like before it is expensive and needs to be applied almost every year in order to prevent reinfection.

To limit infection *Aesculus* species should not be pruned, removed or otherwise worked on unless they pose a danger to the surrounding area (Aesculaap, 2006). Crown reductions and large limb reductions or removals reduce excessive end weight on weakened limbs. This reduces the lever arm effect and the potential for a tree to collapse or fall apart under its own weight, thus reducing health and safety issues. Pruning wounds on healthy trees will act as entry points for *P. syringae*, while arisings from infected trees and contaminated pruning tools will spread the pathogen (Plant Clinic News, 2008). Infected arisings should not be chipped as this could create aerosols of inoculum that spread *P. syringae* (Plant Clinic News, 2008). Infected material should be transported in covered containers directly to a depot or processing facility to prevent the bacterium spreading. There it should be incinerated or composted commercially at high temperatures to destroy *P. syringae* (Aesculaap, 2006). Tools should be disinfected after use on each tree (Aesculaap, 2006) in accordance with British Standard Recommendations for Tree Work (BS 3998:1989) to prevent the spread of the disease. Care should be taken not to disturb the soil around *Aesculus* species as this may also spread *P. syringae* (Aesculaap, 2006).

Planting and transplanting *Aesculus* species is not recommended as they can quickly

become infected, particularly if the site is known to already have had outbreaks of *P. syringae* (Aesculaap, 2006). However, there is some evidence of uninfected trees being found very close to trees that have been heavily infected for some time, suggesting that some *Aesculus* species might have a genetically inherited ability to resist *P. syringae* (Forestry Commission 2008a). Seeds from these trees might form the basis of resistant planting stock for the future. However, the importance of appropriate site selection and good tree care cannot be sufficiently emphasised.

2.4 Other biotic and abiotic factors affecting *Aesculus*

In addition to *Aesculus* species suffering from *C. Ohridella* and *P. syringae* there are a number of less severe biotic and abiotic factors that also affect them.

Guignardia aesculi (Guignardia leaf blotch) is a common fungal infection that originates from North America and was first found in England in 1935 (Strouts and Winter, 2008). It attacks the leaves of *Aesculus* species from July onwards predominately in the southern half of England and is often confused with *C. ohridella*. *G. aesculi* causes large reddish or dull brown, irregular blotches outlined by bright yellow borders or confined by lateral veins. The damage is usually concentrated at the tips and margins of infected leaflets. Tiny black pycnidia (fungal fruiting bodies) are produced on the browned parts, mostly on the upper surface. Severely infected leaves turn brown and fall prematurely, like those infested with *C. ohridella*. Unlike *C. ohridella*, the damage, although unsightly, occurs after most of the growth of the tree has taken place and causes no significant harm. *G. aesculi* can be controlled by the removal and destruction of fallen leaves, as described in section 2.2, to prevent the fungal spores overwintering (Gillman, 2005). Crown thinning to increase air circulation and sunlight penetration reduces periods of leaf wetness, which are favorable for fungal infections. Fungicides, although not always practical to apply in urban areas, also keep the pathogen in check.

Phytophthora citricola and *cactorum* are virulent pathogenic fungus-like water molds, which were first discovered in the UK in the 1970's (Brasier and Strouts, 1976). They

affect many angiosperm and gymnosperm trees around the world. *P. citricola* and *cactorum* cause identical manifestations to *Pseudomonas syringae* but are considered uncommon and restricted to the South of England, accounting for five to ten percent of bleeding cankers on *Aesculus* species in the UK (Strouts and Winter, 2000; Webber and Thorpe, 2004). Like *P. syringae*, there are no known controls for *P. citricola* and *cactorum*.

Pulvinaria regalis (Horse chestnut scale) is a common and widespread insect pest throughout most of the UK. Its origin is unknown but it is thought to have arrived in Europe from overseas in the 1960's and was first recorded in Britain in 1964 (Strouts and Winter, 2008). *P. regalis* affects many angiosperm tree species, including *Acer* (Maple), *Aesculus*, *Cornus* (Dogwood), *Laurus*, *Magnolia*, *Populus* (Poplar), *Prunus*, *Salix* (Willow), *Tillia* (Lime) and *Ulmus* (Elm). Infestations become most apparent in April and May when the female scale insects deposit their eggs on the stem and scaffold branches. The females are five millimeters long and have a flattened brown orange shell covering their bodies. They deposit their eggs under white waxy threads secreted from the rear edge of their shells. After egg laying they die and fall away leaving circular white egg patches on the bark. When the nymphs hatch in summer they migrate to the foliage where they feed on the underside of leaves, moving back to the twigs in autumn where they continue feeding throughout the winter. The females return to the bole of the tree fully grown in March or April to lay eggs. *P. regalis* is not only an aesthetic problem, large colonies can greatly reduce tree growth and vigour, especially in urban environments where trees are already stressed due to lack of water, oxygen and nutrients. Large amounts of honeydew are also produced in which black sooty mould fungus grows. Encouraging beneficial insects and birds, notably *Coccophagus* species (chalcid wasps) and *Exochomus quadripustulatus* (Pine ladybird) (Entocare biological crop protection, No date) to eat the scale insects is the most common control method. Spraying contact insecticides on the undersides of the leaves in summer can kill the nymphs, although it is not always practical in urban areas. Scrubbing the bark in spring with a mild detergent solution to remove the eggs can have some success.

Wood rotting fungi, such as *Armillaria* (Honey fungus), *Ganoderma, Kretzschmaria* and *Rigidoporus* species, are normally secondary infections that cause decay in

stressed, declining or dead trees (Weber and Matteck, 2003). Stress and decline can be the result of many biotic and abiotic factors, some of which are mentioned in this chapter. Any kinds of wounds on suitable host trees are possible places of entry for germinating spores. Once the fungi colonise they slowly break down live and dead tissue, resulting in tree or limb failure or rendering trees structurally unsound. *Aesculus* species, lacking both tannin and resin (Wilkinson, 1981) are more susceptible to rots and are quicker to deteriorate once colonised.

Sciurus carolinesis (Grey squirrel) and to a much lesser extent *Sciurus vulgaris* (Red squirrel) cause damage to the shoots of *Aesculus*, *Fraxinus* (Ash) and *Juglans* (Walnut) species. They remove tissue from the current year's green shoots, usually in spring or early summer when the tree is in full leaf, and eat the exposed pith, which causes shoots to snap, but remain attached to the branch where the leaves die and turn brown (Pepper, 2004). The damage has no long-term effect on trees and is more of an aesthetic problem. *S. carolinesis* can be controlled by humanely shooting, trapping and poison baiting, which are best done from mid March to mid July when food is short. *S. vulgaris* is a protected native species and thus their control is illegal.

Nutrient deficiencies or imbalances inhibit a variety of the tree's metabolic and physiological possesses (Strouts and Winter, 2008), such as the absorption of water, opening and closing of stomata guard cells, photosynthesis, nitrogen fixing and cell reproduction, and thus affect all aspects of the tree's health and growth. Trees need nine macronutrients (calcium, carbon, hydrogen, magnesium, nitrogen, oxygen, phosphorous, potassium and sulphur) and nine micronutrients (boron, chlorine, copper, iron, manganese, molybdenum, nickel, sodium and zinc). Both macro and micronutrients are readily derived in the soil except where they have been depleted. Usually nutrient deficiencies are noticeable by foliage chlorosis, usually yellowing or purpling, or even necrosis if the problem persists. Other symptoms include stunted growth, undersized leaves and dieback. Nutrient deficiencies can be identified through soil samples and remediated through the incorporation of organic matter and fertilizers with the soil or by injecting them under pressure directly into the tree's root system. Alternatively, mycorrhizal inoculation can improve nutrient uptake. However, with the exception of extremely acidic or alkaline soils, along with sandy or gravelly soils lacking organic matter, severe deficiency symptoms in trees more commonly

indicate an inability of the roots to take up available nutrients due to drought, waterlogging, disease or extreme competition.

Drought reduces the uptake of nutrients and impairs photosynthesis. It may also result in leaves being shed to reduce water loss and bark and wood shrinkage, which may cause longitudinal cracks (Strouts and Winter, 2008). To limit the impact of drought, primarily it is essential that the right tree species is chosen for the location. Weed competition around the base of trees can be controlled and a thick layer of organic mulch applied to help retain soil moisture. Additionally, mycorrhizal inoculation can improve water uptake. However, throughout prolonged periods of drought, irrigation can be beneficial, particularly if a tree has recently been transplanted.

Soil compaction represents a big problem for urban and amenity trees. It restricts air and water movement into and through the soil, which results in the deterioration of soil quality and creates a hostile root environment. Reduced pore size and air filled pore spaces increases mechanical resistance to root penetration and normally decreases the soils water retention. The loss of pore space reduces water infiltration and gas diffusion. Levels of soil oxygen decrease and carbon dioxide can increase. As a result trees suffer from nutritional stress and drought, which reduces the trees productivity and vigour (Gross, 1999). As stated previously, soil compaction can be alleviated by breaking up the surface soil with an air spade and injecting high-pressure nitrogen gas and mycorrhizal fungi into the trees root system (deep root aeration) and back filling the hole with sea weed, organic mulch, grit or gravel to allow air and water movement into the soil.

In addition to those mentioned above, bacterial wetwood, mechanical damage, salt damage and *Zeuzera pyrina* (Leopard moth) also cause problems for *Aesculus* species, although to a lesser degree. There are also two unknown disorders, that have not been fully researched, which affect *Aesculus* species: marginal leaf browning ('leaf scorch') which may be caused by a xylum-limited bacterium, and proliferation of the buds and dwarfed shoots on swellings on stems and branches (Strouts and Winter, 2008). The latter, which is similar in appearance to Witch's broom, is common and widespread in England but only affects *A. x carnea*.

Chapter 3: Methodology

3.1 Selected research methodology

The aim of the research was to establish the extent and severity of *C. ohridella* and *P. syringae* on *Aesculus* species, and the success of management techniques used to mitigate these problems in the UK. The objectives of the research were to:

- Establish the extent and severity of *C. ohridella* and *P. syringae* on *Aesculus* species in the UK.
- Determine the number of *Aesculus* species being removed as a result of *C. ohridella* and *P. syringae* in the UK and whether they are being removed unduly.
- Ascertain the success of management techniques used to mitigate *C. ohridella* and *P. syringae* in the UK and establish how widely they are used.
- Identify other biotic and abiotic factors affecting *Aesculus* species in the UK.
- Establish what is being planted in place of removed *Aesculus* species in the UK.
- Ascertain whether a non-native tree species, such as *Aesculus*, should be safeguarded in the UK.

In order to ascertain an accurate overview of the current situation the research had to obtain the maximum number of appropriate respondent's opinions. This meant targeting professionals in all areas of the arboricultural industry, including contractors, consultants, researchers, lecturers and tree officers. The author decided a well-designed questionnaire would be the most feasible method to do this due to the large data group. Given the time constraints of the research and potential quantities of data to be collated it was decided to use an internet based surveying program. This allowed respondents to complete the questionnaire online and enabled the results to be downloaded in a variety of formats for analysis. Survey Monkey (Survey Monkey, 2010) was chosen due to the author's previous experience using the software. A medium level agreement was selected as the most appropriate for the research and was funded by the author. This allowed more than 10 questions to be asked and more than 100 responses to be received as well as enabling full survey design, collection and analysing features.

3.2 Justification of research and methodology

The author's direct experience within the arboricultural industry identified that there were problems facing *Aesculus* species in the UK. The initial background research showed that *C. ohridella* and *P. syringae* were equally current and prominent issues affecting *Aesculus* species and both warranted concern and attention. Secondary research carried out in the literature review highlighted a lack of information relating to the successful management of *C. ohridella* and *P. syringae*. Therefore, it was decided that both these problems, and their solutions, should be included in the research. Primary research in the form of an online questionnaire was selected, as it was the quickest and most efficient way to reach the data group to ensure the broadest spectrum of feedback. Interviews with representatives across the arboricultural industry were also considered but this technique was not implemented, as the questionnaire gathered the required data and provided an extensive range of opinions.

3.3 Implementation of methodology

A concise questionnaire was compiled online using Survey Monkey (Survey Monkey, 2010) (Appendix 1). It contained sixteen questions over six pages. There were three demographic questions, twelve questions seeking the respondents' opinion and one question asking whether they would like to receive a copy of the report. The questionnaire was designed to enable arboriculturalists of all skill levels and experiences to complete it. This was achieved through the inclusion of common names and simple clear instructions.

To ensure a broad variety of data was collected both positivist questions, which are quantitative, and phenomenological questions, which are qualitative (Collis and Hussey, 2003) were employed through a variety of multiple-choice questions and comment boxes. The questionnaire was set up to prompt respondents to answer all closed questions but not the comment boxes and contact details. The survey collection settings provided the option to only accept one response per computer. This was utilised to ensure respondents could not complete multiple questionnaires.

An e-mail introducing the author and research, outlining data protection and providing a link to the questionnaire was designed to capture respondent's interests and ensure the maximum number of responses (Appendix 2). A confidentiality clause was included in the e-mail and questionnaire to ensure compliancy with ethical guidelines and data protection regulations.

The introductory e-mail and questionnaire were piloted by five lecturers involved with the arboriculture and dissertation modules at Writtle College to provide an initial opportunity to gauge the nature and range of responses, and obtain feedback on the usability of the questionnaire. Four completed questionnaires were returned with positive comments on the design and content as well as suggestions for improving the phrasing of questions and answers. Two questions and the possible answers to three questions were reworded to ensure the respondent's understood what was requested of them and a more accurate answer could be obtained. The pilot questionnaire is not included in the report because the changes made were considered insignificant.

Following the piloting, the introductory e-mail with a link to the questionnaire was sent to 577 arboricultural contractors, consultants, researchers, lecturers and tree officers across the UK. E-mail addresses were obtained from the Arboricultural Association's list of approved contractors (Arboricultural Association, 2010a) and registered consultants (Arboricultural Association, 2010b), the International Association of Arboriculture list of certified arborists (International Association of Arboriculture, 2010), the UK Tree Officer Index (UK Tree Officer Index, 2009), and Yell.com (Yell.com, 2009). An identical introductory message with a link to the questionnaire was also posted on Arbtalk, which has almost 5,000 members (Arbtalk, 2009a). However, the majority of these members do not frequent the website regularly and there are normally no more than 300 visitors per day. It is expected that the survey will gain a response rate of between 20 and 30 percent. This would result in between 115 and 173 responses based on the e-mails sent directly to arboricultural contractors, consultants, researchers, lecturers and tree officers.

The survey was online from the 13th December 2009 to the 29th of January 2010. During this time 152 people started the questionnaire, 132 people completed it and

254 comments were left. Therefore the survey gained a response rate of 26.3 percent based on the e-mails sent directly to Arboriculturalists.

3.4 Constraints in the methodology

The methodology utilised in the research was selected to ensure reliability, the process whereby data can be replicated and the same conclusions drawn (Oppenheim, 2000) and validity, whereby a representative data set has been targeted rather than samples chosen to fit the theory (Collis and Hussey, 2003). However, the author recognises that the extent and severity of *C. ohridella* and *P. syringae* is progressing and that management techniques for their control are evolving. Whilst these are matters out of the author's control, they do affect the reliability of the research. The research also relied on the respondents self-completing the questionnaire, which often leads to a lower response rate than other methods of data collection (Oppenheim, 2000).

The author expected many of the respondents not to have used any management techniques to control *C. ohridella* and *P. syringae* due to the lack of information relating to their successful management. The extent and severity of *C. ohridella* and *P. syringae*, despite being more progressed, will be referenced against previous research to gauge validity. However, the success and feasibility of management techniques used to mitigate *C. ohridella* and *P. syringae* is a relatively new area of research and therefore no external references are available to gauge validity. Consequently the research can only have concurrent validity, that is, to record current opinions. Nevertheless, these results will be useful for future research.

Chapter 4: Results

Appendix 3 shows the answers to all closed questions while Appendices 4 to 11 show the answers to all open questions.

4.1 Question 1

Your contact details?

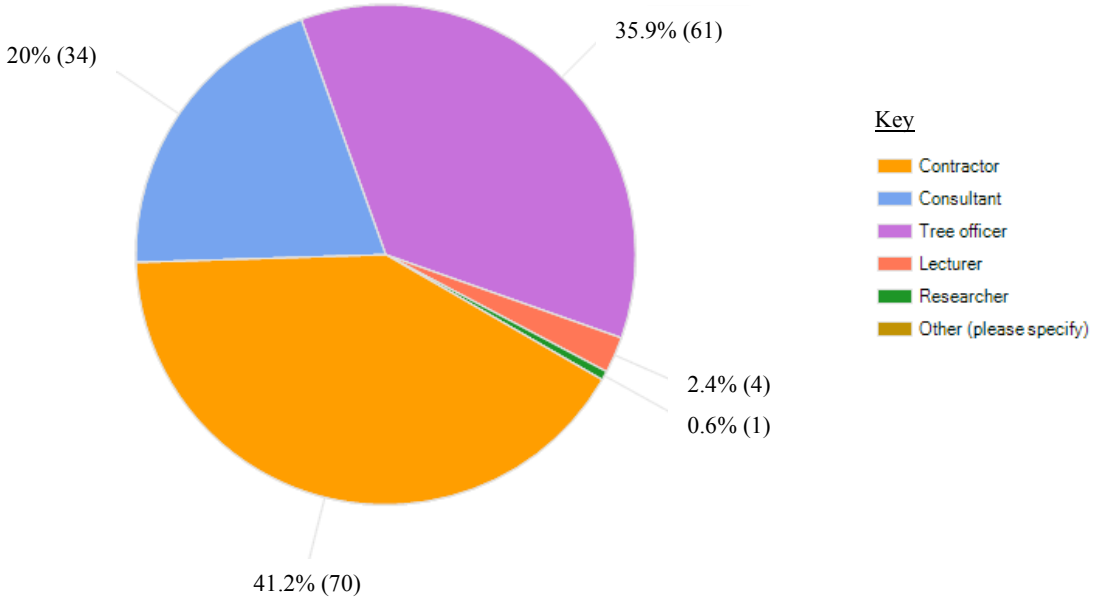
Respondents were asked for their name, the company or organisation for which they worked, e-mail address and telephone number. This information was primarily to allow the author to contact respondents if there were concerns about unclear answers, for additional information or clarification, and, to send a copy of the report if they so requested. The respondent's name and company, or organisation, were also required to ensure respondents did not complete multiple questionnaires on different computers. The inclusion of e-mail addresses and phone numbers was optional to ensure respondents were not deterred from undertaking the questionnaire for data protection fears. However, a confidentiality clause was included in the questionnaire and e-mail (Appendix 1 and 2, respectively) to ensure compliancy with ethical guidelines and data protection regulations. This resulted in 76.3 percent of respondents submitting their e-mail address and 55.3 percent submitting their phone numbers. No respondent's personal details have been included in the report.

4.2 Question 2

The nature of your work?

In order to ascertain whether there were marked differences between professionals within the arboricultural industry, key roles were identified and their distribution is shown in Figure 4. Respondents were able to select as many categories as they deemed to be relevant.

Figure 4: Respondents' occupational distribution.



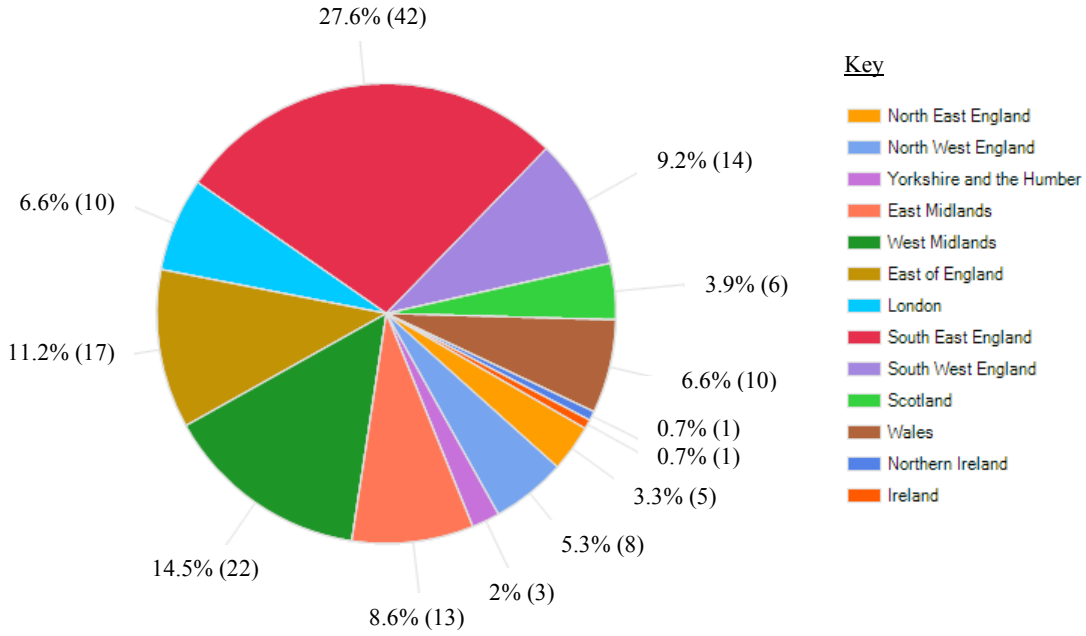
The response rates from contractors (41.2 percent), consultants (20 percent) and tree officers (35.9 percent) predominantly reflects the incidence of these groups within the target audience. Similarly, the low response rates from lecturers (2.4 percent) and researchers (0.6 percent) reflects the lower incidence of these two groups within the target audience. However, it is generally considered that lecturers and researchers have a lower level of involvement with *C. ohridella* and *P. syringae*. There were a number of respondents that selected two categories; fifteen people selected contractor and consultant, one person selected contractor and lecturer, and two people selected consultant and tree officer. None of the respondents selected more than two categories and no other occupational roles were recorded.

4.3 Question 3

The primary location of your work?

Respondent's work locations were vital to establish the extent and severity of *C. ohridella* and *P. syringae* and identify regional trends in the UK. Thirteen regional areas were identified and respondent's distribution is shown in Figure 5.

Figure 5: Respondents' geographical distribution.



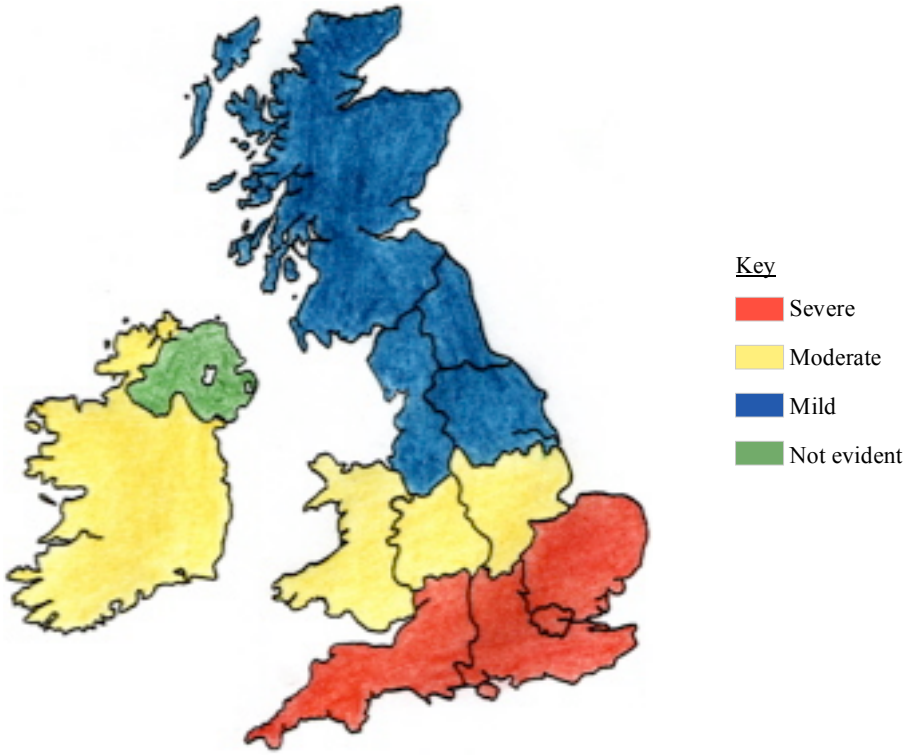
The largest response rates came from Southern (42.4 percent), Central (23.1 percent) and Eastern England (11.2 percent) and Wales (6.6 percent). This reflects the extent and severity of *C. ohridella* and *P. syringae* in the southern half of Great Britain (Forestry Commission, 2008a, b, 2009a). The sample groups from Northern Ireland and Ireland are too small for effective analysis. Nonetheless, these results are included in the research, as they generally support and compliment the other findings.

4.4 Question 4

In your opinion, how would you best describe the level of infestation for horse chestnut leaf miner (*Cameraria ohridella*) in your area?

This question aimed to establish the extent and severity of *C. ohridella* and identify regional trends in the UK. Respondent's answers were averaged and the results are depicted in Figure 6.

Figure 6: The extent and severity of *Cameraria ohridella* in the United Kingdom.



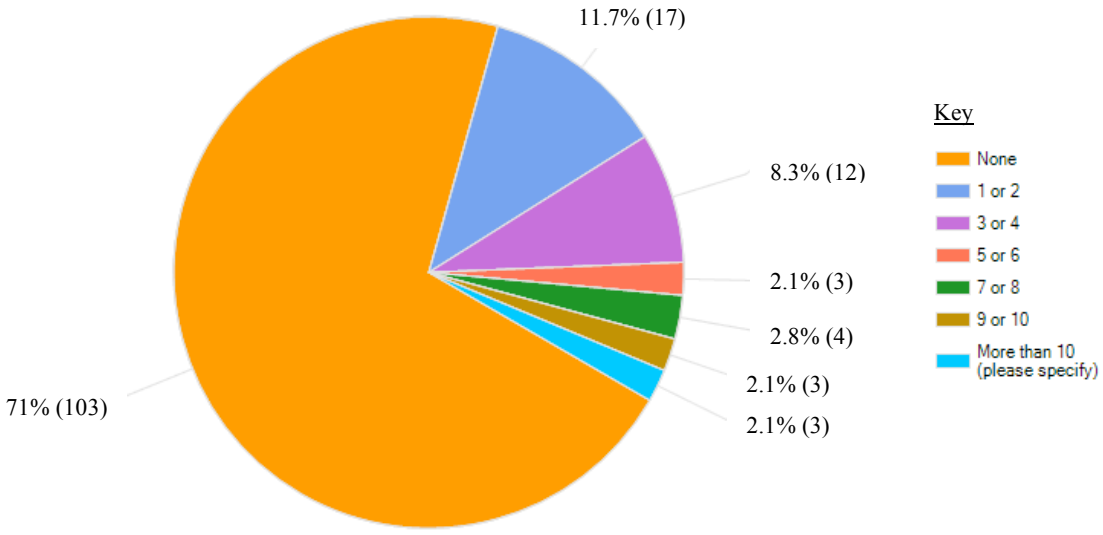
C. ohridella is severe in Southern and Eastern England, moderate in Central England, Wales and Ireland, and is decreasingly evident in Northern England, Scotland and Northern Ireland. There were only two respondents from Northern Ireland and Ireland so these results may be unrepresentative of the region as a whole. Although *C. ohridella* was not evident in Northern Ireland it may nonetheless be present considering its wide spread establishment in the UK. Although more progressed, the extent of *C. ohridella* largely reflects the Forestry Commission's distribution map for England and Wales in 2008 (Forestry Commission, 2009a).

4.5 Question 5

How many horse chestnut trees have you been involved with the removal of, due to leaf miner?

This question aimed to determine the number of *Aesculus* species being removed as a result of *C. ohridella* and whether they are being removed unduly. The results are shown in Figure 7.

Figure 7: Respondents removing *Aesculus* trees affected by *Cameraria ohridella*.



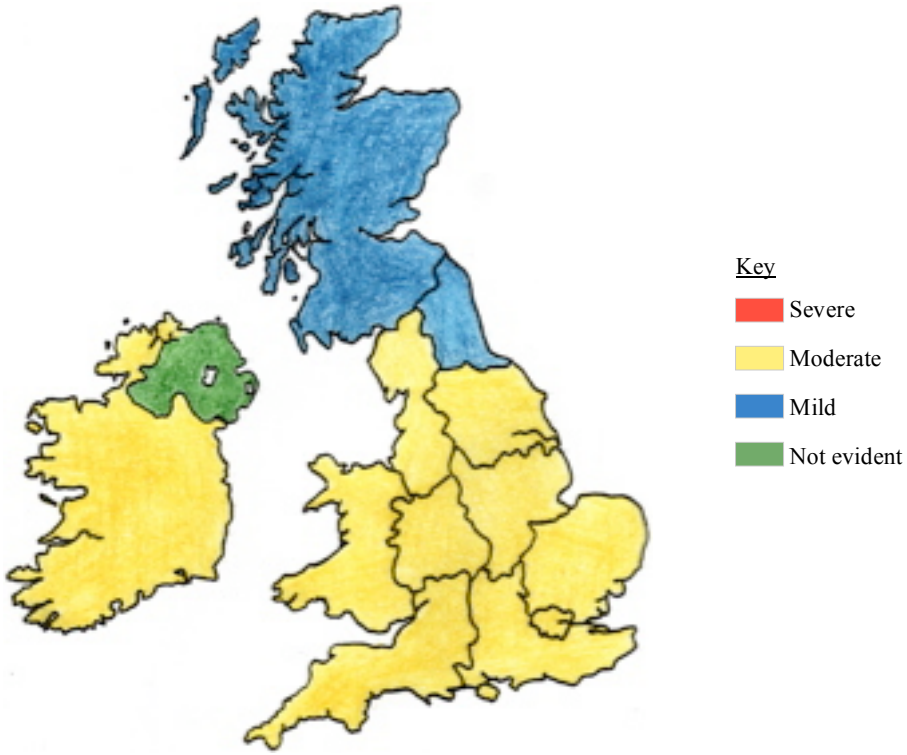
29.1 percent of respondents have been involved with the removal of *Aesculus* trees affected by *C. ohridella*. This has resulted in between 185 and 224 *Aesculus* trees being removed collectively (the 'more than ten' category included answers of 12, 20 and 30). On average, between 1.3 and 1.5 trees have been removed per respondent. Occupational differences were found. Lecturers and researchers had not been involved with the removal of any *Aesculus* species. This may have been because of the smaller sample groups, or, more likely, because of the nature of their work. Geographical differences correlate with the extent and severity of *C. ohridella*.

4.6 Question 6

In your opinion, how would you best describe the level of infection for horse chestnut bleeding canker (*Pseudomonas syringae* pathovar *aesculi*) in your area?

This question aimed to establish the extent and severity of *P. syringae* and identify regional trends in the UK. Respondent's answers were averaged and the results are depicted in Figure 6.

Figure 8: The extent and severity of *Pseudomonas syringae* in the United Kingdom.



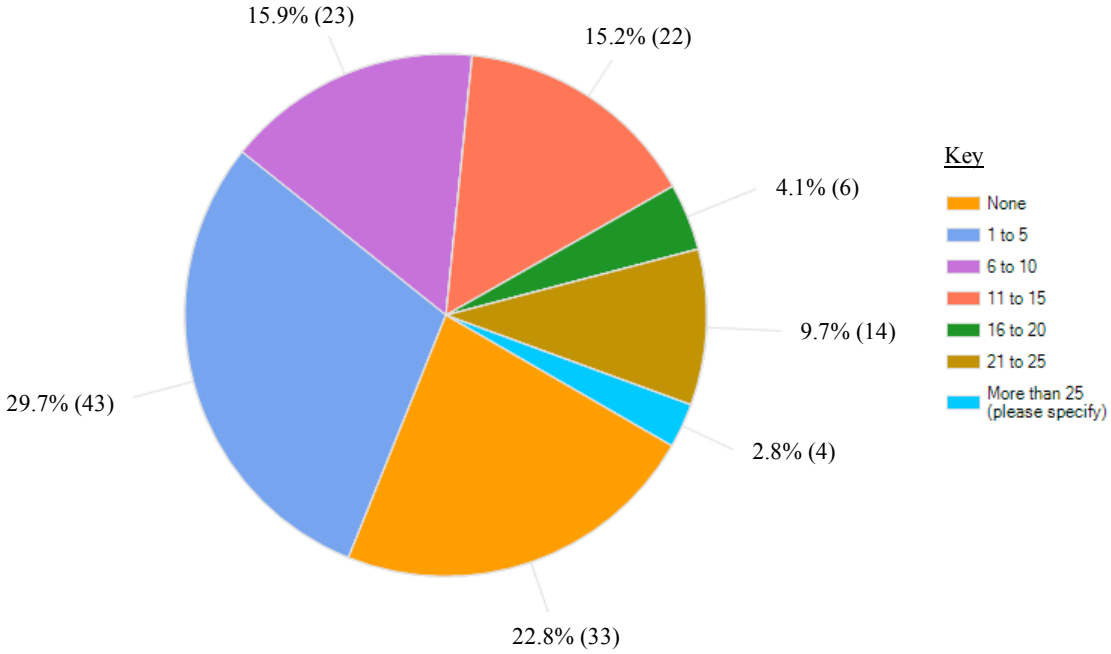
P. syringae is moderate throughout most of the UK with the exception of North East England, Scotland and Northern Ireland, where it is less evident. Again, there were only two respondents from Northern Ireland and Ireland so these results may be unrepresentative of the region as a whole. Although *P. syringae* was not documented in Northern Ireland it may be present considering its wide spread establishment in the UK, this is similar to the results for *C. ohridella*. The extent of *P. syringae* largely reflects the Forestry Commission's survey map for Great Britain in 2007 (Forestry Commission, 2008b).

4.7 Question 7

How many horse chestnut trees have you been involved with the removal of, due to bleeding canker?

This question aimed to determine the number of *Aesculus* species being removed as a result of *P. syringae*. The results are shown in Figure 9.

Figure 9: Respondents removing *Aesculus* trees affected by *Pseudomonas syringae*.



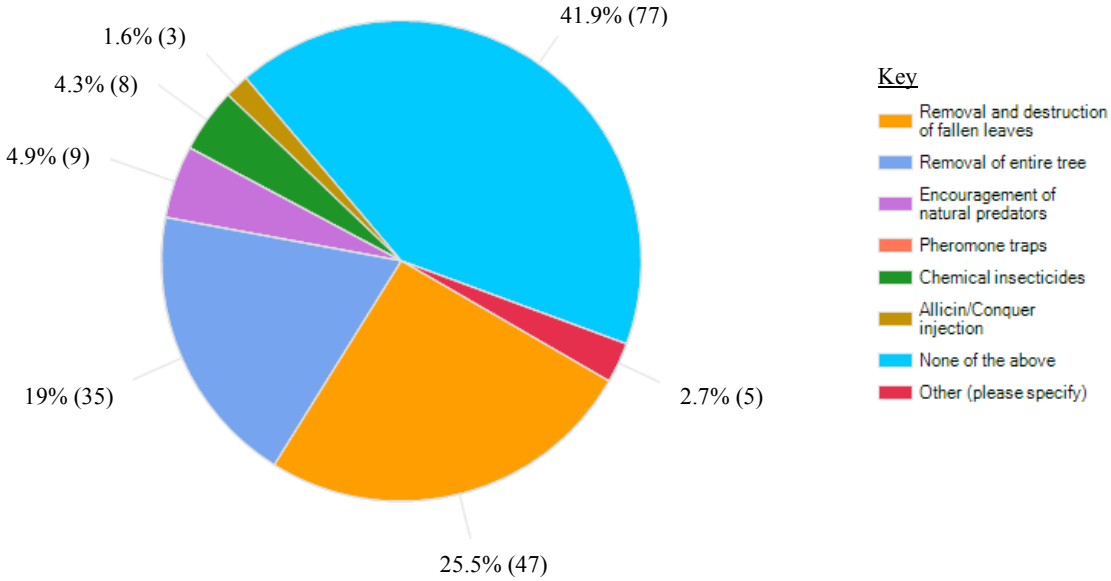
77.2 percent of respondents have been involved with the removal of *Aesculus* trees affected by *P. syringae*. This has resulted in between 1,053 and 1,485 trees being removed overall (the 'more than 25' category included answers of 30, 50, 60 and 100). On average between 7.3 and 10.2 trees have been removed per respondent. As with *Aesculus* removal due to *C. ohridella* there were occupational differences in that lecturers and researchers had not been involved with the removal of any trees. Again geographical differences correlate with the extent and severity of *P. syringae*.

4.8 Question 8

Have you used any of the following management techniques to reduce horse chestnut leaf miner?

Respondents were requested to select as many categories as they deemed to be relevant. The results are shown in Figure 10.

Figure 10: Management techniques used by respondents to reduce *Cameraria ohridella*.



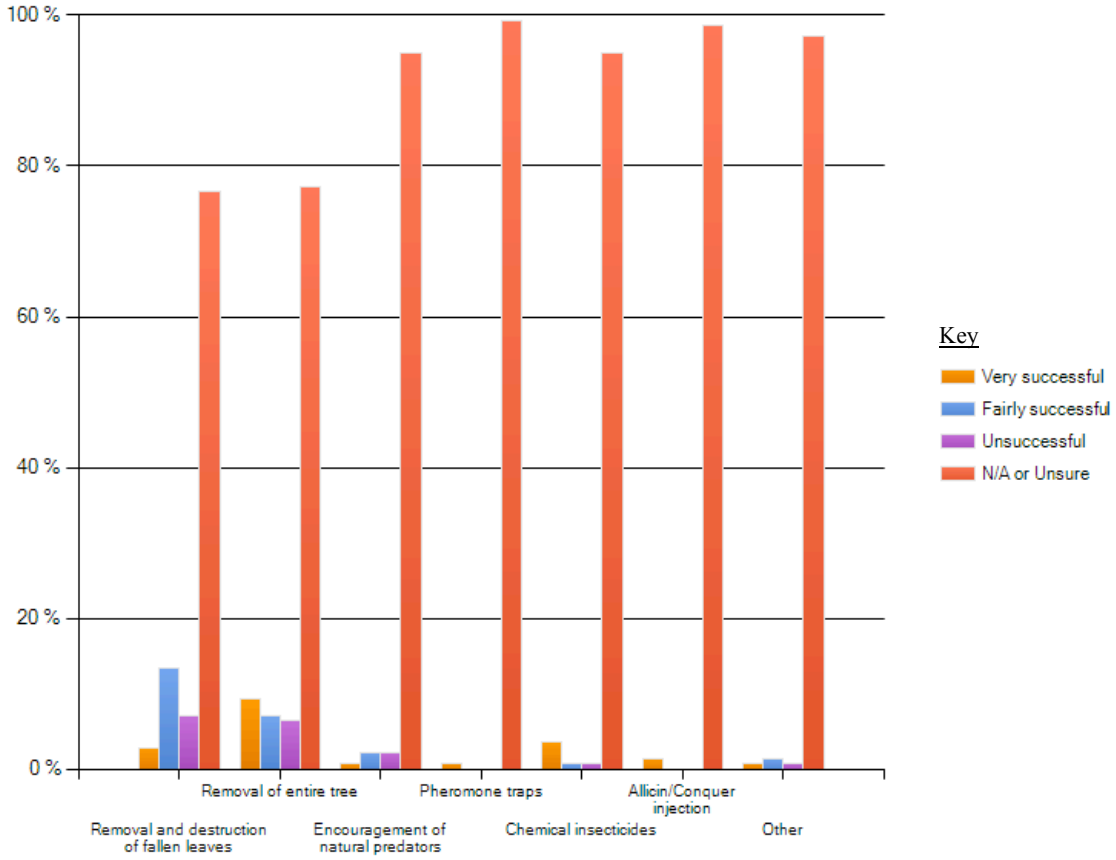
As expected, many respondents had not used any management techniques to control *C. ohridella*. Of those that had implemented management techniques to control *C. ohridella*, the majority (25.5 percent) selected the removal and destruction of fallen leaves. Alarmingly, 19 percent of respondents said they removed the entire tree to control *C. ohridella*. This varied from the 29 percent of respondents that said they had been involved with the removal of *Aesculus* trees affected by *C. ohridella* in question 5. The significance of this discrepancy is discussed in Chapter 5. Other management techniques suggested by respondents included: mulching to suppress the emerging adult moths in spring, removal of weak branches, crown thinning, reductions and retrenchment pruning (Appendix 4). There was no evidence of occupational or geographical differences in the management of *C. ohridella*.

4.9 Question 9

In your opinion, how successful have these techniques been?

This question aimed to ascertain the success of management techniques used by respondents to mitigate *C. ohridella*. The results are shown in Figure 11. Respondents were also asked to comment on management techniques.

Figure 11: The success of respondent's *Cameraria ohridella* management techniques.



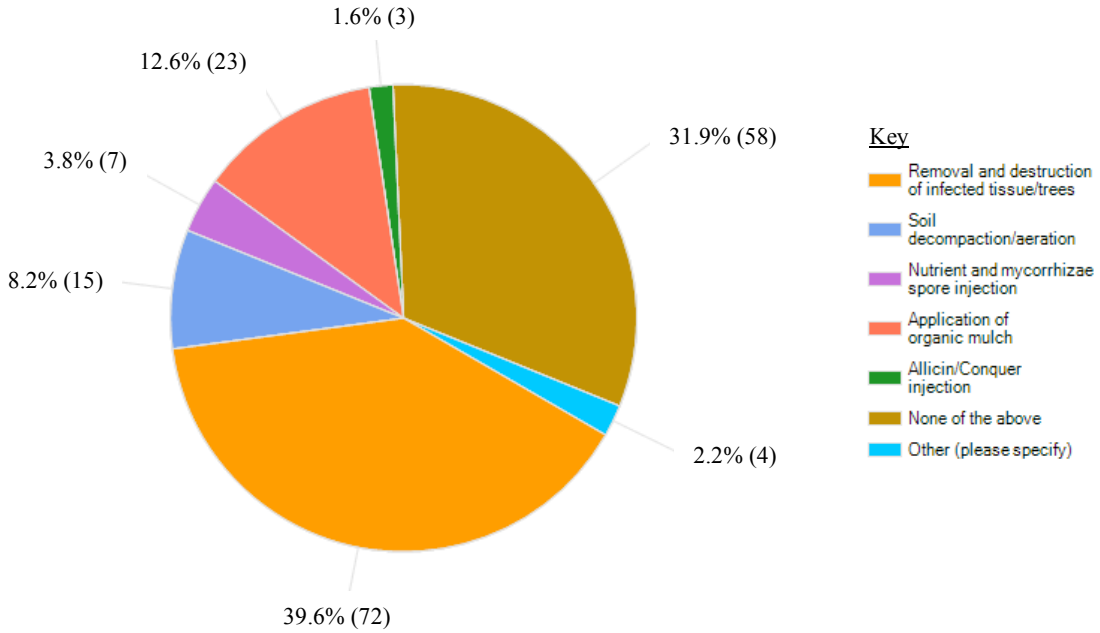
While many respondents had not used any management techniques to control *C. ohridella*, it was fairly conclusive that the majority of respondents, who had, were unsure of their success. A small percentage of respondents (6.3 percent) said the management techniques were very successful or fairly successful, 2.7 percent and 3.5 percent respectively. There were 27 comments from respondents for this question (Appendix 5). They predominately said management techniques were too costly due to their annual nature, it was too early to evaluate the results of the management techniques utilised, and the practice of removing fallen leaves in urban areas was undertaken already.

4.10 Question 10

Have you used any of the following management techniques to reduce horse chestnut bleeding canker?

Respondents were instructed to select as many categories as they deemed to be relevant. The results are shown in Figure 12.

Figure 12: Management techniques used by respondents to reduce *Pseudomonas syringae*.



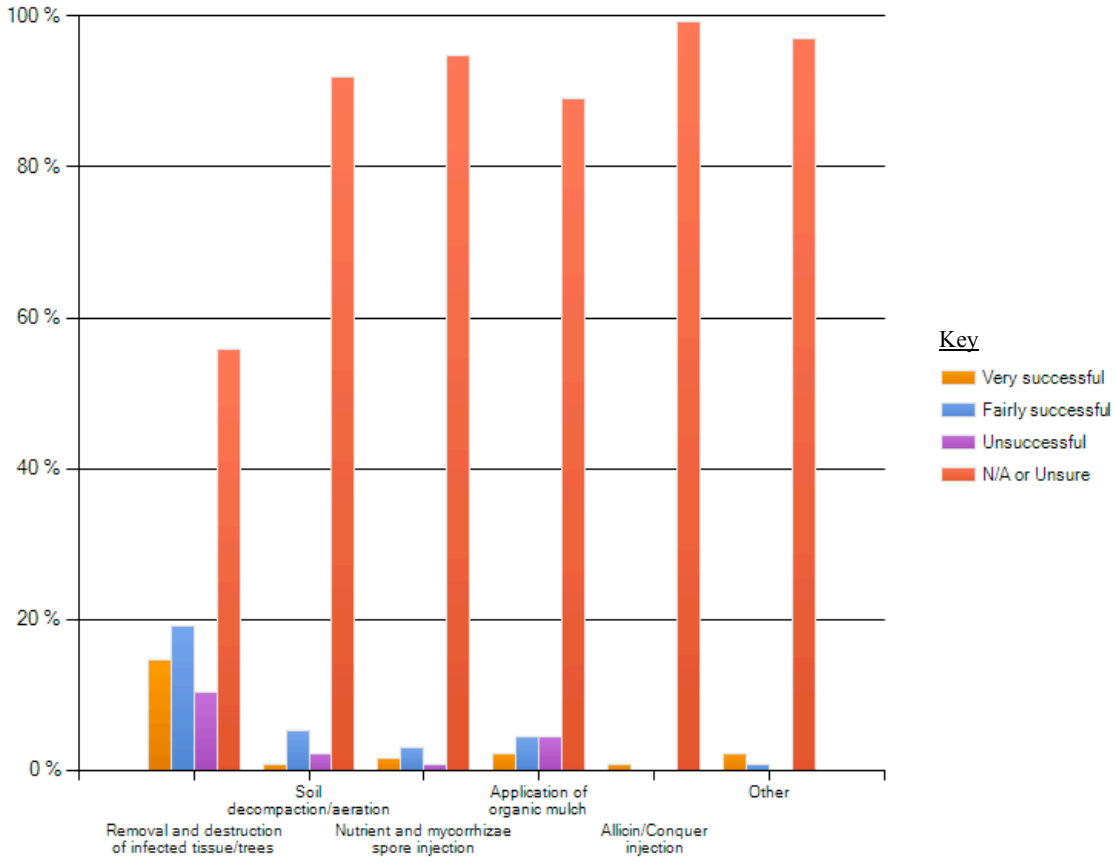
Many respondents had used a variety of management techniques to control *P. syringae*. A significant number of respondents (39.6 percent) selected the removal and destruction of infected tissue/trees to control *P. syringae*. This varied considerably from the 77.2 percent of respondents that said they had been involved with the removal of *Aesculus* trees affected by *P. syringae* in question 7. The significance of this discrepancy is discussed in Chapter 5. Other management techniques suggested by respondents included: crown reductions of infected parts to reduce the hazard of limb drop, and the application of Pancil T (octhilinone) or potassium phosphite for their fungicidal properties (Appendix 6). There was no evidence of occupational or geographical differences in the management of *P. syringae*.

4.11 Question 11

In your opinion, how successful have these techniques been?

This question aimed to ascertain the success of management techniques used by respondents to mitigate *P. syringae*. The results are shown in Figure 13. Respondents were also asked to comment on any management techniques.

Figure 13: The success of respondent's *Pseudomonas syringae* management techniques.



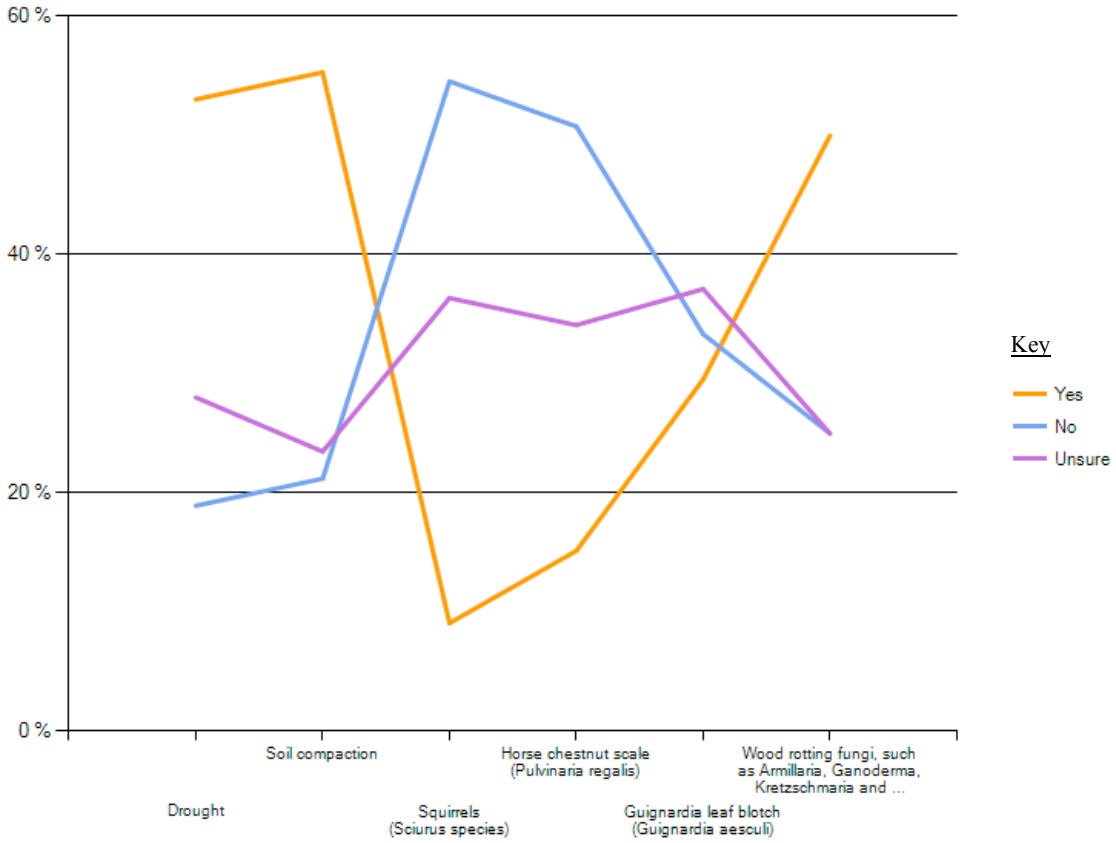
It was fairly conclusive that the majority of respondents that had used management techniques to control *P. syringae* were unsure of their success. A small percentage of respondents (7.7 percent) said the management techniques were very successful or fairly successful. More significantly 38.8 percent of respondents said that the removal and destruction of infected tissue/trees was very successful or fairly successful. There

were 28 comments from respondents for this question (Appendix 7). Predominately, they said that they used crown reductions and large limb reductions or removals, to reduce health and safety issues. Tree removals were used where they were structurally unsafe, where the spread of *P. syringae* jeopardised the health of other *Aesculus* trees, or for aesthetic reasons. Some respondents also said that it was too early to evaluate the results of the management techniques utilised. Conversely, other respondents said that there was not sufficient evidence that these management techniques worked and that they were too costly.

4.12 Question 12

In your opinion, do you think any of the following factors are also contributing to the decline of horse chestnut trees?

Figure 14: Respondents' opinion on other biotic and abiotic factors affecting *Aesculus* species.



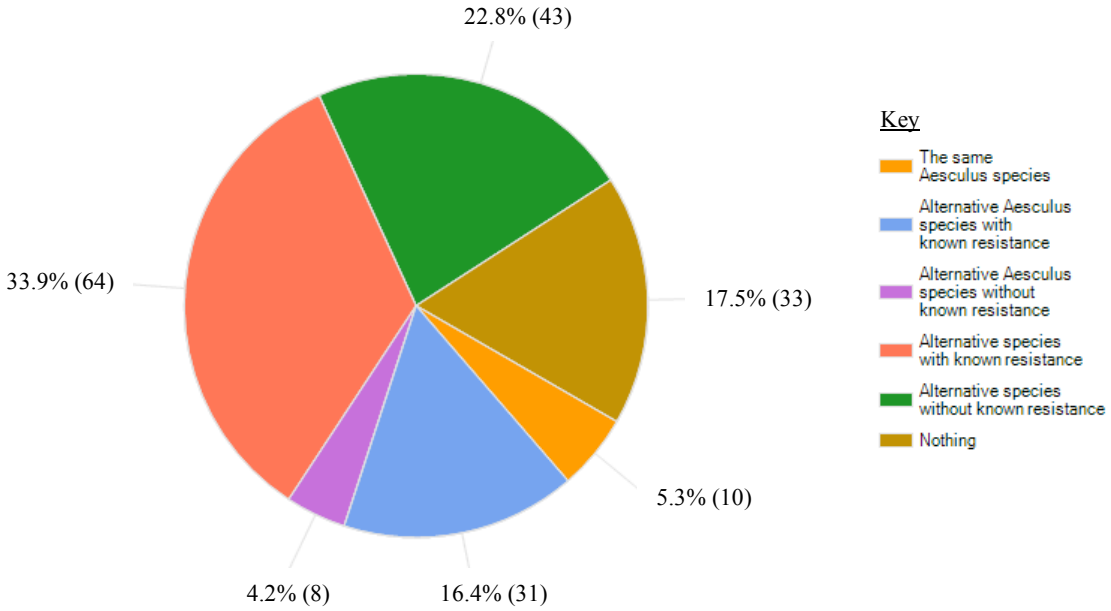
Respondents thought that drought, soil compaction and wood rotting fungi were contributing to the decline of *Aesculus* species (Figure 14). *Sciurus* species and *Pulvinaria regalis* were not thought to contribute to the decline of *Aesculus* species. Generally, respondents were unsure of the affects of *Guignardia aesculi* on *Aesculus* species. There were 34 comments from respondents for this question (Appendix 8). They predominately said that secondary infection by wood rotting fungi was the main factor killing *Aesculus* species and that the other factors would have a negative affect on any tree, and can not be directly linked to the decline of the species. Bacterial wetwood, water logging, poor pruning techniques, vandalism and an over emphasis on sanitation felling were also mentioned. There was no evidence of occupational or geographical differences.

4.13 Question 13

What are you planting in place of removed horse chestnut trees?

Respondents were encouraged to select more than one answer and were asked to specify what species they were using. The results are shown in Figure 15.

Figure 15: Respondents replacement species.



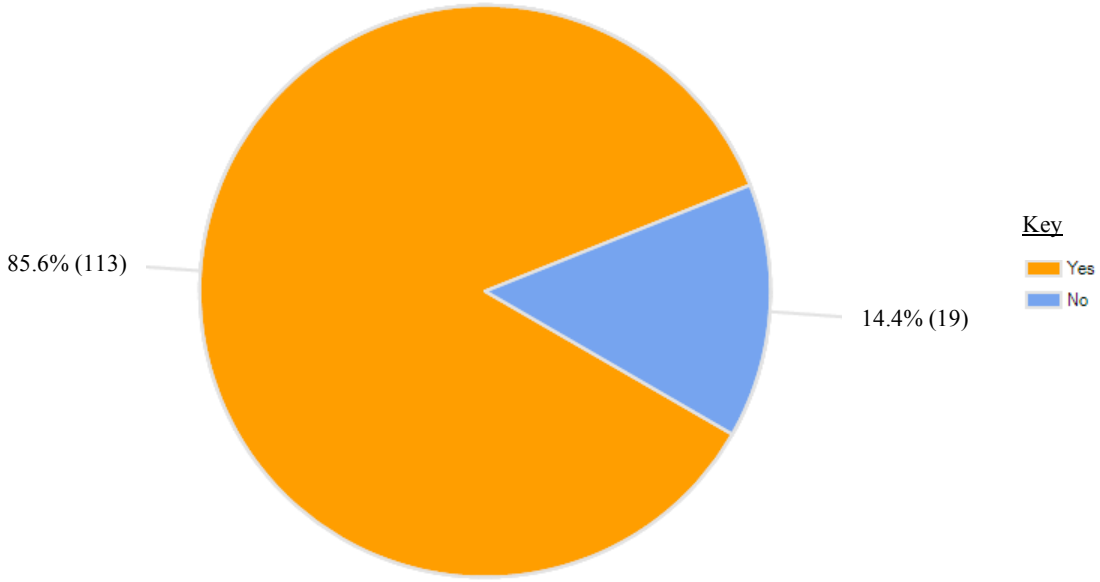
The majority of respondents (56.7 percent) selected alternate species for the replacement of removed *Aesculus* species. Interestingly 25.9 percent of respondents selected replanting the removed *Aesculus* species with the same species, notably 16.4 percent selected resistant *Aesculus* species. In addition there were 57 comments from respondents for this question, predominately specifying which tree species they most commonly replanted with (Appendix 9). The majority chose native species, including *Acer*, *Betula* (Birch), *Carpinus* (Hornbeam), *Fagus* (Beech), *Fraxinus*, *Pinus* (Pine), *Quercus* (Oak), *Sorbus* (Whitebeam) and *Tilia*. *Castanea* (Sweet chestnut), *Juglans* and *Platanus* (Plane) species were also chosen. *Castanea* and *Tilia* were common replacements for avenue trees. Where *Aesculus* species were chosen, it was primarily to preserve the character of the area. *A. indica* and *A. x carnea* were chosen for their resistance to *C. ohridella*. *A. hippocastanum* seedlings from parent plants showing some resistance to *P. syringae* through genetic variation were also chosen. There were no occupational or geographical differences.

4.14 Question 14

In your opinion, do you think a non-native tree species, such as horse chestnut should be safeguarded?

Respondents were asked to explain their answers. The results are shown in Figure 16.

Figure 16: Respondents' views on saving *Aesculus* species.



85.6 percent of respondents thought that *Aesculus* species should be safeguarded while 14.4 percent did not agree. There were 72 comments from respondents for this question (Appendix 10). The majority of respondents who thought *Aesculus* species should be safeguarded said that they have been successful in the UK environment, provide significant visual, amenity and historic value, and have become ingrained in our culture, due to their fruit, conkers. Some respondents also said that they regard *Aesculus* as native trees as they have been naturalising in the UK for a number of centuries. The minority of respondents who thought *Aesculus* species should not be safeguarded said that it was because they were non-native, that the problems facing them are natural phenomena, and that funds should be concentrated on planting alternative species. Some respondents thought the term safeguard was ambiguous or too strong a word. Instead they thought reasonable, practicable measures should be taken to protect the species.

4.15 Question 15

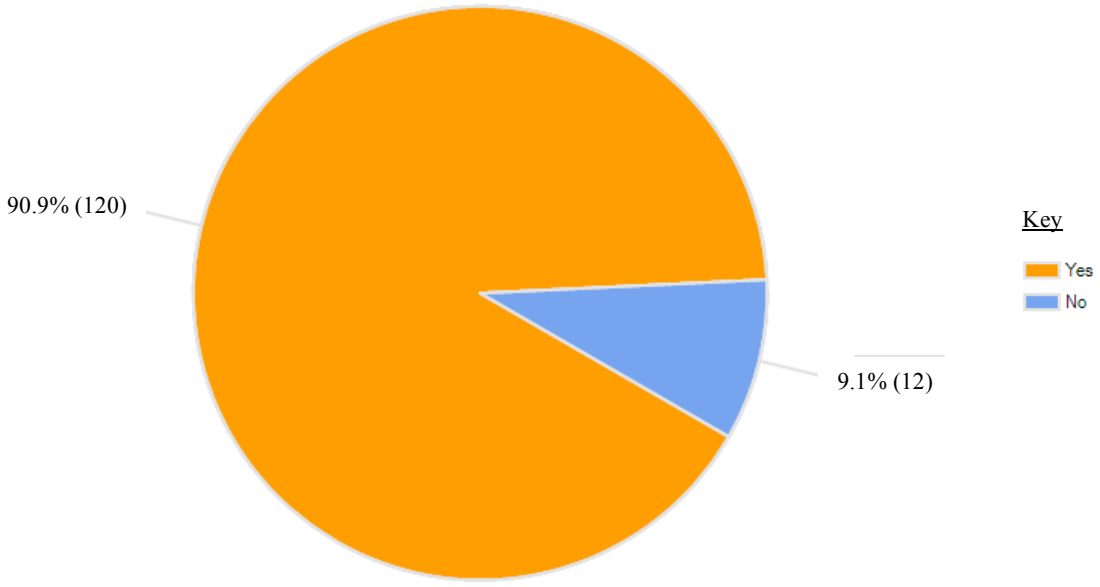
Is there anything else you would like to add?

There were 36 comments from respondents for this question (Appendix 11). The majority of respondents expressed concern over the situation and said that there was little information available regarding the management of *C. ohridella* and *P. syringae,* and, that many *Aesculus* species are being removed unduly as a result. Of most concern is the removal of young healthy *Aesculus* species to reduce future costs. Respondents also speculated that the cold winter of 2009/10 might reduce the numbers of adult moths emerging the following spring. Numerous respondents wished the author luck. A few thought that the questions could have been better posed or that they were not relevant to them but had to be completed to proceed to the next question, which caused them difficulty.

4.16 Question 16

Thank you very much for your time. Would you like to receive information on the findings of this research?

Figure 17: Respondents wanting a copy of the report.



The majority of respondents (90.9 percent) who completed the questionnaire said they would like to be sent a copy of the report while 9.1 percent declined (Figure 17). Two respondents did not leave their email addresses to facilitate the sending of the report.

Chapter 5: Discussion

The results of the research found that 59 percent of respondents commented freely on the subject topic and 90.9 percent requested a copy of the report. These two statistics demonstrate that the target audience was found.

The results show that the extent of *C. ohridella* on *Aesculus* species in the UK has become more progressed since the last survey in 2008 (Forestry Commission, 2009a). Where as, there has been no noticeable change in the extent or severity of *P. syringae* since the last survey in 2007 (Forestry Commission, 2008a, b). *C. ohridella* is severe in Southern and Eastern England, moderate in Central England, Wales and Ireland, and becomes decreasingly evident in Northern England, Scotland and Northern Ireland. *P. syringae* is moderate throughout most of the UK with the exception of North East England, Scotland and Northern Ireland, where it is less evident.

Low response rates from Northern Ireland and Ireland may invalidate the results for these areas. However, they were included in the research, as they supported and complimented the other findings.

The primary research found that 78.3 percent of respondents had been involved with the removal of *Aesculus* trees affected by *C. ohridella* or *P. syringae*. This has resulted in between 1,238 and 1,709 trees being removed collectively. On average between 8.5 and 11.8 trees have been removed per respondent. This represents a significant threat to the *Aesculus* tree population particularly when considering the small sample size (145 people). The majority of trees removed as a result of *C. ohridella* (between 185 and 224) are structurally sound but aesthetically impaired (Freise and Heitland, 1999; Thalmann *et al.*, 2003), while many of the trees removed as a result of *P. syringae* are still structurally sound but removed for health and safety concerns (Anderson, 2006).

The difference in respondents removing *Aesculus* trees affected by *C. ohridella* in question 5 (29 percent) and question 8 (19 percent) suggests that they would not necessarily recommend removal as a management technique, however, they are being

instructed to do so. This is even more evident with *P. syringae* in question 7 (77.2 percent) and question 10 (39.6 percent).

The general opinion expressed on the management techniques for the control of *C. ohridella* or *P. syringae* was that action was being taken too soon, before the long-term impacts are fully understood. This supports the argument for further research, in the form of field trials, to be undertaken. Also, that the management techniques available are not cost effective and where they had been used it was too early to evaluate the results. However, a small percentage of respondents said they had some success with the management techniques, notably 38.8 percent of respondents said that the removal and destruction of infected tissue/trees was very successful or fairly successful in preventing the spread of *P. syringae*. Interestingly, the application of Pancil T (octhilinone) and potassium phosphite to control *P. syringae* was mentioned and yet the literature review found no information on this practice despite potassium phosphite being widely used to treat *Phytophthora* (AGRIINFOTECH, No date).

There was a general consensus amongst respondents that the other biotic and abiotic factors mentioned in the questionnaire would have a negative affect on any tree, and can not be directly linked to the decline of the species. However, respondents thought that drought, soil compaction and wood rotting fungi were having a significant affect on many *Aesculus* trees. A number of other factors were also posited, notably water logging because of recent wet years.

There was a clear consensus on replanting alternative native species but also *Aesculus* species to preserve the character of an area. *A. indica* and *A. x carnea* were chosen for their resistantance to *C. ohridella*. *A. hippocastanum* seedlings from parent plants showing some resistance to *P. syringae* through genetic variation were also chosen.

There was a clear opinion, 85.6 percent of respondents, that *Aesculus* species should be reasonably safeguarded because they have been successful in the UK environment, provide significant visual, amenity and historic value, and have become ingrained in our culture, due to their fruit, conkers. The contrasting argument was that *Aesculus* is a failing species in UK and as there are no simple, cost effective solutions to their management, nature should be allowed to take its course.

There was a general consensus amongst respondents that there is little information available regarding the management of *C. ohridella* and *P. syringae,* and that many *Aesculus* species are being removed unduly as a result. Of most concern is an over emphasis on sanitation felling and the removal of young healthy *Aesculus* species to reduce future costs.

A few respondents thought that the questions could have been better phrased or that they were not relevant to them but had to be completed to proceed to the next question, which caused them difficulty.

Some of the 20 people that started but did not complete the questionnaire informed the author of the reasons for this. These included arboriculturalists that had little experience with *C. ohridella* and *P. syringae* and felt that their knowledge was not sufficient to opine or that the questionnaire did not let them progress with unanswered questions that they felt unable to complete accurately. The first reason is beyond the author's control but the second was due to the questionnaire being set up to prompt respondents to answer all closed questions, with exception to the comment boxes and contact details. This was intended to force decisions, however, this could have been more effectively achieved through a more sophisticated 'skip logic' feature on Survey Monkey. 'Skip logic' is designed to direct respondents through different paths in the survey based on responses to certain questions, enabling them to miss questions that are irrelevant to them. However, the author found that this feature of the questionnaire software was too basic and not sufficiently adaptable to achieve what was required.

It may have been beneficial to ask respondents to state their relevant professional qualifications and memberships to professional organisations. This would have helped to gauge their means of keeping up to date with current practices, research and topical issues.

Chapter 6: Conclusion

The research established that *C. ohridella* and *P. syringae* are prevalent throughout the UK, and that many *Aesculus* species are being removed unduly, before the long-term impacts are fully understood. This is predominantly due to the lack of information on the success of management techniques for *C. ohridella* and *P. syringae*, the cost of such management techniques, and an over emphasis on sanitation felling and health and safety (Anderson, 2006). Where management techniques had been used there was a general consensus that it was too early to evaluate the results. However, a small percentage of respondents reported some success, suggesting that management techniques can be effective in mitigating *C. ohridella* and *P. syringae*. This highlight the need for further research to be undertaken, in the form of field trials, in order to develop, refine and evaluate management techniques for *C. ohridella* and *P. syringae*. This is reinforced by the hypothesised host range expansion of *C. ohridella* (CONROCAM, 2004) and the fifty closely related pathovars of *P. syringae* (Green *et al.*, 2009) that pose a threat to other European plant species.

If management techniques do not adapt to control *C. ohridella* and *P. syringae*, as well as many other emerging pests and diseases, many of the UK's dominant landscape trees may follow the way of the elm and disappear over the next century. However, it must be remembered that trees and woodland live in cycles of natural phenomena such as climate, weather, pests and diseases. These cycles can be measured over decades or even years, and there is a limit to what human intervention can do to influence their outcomes.

The report has been e-mailed to 120 questionnaire respondents who requested it through the questionnaire and has been made available on Arbtalk. The author hopes that it will increase understanding of the present threat to *Aesculus* species, provide guidance on how to actively manage *C. ohridella* and *P. syringae* and highlight the need for further research to be undertaken.

Chapter 7: Recommendations

The basic surveying program along with the small sample size limited the research. In order to improve validity, a more sophisticated surveying program, enabling tailored responses would be used, to allow respondents to complete questions applicable to them and their previous answers. A larger sample size would also be obtained through better targeting, using professional organisations and magazines, and by providing more incentive for respondents to complete the questionnaire.

More importantly the research highlighted the need for further research, in the form of field trials, to be undertaken in order to develop, refine and evaluate management techniques for *C. ohridella* and *P. syringae*. This research would ascertain the long-term success of such management techniques, helping to develop people's levels of understanding and confidence in their effects. If these management techniques are shown to be effective they may become more financially viable, as people are frequently more willing to invest in proven controls.

Word Count: 11,048

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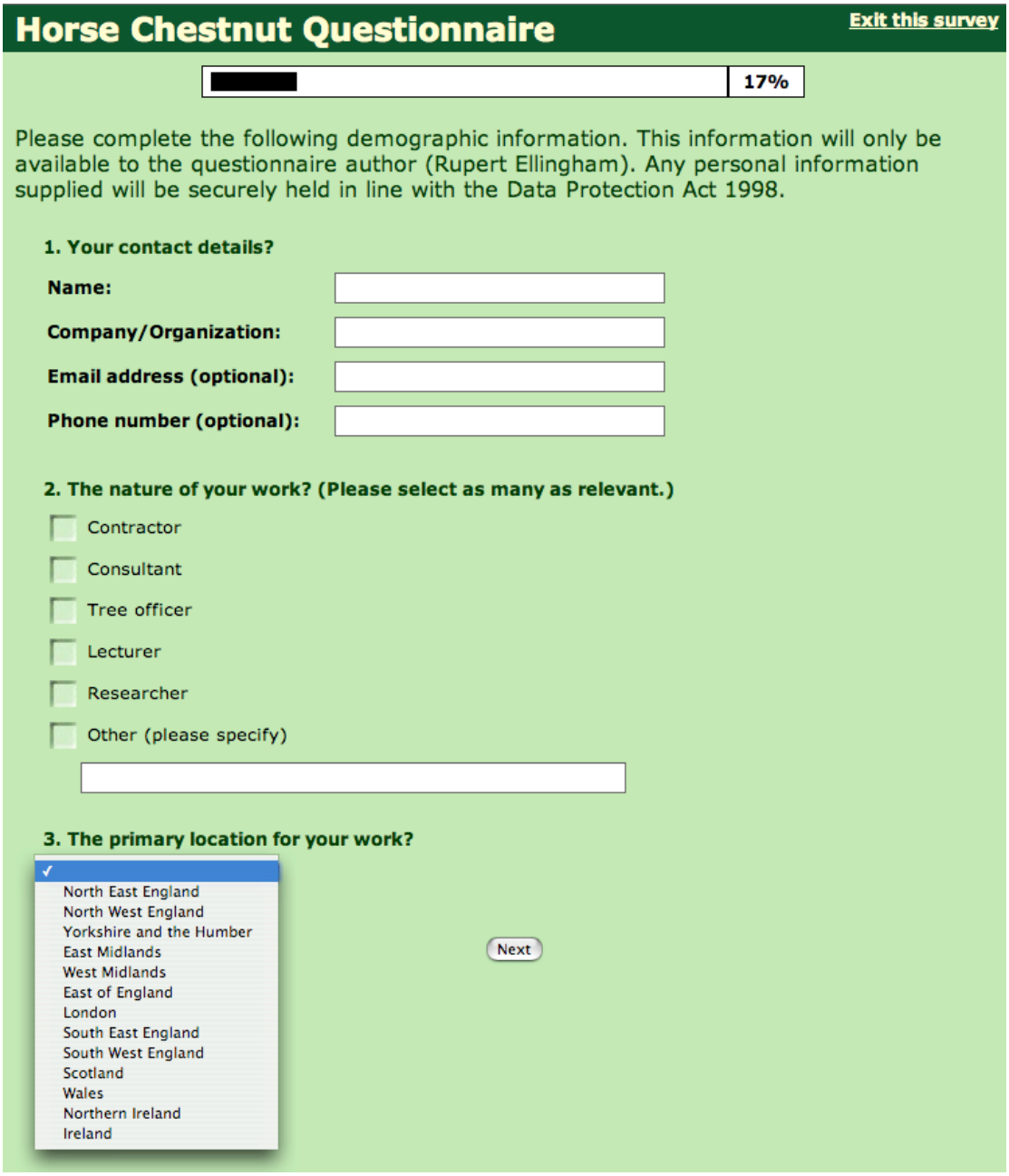
Appendances

Appendix 1: Online questionnaire (page one).



Horse Chestnut Questionnaire Exit this survey

17%

Please complete the following demographic information. This information will only be available to the questionnaire author (Rupert Ellingham). Any personal information supplied will be securely held in line with the Data Protection Act 1998.

1. Your contact details?

Name:

Company/Organization:

Email address (optional):

Phone number (optional):

2. The nature of your work? (Please select as many as relevant.)

- Contractor
- Consultant
- Tree officer
- Lecturer
- Researcher
- Other (please specify)

3. The primary location for your work?

- North East England
- North West England
- Yorkshire and the Humber
- East Midlands
- West Midlands
- East of England
- London
- South East England
- South West England
- Scotland
- Wales
- Northern Ireland
- Ireland

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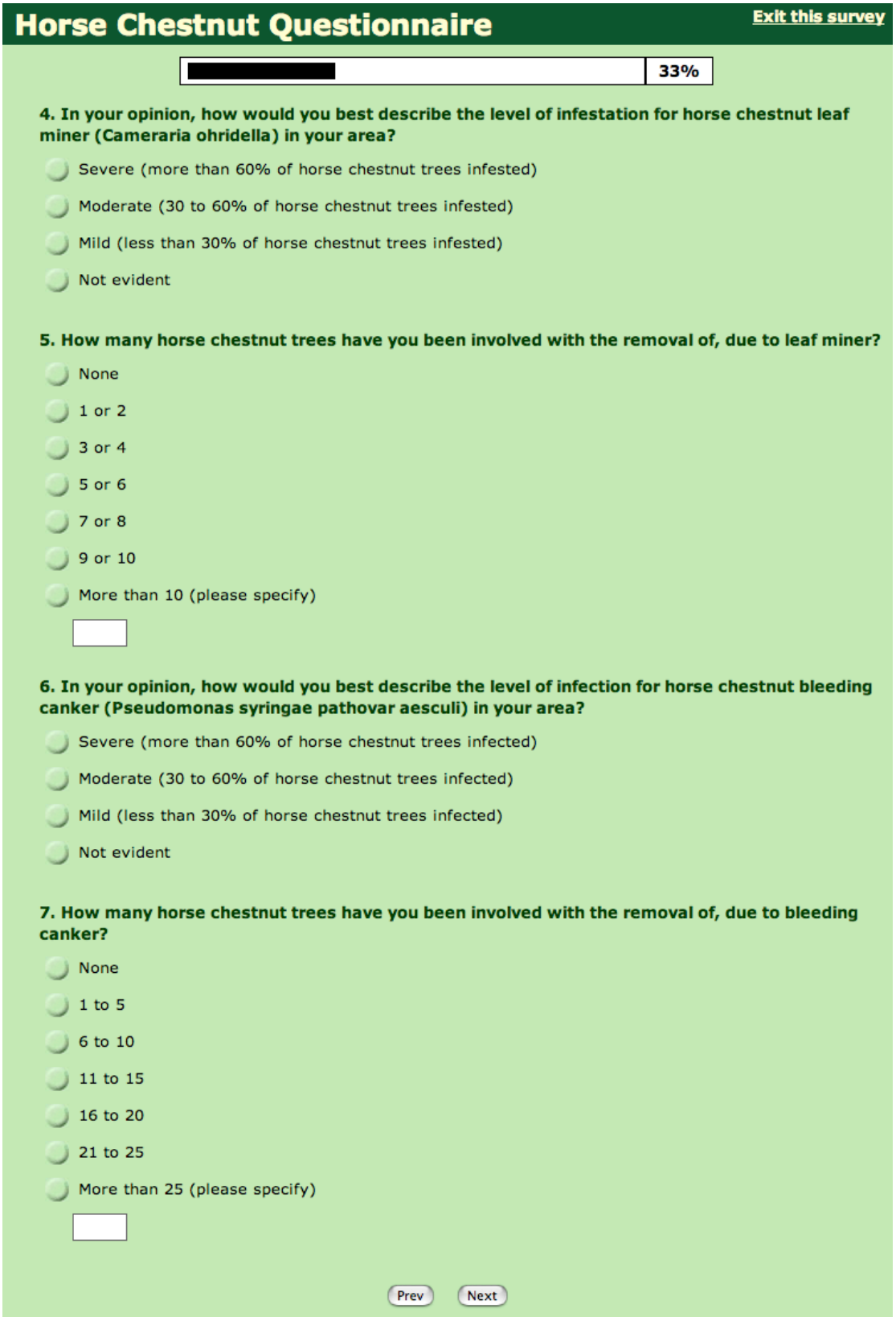
Appendix 1 continued: Online questionnaire (page two).



Horse Chestnut Questionnaire Exit this survey

33%

4. In your opinion, how would you best describe the level of infestation for horse chestnut leaf miner (Cameraria ohridella) in your area?

- Severe (more than 60% of horse chestnut trees infested)
- Moderate (30 to 60% of horse chestnut trees infested)
- Mild (less than 30% of horse chestnut trees infested)
- Not evident

5. How many horse chestnut trees have you been involved with the removal of, due to leaf miner?

- None
- 1 or 2
- 3 or 4
- 5 or 6
- 7 or 8
- 9 or 10
- More than 10 (please specify)

6. In your opinion, how would you best describe the level of infection for horse chestnut bleeding canker (Pseudomonas syringae pathovar aesculi) in your area?

- Severe (more than 60% of horse chestnut trees infected)
- Moderate (30 to 60% of horse chestnut trees infected)
- Mild (less than 30% of horse chestnut trees infected)
- Not evident

7. How many horse chestnut trees have you been involved with the removal of, due to bleeding canker?

- None
- 1 to 5
- 6 to 10
- 11 to 15
- 16 to 20
- 21 to 25
- More than 25 (please specify)

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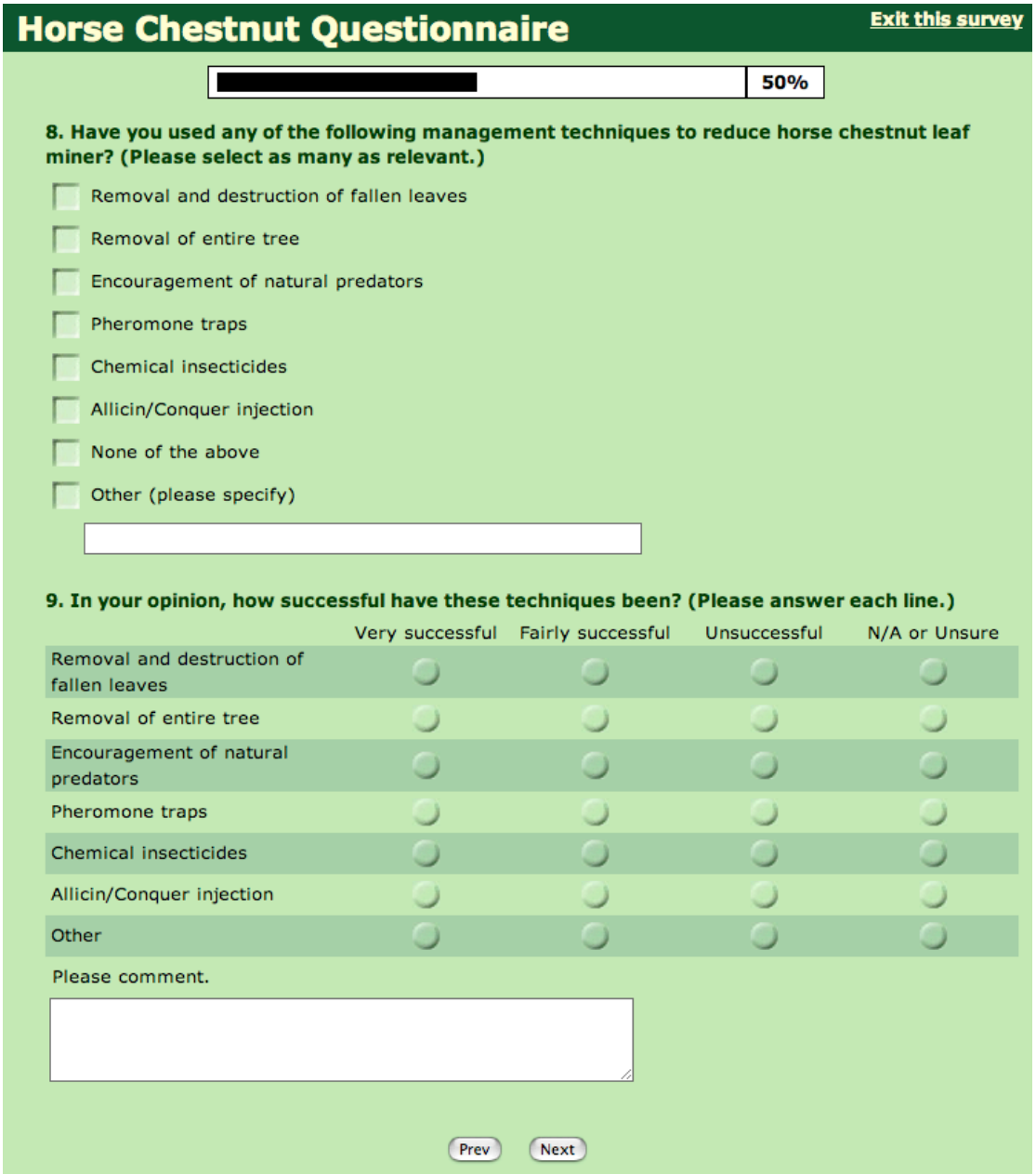
Appendix 1 continued: Online questionnaire (page three).



Horse Chestnut Questionnaire Exit this survey

50%

8. Have you used any of the following management techniques to reduce horse chestnut leaf miner? (Please select as many as relevant.)

- [ ] Removal and destruction of fallen leaves
- [ ] Removal of entire tree
- [ ] Encouragement of natural predators
- [ ] Pheromone traps
- [ ] Chemical insecticides
- [ ] Allicin/Conquer injection
- [ ] None of the above
- [ ] Other (please specify)

9. In your opinion, how successful have these techniques been? (Please answer each line.)

	Very successful	Fairly successful	Unsuccessful	N/A or Unsure
Removal and destruction of fallen leaves	○	○	○	○
Removal of entire tree	○	○	○	○
Encouragement of natural predators	○	○	○	○
Pheromone traps	○	○	○	○
Chemical insecticides	○	○	○	○
Allicin/Conquer injection	○	○	○	○
Other	○	○	○	○

Please comment.

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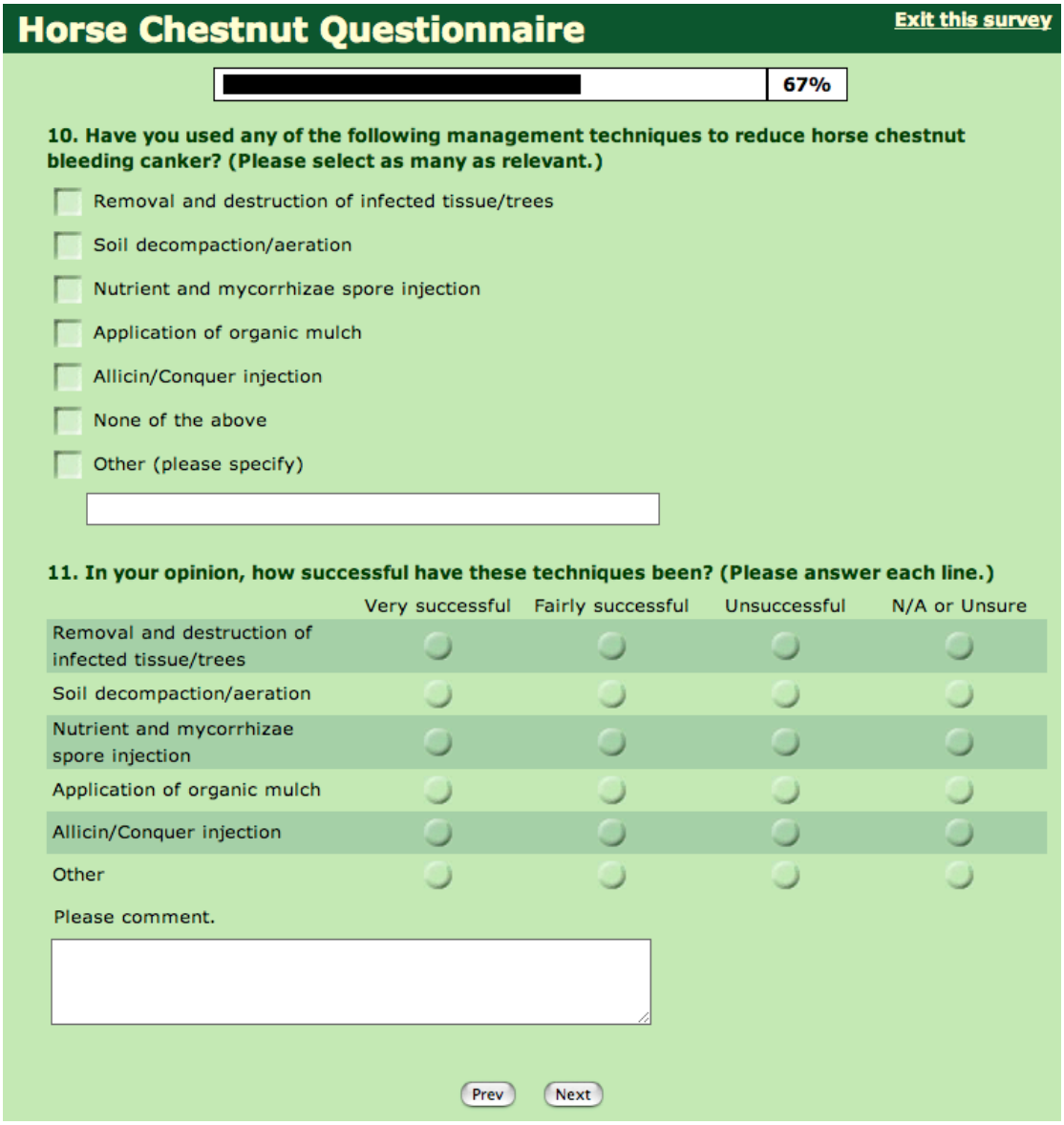
Appendix 1 continued: Online questionnaire (page four).



Horse Chestnut Questionnaire Exit this survey

67%

10. Have you used any of the following management techniques to reduce horse chestnut bleeding canker? (Please select as many as relevant.)

- [ ] Removal and destruction of infected tissue/trees
- [ ] Soil decompaction/aeration
- [ ] Nutrient and mycorrhizae spore injection
- [ ] Application of organic mulch
- [ ] Allicin/Conquer injection
- [ ] None of the above
- [ ] Other (please specify)

11. In your opinion, how successful have these techniques been? (Please answer each line.)

	Very successful	Fairly successful	Unsuccessful	N/A or Unsure
Removal and destruction of infected tissue/trees	○	○	○	○
Soil decompaction/aeration	○	○	○	○
Nutrient and mycorrhizae spore injection	○	○	○	○
Application of organic mulch	○	○	○	○
Allicin/Conquer injection	○	○	○	○
Other	○	○	○	○

Please comment.

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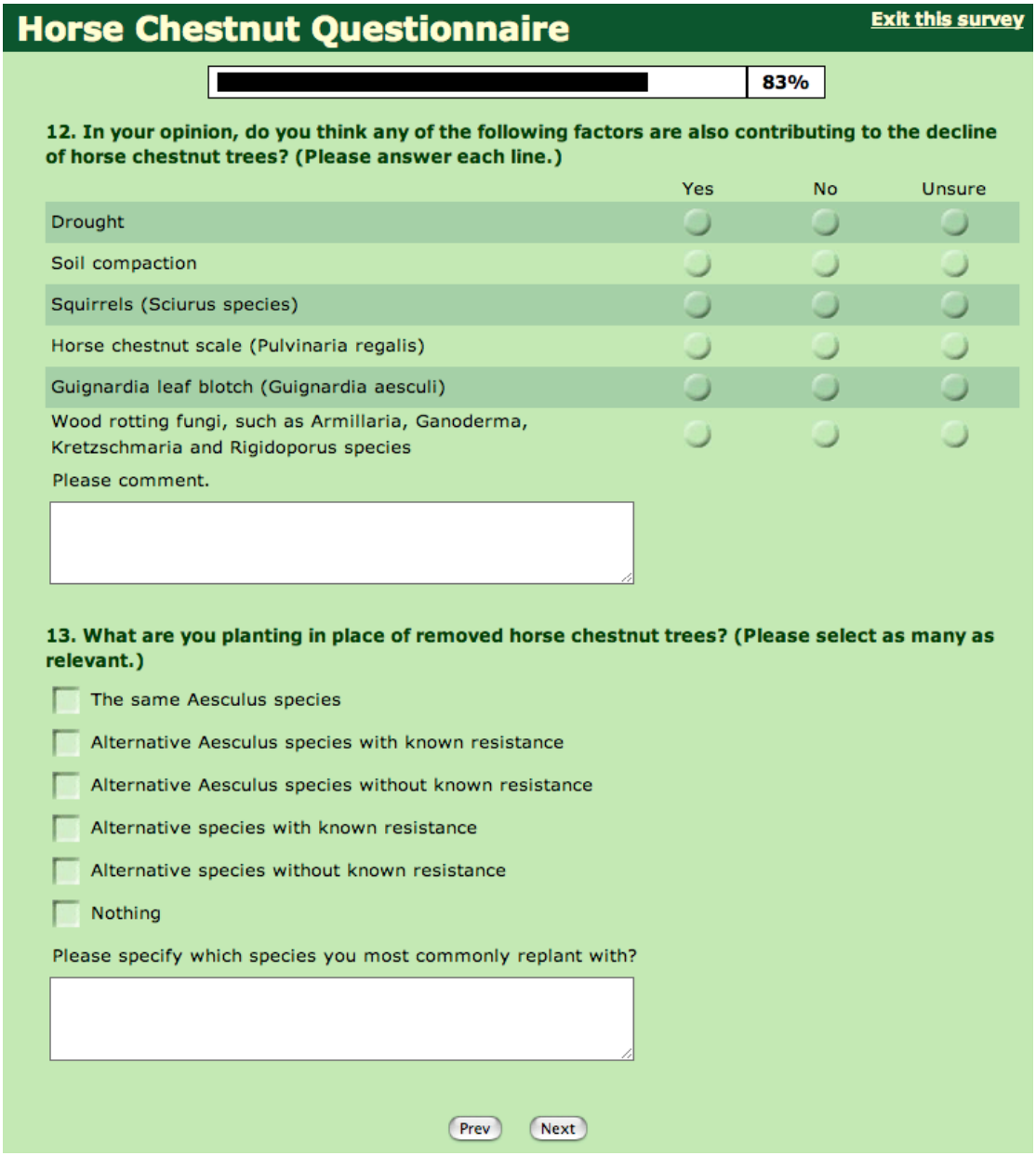
Appendix 1 continued: Online questionnaire (page five).



Horse Chestnut Questionnaire Exit this survey

83%

12. In your opinion, do you think any of the following factors are also contributing to the decline of horse chestnut trees? (Please answer each line.)

	Yes	No	Unsure
Drought	○	○	○
Soil compaction	○	○	○
Squirrels (Sciurus species)	○	○	○
Horse chestnut scale (Pulvinaria regalis)	○	○	○
Guignardia leaf blotch (Guignardia aesculi)	○	○	○
Wood rotting fungi, such as Armillaria, Ganoderma, Kretzschmaria and Rigidoporus species	○	○	○

Please comment.

13. What are you planting in place of removed horse chestnut trees? (Please select as many as relevant.)

- ☐ The same Aesculus species
- ☐ Alternative Aesculus species with known resistance
- ☐ Alternative Aesculus species without known resistance
- ☐ Alternative species with known resistance
- ☐ Alternative species without known resistance
- ☐ Nothing

Please specify which species you most commonly replant with?

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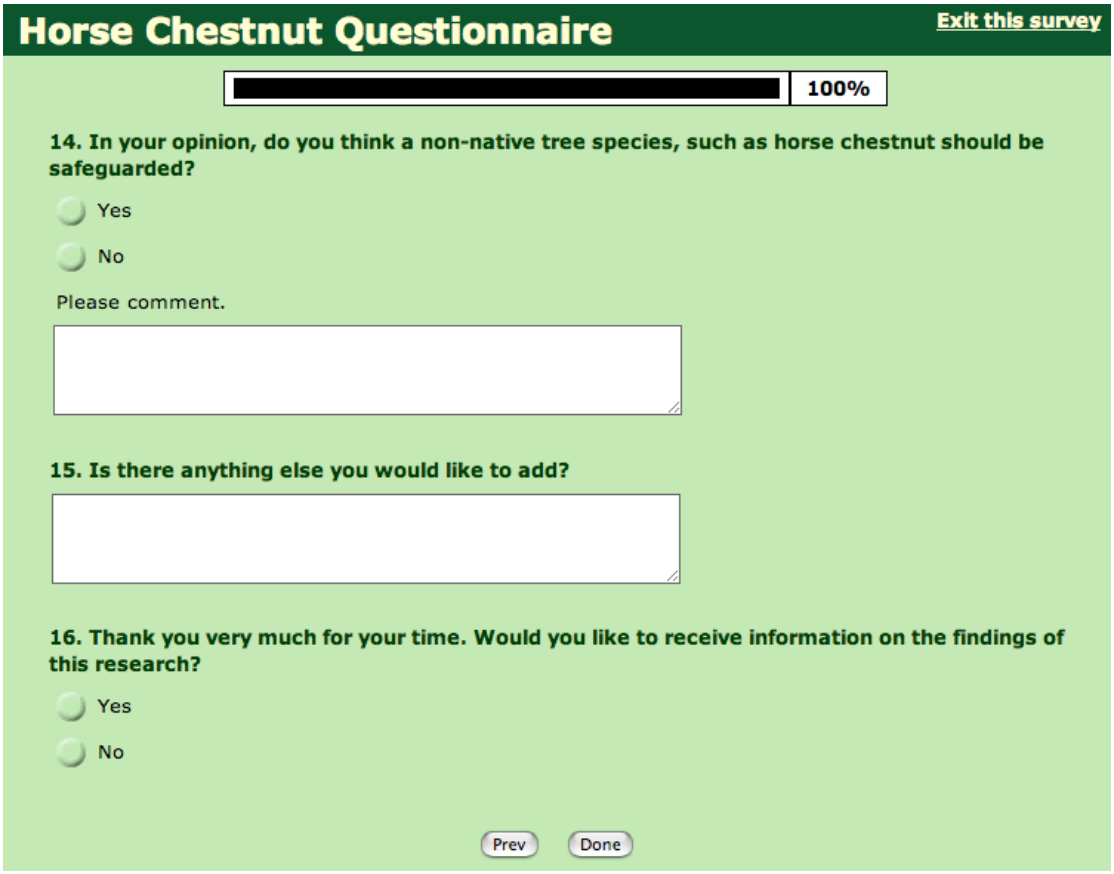
Appendix 1 continued: Online questionnaire (page six).



Appendix 2: Email introducing the author and research, outlining data protection and providing a link to the questionnaire.

Dear Sir/Madam,

I am currently undertaking a dissertation at Writtle College on the extent and severity of horse chestnut leaf miner and bleeding canker, and the success of management techniques used to mitigate these problems. Attached is a link to a questionnaire that will be sent to five hundred people across the UK involved within the tree industry. I would be very grateful if you could take the time to complete the questionnaire, which will take five to ten minutes. If you do not have time now then please do complete it at a later date. The survey is online until the 29th of January 2010.

The results will provide a better insight into the spread of Horse chestnut leaf miner and bleeding canker, the number of trees removed as a result, the effectiveness of the various management techniques being used to mitigate these problems, and what is being planted in their place. The findings will be available to everyone involved in the research. Please find the questionnaire here:

http://www.surveymonkey.com/s/MNWSRXC

All information obtained will be held by Writtle College and may be used to inform other studies carried out by the college. Any enquires regarding data protection should be addressed to the college secretary.

Yours sincerely,

Rupert Ellingham FdSc LDM

Appendix 3: Questionnaire results.

1. Your contact details?	**Response Percentage**	**Response Count**
Name	100%	152
Company/Organisation	100%	152
Email address (optional)	77.6%	118
Phone number (optional)	55.3%	84
	Answered question	*152*
	Skipped question	*0*

2. The nature of your work? (Please select as many as relevant.)	**Response Percentage**	**Response Count**
Contractor	41.2%	70
Consultant	20%	34
Tree officer	35.9%	61
Lecturer	2.4%	4
Researcher	0.6%	1
Other (please specify)	0%	0
	Answered question	*152*
	Skipped question	*0*

3. The primary location of your work?	**Response Percentage**	**Response Count**
North East England	3.3%	5
North West England	5.3%	8
Yorkshire and the Humber	2%	3
East Midlands	8.6%	13
West Midlands	14.5%	22
East of England	11.2%	17
London	6.6%	10
South East England	27.6%	42
South West England	9.2%	14
Scotland	3.9%	6
Wales	6.6%	10
Northern Ireland	0.7%	1
Ireland	0.7%	1
	Answered question	*152*
	Skipped question	*0*

Appendix 3 continued: Questionnaire results.

4. In your opinion, how would you best describe the level of infestation for horse chestnut leaf miner (*Cameraria ohridella*) in your area?	**Response Percentage**	**Response Count**
Severe (more than 60% of horse chestnut trees infested)	43.4%	63
Moderate (30 to 60% of horse chestnut trees infested)	24.1%	35
Mild (less than 30% of horse chestnut tress infested)	20%	29
Not evident	12.4%	18
Answered question		*145*
Skipped question		*7*

4a. Infestation of leaf miner in North East England.	**Response Percentage**	**Response Count**
Severe (more than 60% of horse chestnut trees infested)	0%	0
Moderate (30 to 60% of horse chestnut trees infested)	0%	0
Mild (less than 30% of horse chestnut tress infested)	40%	2
Not evident	60%	3
Answered question		*5*
Skipped question		*0*

4b. Infestation of leaf miner in North West England.	**Response Percentage**	**Response Count**
Severe (more than 60% of horse chestnut trees infested)	0%	0
Moderate (30 to 60% of horse chestnut trees infested)	28.6%	2
Mild (less than 30% of horse chestnut tress infested)	42.9%	3
Not evident	28.6%	2
Answered question		*7*
Skipped question		*1*

4c. Infestation of leaf miner in Yorkshire and the Humber.	**Response Percentage**	**Response Count**
Severe (more than 60% of horse chestnut trees infested)	0%	0
Moderate (30 to 60% of horse chestnut trees infested)	0%	0
Mild (less than 30% of horse chestnut tress infested)	66.7%	2
Not evident	33.3%	1
Answered question		*3*
Skipped question		*0*

Appendix 3 continued: Questionnaire results.

4d. Infestation of leaf miner in the East Midlands.	**Response Percentage**	**Response Count**
Severe (more than 60% of horse chestnut trees infested)	16.7%	2
Moderate (30 to 60% of horse chestnut trees infested)	50%	6
Mild (less than 30% of horse chestnut tress infested)	25%	3
Not evident	8.3%	1
Answered question		*12*
Skipped question		*1*

4e. Infestation of leaf miner in the West Midlands.	**Response Percentage**	**Response Count**
Severe (more than 60% of horse chestnut trees infested)	10%	2
Moderate (30 to 60% of horse chestnut trees infested)	45%	9
Mild (less than 30% of horse chestnut tress infested)	35%	7
Not evident	10%	2
Answered question		*20*
Skipped question		*2*

4f. Infestation of leaf miner in the East of England.	**Response Percentage**	**Response Count**
Severe (more than 60% of horse chestnut trees infested)	87.5%	14
Moderate (30 to 60% of horse chestnut trees infested)	6.3%	1
Mild (less than 30% of horse chestnut tress infested)	6.3%	1
Not evident	0%	0
Answered question		*16*
Skipped question		*1*

4g. Infestation of leaf miner in London.	**Response Percentage**	**Response Count**
Severe (more than 60% of horse chestnut trees infested)	88.9%	8
Moderate (30 to 60% of horse chestnut trees infested)	11.1%	1
Mild (less than 30% of horse chestnut tress infested)	0%	0
Not evident	0%	0
Answered question		*9*
Skipped question		*1*

Appendix 3 continued: Questionnaire results.

4h. Infestation of leaf miner in South East England.	**Response Percentage**	**Response Count**
Severe (more than 60% of horse chestnut trees infested)	70.7%	29
Moderate (30 to 60% of horse chestnut trees infested)	22%	9
Mild (less than 30% of horse chestnut tress infested)	7.3%	3
Not evident	0%	0
Answered question		*41*
Skipped question		*1*

4i. Infestation of leaf miner in South West England.	**Response Percentage**	**Response Count**
Severe (more than 60% of horse chestnut trees infested)	50%	7
Moderate (30 to 60% of horse chestnut trees infested)	28.6%	4
Mild (less than 30% of horse chestnut tress infested)	7.1%	1
Not evident	14.3%	2
Answered question		*14*
Skipped question		*0*

4j. Infestation of leaf miner in Scotland.	**Response Percentage**	**Response Count**
Severe (more than 60% of horse chestnut trees infested)	0%	0
Moderate (30 to 60% of horse chestnut trees infested)	0%	0
Mild (less than 30% of horse chestnut tress infested)	50%	3
Not evident	50%	3
Answered question		*6*
Skipped question		*0*

4k. Infestation of leaf miner in Wales.	**Response Percentage**	**Response Count**
Severe (more than 60% of horse chestnut trees infested)	10%	1
Moderate (30 to 60% of horse chestnut trees infested)	20%	2
Mild (less than 30% of horse chestnut tress infested)	40%	4
Not evident	30%	3
Answered question		*10*
Skipped question		*0*

Appendix 3 continued: Questionnaire results.

4l. Infestation of leaf miner in Northern Ireland.	**Response Percentage**	**Response Count**
Severe (more than 60% of horse chestnut trees infested)	0%	0
Moderate (30 to 60% of horse chestnut trees infested)	0%	0
Mild (less than 30% of horse chestnut tress infested)	0%	0
Not evident	100%	1
Answered question		*1*
Skipped question		*0*

4m. Infestation of leaf miner in Ireland.	**Response Percentage**	**Response Count**
Severe (more than 60% of horse chestnut trees infested)	0%	0
Moderate (30 to 60% of horse chestnut trees infested)	100%	1
Mild (less than 30% of horse chestnut tress infested)	0%	0
Not evident	0%	0
Answered question		*1*
Skipped question		*0*

5. How many horse chestnut trees have you been involved with the removal of, due to leaf miner?		**Response Percentage**	**Response Count**
None		71%	103
1 or 2		11.7%	17
3 or 4		8.3%	12
5 or 6		2.1%	3
7 or 8		2.8%	4
9 or 10		2.1%	3
More than 10 (please specify)	(12, 20, 30)	2.1%	3
Answered question			*145*
Skipped question			*7*

6. In your opinion, how would you best describe the level of infection for horse chestnut bleeding canker (*Pseudomonas syringae* pathovar *aesculi*) in your area?	**Response Percentage**	**Response Count**
Severe (more than 60% of horse chestnut trees infected)	13.1%	19
Moderate (30 to 60% of horse chestnut trees infected)	51%	74
Mild (less than 30% of horse chestnut tress infected)	30.3%	44
Not evident	5.5%	8
Answered question		*145*
Skipped question		*7*

Appendix 3 continued: Questionnaire results.

6a. Infection of bleeding canker in North East England	**Response Percentage**	**Response Count**
Severe (more than 60% of horse chestnut trees infected)	0%	0
Moderate (30 to 60% of horse chestnut trees infected)	20%	1
Mild (less than 30% of horse chestnut tress infected)	60%	3
Not evident	20%	1
	Answered question	*5*
	Skipped question	*0*

6b. Infection of bleeding canker in North West England	**Response Percentage**	**Response Count**
Severe (more than 60% of horse chestnut trees infected)	14.3%	1
Moderate (30 to 60% of horse chestnut trees infected)	71.4%	5
Mild (less than 30% of horse chestnut tress infected)	14.3%	1
Not evident	0%	0
	Answered question	*7*
	Skipped question	*1*

6c. Infection of bleeding canker in Yorkshire and the Humber	**Response Percentage**	**Response Count**
Severe (more than 60% of horse chestnut trees infected)	0%	0
Moderate (30 to 60% of horse chestnut trees infected)	66.7%	2
Mild (less than 30% of horse chestnut tress infected)	33.3%	1
Not evident	0%	0
	Answered question	*3*
	Skipped question	*0*

6d. Infection of bleeding canker in the East Midlands	**Response Percentage**	**Response Count**
Severe (more than 60% of horse chestnut trees infected)	16.7%	2
Moderate (30 to 60% of horse chestnut trees infected)	66.7%	8
Mild (less than 30% of horse chestnut tress infected)	16.7%	2
Not evident	0%	0
	Answered question	*12*
	Skipped question	*1*

Appendix 3 continued: Questionnaire results.

6e. Infection of bleeding canker in the West Midlands	**Response Percentage**	**Response Count**
Severe (more than 60% of horse chestnut trees infected)	20%	4
Moderate (30 to 60% of horse chestnut trees infected)	55%	11
Mild (less than 30% of horse chestnut tress infected)	20%	4
Not evident	5%	1
	Answered question	*20*
	Skipped question	*2*

6f. Infection of bleeding canker in the East of England	**Response Percentage**	**Response Count**
Severe (more than 60% of horse chestnut trees infected)	25%	4
Moderate (30 to 60% of horse chestnut trees infected)	50%	8
Mild (less than 30% of horse chestnut tress infected)	25%	4
Not evident	0%	0
	Answered question	*16*
	Skipped question	*1*

6g. Infection of bleeding canker in London	**Response Percentage**	**Response Count**
Severe (more than 60% of horse chestnut trees infected)	22.2%	2
Moderate (30 to 60% of horse chestnut trees infected)	44.4%	4
Mild (less than 30% of horse chestnut tress infected)	33.3%	3
Not evident	0%	0
	Answered question	*9*
	Skipped question	*1*

6h. Infection of bleeding canker in South East England	**Response Percentage**	**Response Count**
Severe (more than 60% of horse chestnut trees infected)	9.8%	4
Moderate (30 to 60% of horse chestnut trees infected)	51.2%	21
Mild (less than 30% of horse chestnut tress infected)	39%	16
Not evident	0%	0
	Answered question	*41*
	Skipped question	*1*

Appendix 3 continued: Questionnaire results.

6i. Infection of bleeding canker in South West England	**Response Percentage**	**Response Count**
Severe (more than 60% of horse chestnut trees infected)	14.3%	2
Moderate (30 to 60% of horse chestnut trees infected)	42.9%	6
Mild (less than 30% of horse chestnut tress infected)	35.7%	5
Not evident	7.1%	1
Answered question		*14*
Skipped question		*0*

6j. Infection of bleeding canker in Scotland	**Response Percentage**	**Response Count**
Severe (more than 60% of horse chestnut trees infected)	0%	0
Moderate (30 to 60% of horse chestnut trees infected)	16.7%	1
Mild (less than 30% of horse chestnut tress infected)	33.3%	2
Not evident	50%	3
Answered question		*6*
Skipped question		*0*

6k. Infection of bleeding canker in Wales	**Response Percentage**	**Response Count**
Severe (more than 60% of horse chestnut trees infected)	0%	0
Moderate (30 to 60% of horse chestnut trees infected)	60%	6
Mild (less than 30% of horse chestnut tress infected)	30%	3
Not evident	10%	1
Answered question		*10*
Skipped question		*0*

6l. Infection of bleeding canker in Northern Ireland	**Response Percentage**	**Response Count**
Severe (more than 60% of horse chestnut trees infected)	0%	0
Moderate (30 to 60% of horse chestnut trees infected)	0%	0
Mild (less than 30% of horse chestnut tress infected)	0%	0
Not evident	100%	1
Answered question		*1*
Skipped question		*0*

Appendix 3 continued: Questionnaire results.

6m. Infection of bleeding canker in Ireland	**Response Percentage**	**Response Count**
Severe (more than 60% of horse chestnut trees infected)	0%	0
Moderate (30 to 60% of horse chestnut trees infected)	100%	1
Mild (less than 30% of horse chestnut tress infected)	0%	0
Not evident	0%	0
Answered question		*1*
Skipped question		*0*

7. How many horse chestnut trees have you been involved with the removal of, due to bleeding canker?		**Response Percentage**	**Response Count**
None		22.8%	33
1 to 5		29.7%	43
6 to 10		15.9%	23
11 to 15		15.2%	22
16 to 20		4.1%	6
21 to 25		9.7%	14
More than 25 (please specify)	(30, 50, 60, 100)	2.8%	4
Answered question			*145*
Skipped question			*7*

8. Have you used any of the following management techniques to reduce horse chestnut leaf miner? (Please select as many as relevant.)		**Response Percentage**	**Response Count**
Removal and destruction of fallen leaves		25.5%	47
Removal of entire tree		19%	35
Encouragement of natural predators		4.9%	9
Pheromone traps		0%	0
Chemical insecticides		4.3%	8
Allicin/Conquer injection		1.6%	3
None of the above		41.9%	77
Other (please specify)	(see Appendix 4)	2.7%	5
Answered question			*141*
Skipped question			*11*

Appendix 3 continued: Questionnaire results.

9. In your opinion, how successful have these techniques been? (Please answer each line.)

	Very Successful	Fairly Successful	Un-successful	N/A or Unsure	Response Count
Removal & destruction of fallen leaves	2.8% (4)	13.5% (19)	7.1% (10)	76.6% (108)	141
Removal of entire tree	9.2% (13)	7.1% (10)	6.4% (9)	77.3% (109)	141
Encouragement of natural predators	0.7% (1)	2.1% (3)	2.1% (3)	95% (134)	141
Pheromone traps	0.7% (1)	0% (0)	0% (0)	99.3% (140)	141
Chemical insecticides	3.5% (5)	0.7% (1)	0.7% (1)	95% (134)	141
Allicin/Conquer injection	1.4% (2)	0% (0)	0% (0)	98.6% (139)	141
Other	0.7% (1)	1.4% (2)	0.7% (1)	97.2% (137)	141
			Please comment (see Appendix 5)		27
			Answered question		*141*
			Skipped question		*11*

10. Have you used any of the following management techniques to reduce horse chestnut bleeding canker? (Please select as many as relevant.)		**Response Percentage**	**Response Count**
Removal and destruction of infected tissue/trees		39.6%	72
Soil decompaction/aeration		8.2%	15
Nutrient and mycorrhizae spore injection		3.8%	7
Application of organic mulch		12.6%	23
Allicin/Conquer injection		1.6%	3
None of the above		31.9%	58
Other (please specify)	(see Appendix 6)	2.2%	4
		Answered question	*136*
		Skipped question	*16*

Appendix 3 continued: Questionnaire results.

11. In your opinion, how successful have these techniques been? (Please answer each line.)

	Very Successful	Fairly Successful	Un-successful	N/A or Unsure	Response Count
Removal and destruction of infected tissue/trees	14.7% (20)	19.1% (26)	10.3% (14)	55.9% (76)	136
Soil decompaction/aeration	0.7% (1)	5.1% (7)	2.2% (3)	91.9% (125)	136
Nutrient and mycorrhizae spore injection	1.5% (2)	2.9% (4)	0.7% (1)	94.9% (129)	136
Application of organic mulch	2.2% (3)	4.4% (6)	4.4% (6)	89% (121)	136
Allicin/Conquer injection	0.7% (1)	0% (0)	0% (0)	99.3% (135)	136
Other	2.2% (3)	0.7% (1)	0% (0)	97.1% (132)	136
			Please comment (see Appendix 7)		28
			Answered question		*136*
			Skipped question		*16*

12. In your opinion, do you think any of the following factors are also contributing to the decline of horse chestnut trees? (Please answer each line.)

	Yes	No	Unsure	Response Count
Drought	53% (70)	18.9% (25)	28% (37)	132
Soil compaction	55.3% (73)	21.2% (28)	23.5% (31)	132
Squirrels (*Sciurus* species)	9.1% (12)	54.5% (72)	36.4% (48)	132
Horse chestnut scale (*Pulvinaria regalis*)	15.2% (20)	50.8% (67)	34.1% (45)	132
Guignardia leaf blotch (*Guignardia aesculi*)	29.5% (39)	33.3% (44)	37.1% (49)	132
Wood rotting fungi, such as *Armillaria*, *Ganoderma* and *Rigidoporus* species	50% (66)	25% (33)	25% (33)	132
		Please comment (see Appendix 8)		34
		Answered question		*132*
		Skipped question		*20*

Appendix 3 continued: Questionnaire results.

13. What are you planting in place of removed horse chestnut trees? (Please select as many as relevant.)	**Response Percentage**	**Response Count**
The same *Aesculus* species	5.3%	10
Alternative *Aesculus* species with known resistance	16.4%	31
Alternative *Aesculus* species without known resistance	4.2%	8
Alternative species with known resistance	33.9%	64
Alternative species without known resistance	22.8%	43
Nothing	17.5%	33
Please specify which species you most commonly replant with? (See Appendix 9)		57
Answered question		*132*
Skipped question		*20*

14. In your opinion, do you think a non-native tree species, such as horse chestnut should be safeguarded?	**Response Percentage**	**Response Count**
Yes	85.6%	113
No	14.4%	19
Please comment (see Appendix 10)		72
Answered question		*132*
Skipped question		*20*

15. Is there anything else you would like to add?		**Response Count**
(See Appendix 11)		36
Answered question		*36*
Skipped question		*116*

16. Thank you very much for your time. Would you like to receive information on the findings of this research?	**Response Percentage**	**Response Count**
Yes	90.9%	120
No	9.1%	12
Answered question		*132*
Skipped question		*20*

Appendix 4: Respondents' comments for question eight.

1 Removal of weak branches due to leaf loss

2 Crown thinning

3 Mulch

4 Retrenchment pruning

5 Reductions

Appendix 5: Respondents' comments for question nine.

1 By the time we are approached the tree is virtually dead.

2 In my area of work, which is working around Worcestershire, a lot of small trees are dying, between 10 and 20 years, a lot of the bigger trees are in not to bad a condition.

3 I haven't been involved with a tree that has had a client that wants to spend that much money on. They generally take a longer-term view on their investment and primary objective is reducing their liabilities, brown shriveled leaves on an otherwise healthy branch don't get money spent on it. Some clients remove trees for aesthetic reasons.

4 May be present on other trees within the site.

5 Sanitation measures are very dependant upon the growth environment of affected trees.

6 Was severe in 2008, removed leaves- less severe in 2009

Appendix 5 continued: Respondents' comments for question nine.

7 We have advised clients to remove fallen leaf matter to delay infection rates

8 Waiting to see next year's results.

9 Not based on a long enough time span for any obvious/definitive results

10 Have recommended collecting fallen leaves to tree owners of TPO trees, but do not know if they have done so.

11 Clients are advised to undertake sanitation measures, however how thorough they are or how successful they are is debatable.

12 To early to say if the Allicin has had an impact.

13 I do not believe my authority could afford any control measures or that they would work. Leaves are only removed where they are a problem and not in an attempt to control leaf miner.

14 The trees concerned were over mature anyway; they were also located in highway situations so long-term control measures were not entirely practical.

15 All the trees with the leaf miner have been privately owned, I have only advised.

16 Will look into pheromone traps and natural predators, more info please.

17 Some evidence that removal of leaves delays reinfestation. Our current position is that chemical treatment of individual trees is only likely to have a temporary effect, so we don't recommend due to cost.

18 Still monitoring effects so no action taken to date.

Appendix 5 continued: Respondents' comments for question nine.

19 Fallen leaves are removed in urban areas whether they are infested or not.

20 Whilst we have not undertaken any specific management measures with regards we have assisted with research being undertaken by Bartlett Tree Expert Laboratories and independent arboricultural consultants.

21 There was hope that a hard winter might reduce numbers of leaf miner ... so we are yet to see.

22 None of the above have been used due to the obvious problems of using insecticides on mature and early mature trees, cost effectiveness and the need for potentially repeat injections. However where able I am considering the removal and burning of leaves where this can be cost effective.

23 The practicality and costs involved in such measures most usually preclude their use.

24 Not cost effective to control.

25 Not financially viable.

26 Personally in my opinion the overall state of infections is improving. The outbreak seems to be happening later in the year and not as aggressive, as though the trees are fighting it better.

27 Tried Allicin - no results back yet.

Appendix 6: Respondents' comments for question ten.

1 Crown reduction of infected parts to reduce hazards, then leave alone.

2 Painting pared-back area with Pancil T (octhilinone active ingredient)

3 Phosphite treatments.

4 Application of potassium phosphite

Appendix 7: Respondents' comments for question eleven.

1 As before, I haven't been involved with a tree that has had a client that wants to spend that much money on. They generally take a longer-term view on their investment and primary objective is reducing their liabilities, the occasional dead branch may be removed. Some clients may remove the tree for aesthetic reasons.

2 Canker damage was extensive. It was identified but not tested in a lab.

3 The best treatment we've experienced is a strategic crown reduction to reduce liability issues, and then leave the tree alone subject to monitoring. Most trees seem to either recover, or adapt and continue to thrive even with the infection. Removal of the infected tree is obviously very successful. The tree is gone so no more infection. Removal of infected parts has not been tried, as it would be almost impossible to remove all infected parts from most trees.

4 Depends on severity of infection.

5 Too early to tell

Appendix 7 continued: Respondents' comments for question eleven.

6 Again based on reasonably short time scale (3 years) but only evolved in fairly localised infection. Destruction seems to have had an effect as movement to/infection of other trees has not yet been identified, despite large Aesculus spp. population in vicinity.

7 Removal has not been a management technique to reduce the disease in the area per se, but a response to the health/safety of the individual tree.

8 The theory behind improving tree health and vitality is clearly sound, however the time span before seeing solid results is long and imprecise.

9 To early to say for the Allicin Injection (only carried out last summer).

10 Removal of infected tissue can result in decayed pruning cuts.

11 I administer TPO's and works to trees in designated Conservation Areas I see many trees affected by "bleeding canker" and am not convinced that any of the control measures would work.

12 We will be attempting decompaction/aeration during this year (2010).

13 Almost all trees are infected but some offer more symptoms than others. Following loss of large limbs, including one near miss involving a party of school children, probably due to secondary infection we are being more proactive and removing trees with large areas of bark loss. It does appear to be worse in some years than others.

14 Dealing with TPO's applicant tend to leave it too late for remedial works, resulting in applications to fell dysfunctional trees.

15 Not enough data available for considered comment.

Appendix 7 continued: Respondents' comments for question eleven.

16 In parks and woodlands we have few horse chestnuts so I have removed infected trees because they were in severe decline and unsightly.

17 We are not convinced with some of the alternative treatment measures so have opted for sanitation methods by removing heavily infected trees.

18 Many trees recover and improve whereas very few actually die.

19 Would only consider or use because of potential cost implications and also the majority of infected trees at the minute are early mature and not worthy of retention. Would consider trials of several of the above techniques on the mature high value trees we have showing early signs of infection.

20 No evidence of linkage between treatment & recovery. (Not aware of any controlled treatments, so how does one know whether any recovery seen was not spontaneous/not related to treatment?)

21 In no instance has it been fully established that the bleeding evident is associated with an identifiable decease.

22 It removes the tree but not the problem!

23 In conjunction with Pancil T as above. Only viable for relatively small areas of bark.

24 In one Street of 36 trees we had to remove 9 in the first year and monitored the rest. It was only necessary to remove 1 more over the next 3 years suggesting that removing the worst did reduce the risk to the others. It would have been difficult to test techniques such as aeration or mulching.

Appendix 7 continued: Respondents' comments for question eleven.

25 Phosphite treatments been very successful in controlling bleeding canker, especially in conjunction with mulching with fresh woodchip.

26 Only felling trees when they pose a safety risk.

27 Treatment of bleeding canker requires a combination of all four treatments ticked. Each one individually will help but not significantly reduce bleeding canker. The treatments ticked all improve tree vitality. This is the key to bleeding canker management. We know infected trees can recover and survive. If you alleviate all the stresses trees face through fertilisation, soil decompaction etc the tree has a far greater chance of recovery. I am presently writing a paper on this for EssentialARB. Please contact me if you want a copy. In addition my trial was filmed by BBC Countryfile and aired on October 11 2009. The other key to managing bleeding canker is leaf miner control. Leaf miner reduces a tree photosynthetic productivity by 30-40%. This is a massive energy drain. Our experiments have shown that bleeding canker lesion size is always greater in trees where leaf miner has not been controlled compared to trees where we control leaf miner using a soil drench insecticide which is highly effective and fully registered for UK amenity environments.

28 Tried Allicin - no results back yet

Appendix 8: Respondents' comments for question twelve.

1 The only problem I have seen on horse chestnut is bacterial wet rot

2 I think its infection getting into the cambium that's killing them off.

Appendix 8 continued: Respondents' comments for question twelve.

3 The decay fungi are colonising stressed and weakened (drought & compaction) trees. Seen Rigidoporus ulmarius more in the last couple of years

4 In general seem to be fine in this region although most Horse chestnuts in decline have been badly pruned/pollarded/neglected.

5 Humid Spring/Summer weather. Armillaria/Flamulinia, common as a secondary infection.

6 Armillaria species are often associated with declining trees, suffering from bleeding canker, and therefore appear to be opportunist secondary invaders of such weekend trees

7 Armillaria is the biggest killer of Chestnut here.

8 In my opinion, these ALL will have an effect, once the tree(s) in question have been weakened by another factor (Cameraria spp., Pseudomonas). But I wouldn't focus on any particular one, as being any more of a threat to the population, as in my experience there is no increase in the other factors.

9 Drought - possibly... or climate change as a suite of conditions in general

10 Ustulina deusta and the collapse of 1x H/C, weakening defense allowing other diseases such as Armillaria to enter x1.

11 Soil compaction, particularly in public places, is an issue for all trees.

12 Guignardia less so in recent years or marred by Leaf Miner.

Appendix 8 continued: Respondents' comments for question twelve.

13 Depends on season drought occurs in. May help prevent spread of water borne Phytophora spores but can also stress trees and increase susceptibility to disease. Guignardia usually occurs at end of growing season so shouldn't affect trees vitality adversely. Squirrels only really problematic on beech for bark stripping, horse chestnut bark not usually attacked. Other wood rotting fungi are just part of normal life cycle of a tree but may colonise earlier if weakened by canker.

14 We have had 3 very wet summers with no other apparent environmental factors involved.

15 From my observations, when large areas of bark are lost, Pleurotus ostreatus gains entry to the wood and very quickly reduces the strength of even large limbs to the point were they snap off with little warning, even on windless days at any season of the year.

16 HC Scale is a very minor problem and in Blackburn, although present, it does not contribute to HC decline.

17 Of course there are a number of biotic and abiotic factors, which affect HC. None of the above are a particular issue for the survival of species as a whole.

18 Mild weather is a major factor; fungal spread in all species has gone through the roof this year. Nothing is killing of the small insects in the wintertime. This year may be different considering the cold weather in Jan. We will have to wait and see!

19 Tree decline and death usually results as a combination of canker, leaf miner and drought.

Appendix 8 continued: Respondents' comments for question twelve.

20 I think that the combination of factors is making this species more susceptible to the decline.

21 Most of the above can contribute to the decline of an individual tree. However, not usually to chestnut tree populations as a whole.

22 A combination of factors are impacting on horse chestnuts and its difficult to pin point any one as a result of another. These trees may already be stressed by a pathogen, which is not yet visible (fruiting) or is latent and leaf. Pseudomonas may get a hold on the tree. Things may be the other way round.

23 Fully and over-mature Horse chestnuts appear to be highly prone to wood-colonising decay fungi in addition to being susceptible to bleeding canker.

24 As far as I am aware the bacteria are water borne and come in through the roots. But, trees that are hard pruned definitely suffer badly!

25 Also past poor pruning in non-council trees resulting in large wounds etc. Vandalism.

26 Don't confuse. Many other factors such as drought, squirrel damage, would add to the stress of the trees system and energy reserves on any tree. Pulvinaria tends to like already stressed trees where cracks and fissures occur on the stem twigs and branches and entry point for sap sucking is easier. Pathogenic fungi such as Armillaria, like trees that are stressed as with any thing in nature when trees are stressed and the system is at a low ebb this is a perfect time for entry to the host as it has less resistancy in the way of energy and natural defense such as the production of phenols.

Appendix 8 continued: Respondents' comments for question twelve.

27 The factors listed above affect all trees, however with horse chestnuts this is a further stress added to the tree on top of the leaf minor or the bleeding canker. This is likely to see horse chestnuts suffer stress and strain quicker and with less resilience.

28 Clearly drought, compaction & decay cause 'decline' - but whether that makes them more susceptible to Cam.o is highly dubious; general susceptibility to BC MAY, POSSIBLY be increased, but no clear evidence. Squirrels - not found to be a MAJOR issue with HC (...?) Can't say that Pulv or Guig are anything more that disfiguring.

29 Lack of accurate identification and over emphasis on sanitation felling is probably the worse threat to chestnuts.

30 I believe there is an association between bleeding canker followed by secondary infection by Armillaria.

31 Waterlogging / poor drainage.

32 HC can be prone to colonisation by Kretzschmaria deusta.

33 Stressed trees are generally always more susceptible to pest and disease attack. Alleviate the stress and a tree has a significantly greater chance of survival.

34 It seems to be a combination of factors: leaf miner, canker and Guignardia as well as other abiotic factors in specific cases.

Appendix 9: Respondents' comments for question thirteen.

1 beech, lime, ash

2 Quercus

3 Nothing in particular, usual site factors considered, Aesculus sp. used where integral character of area other (large where appropriate) trees normally recommended.

4 depends on clients requirements, whitebeam need little maintenance but like to plant birch/oak/beech/etc.

5 Depends if the tree has had a TPO, then usually the council have given options such as Ash, Beech, Birch.

6 Red Horse chestnut, Buckeye, Silver Lime, Hop Hornbeam

7 Aesculus indica

8 Acer, Quercus, Pinus,

9 Locally grown natural seedlings of removed trees (where possible).

10 A. hippocastanum.

11 OAK, as requested by the LA

12 Sweet chestnut

13 The collection and planting of seeds from previously affected and unaffected H/C in an attempt to reduce the infection rate by their genetic variability

Appendix 9 continued: Respondents' comments for question thirteen.

14 We tend to recommend species that are less inclined to drop branches in urban areas as we don't find Horse Chestnut to be a particularly reliable tree under the coastal wind exposure conditions such as we have here. Replant with Oak or Maple.

15 Castanea sativa (in historic park setting to replace Aesculus avenue trees) Aesculus flava, turbinata and glabra.

16 Fraxinus excelsior and Ulmus americana Princeton.

17 Native Species.

18 Aesculus indica or native species. Avenue planting is a problem of what species to plant for the long term given other factors.

19 Tilia cordata/europaea in avenues, Juglans regia (similar crown shape to H/chestnut but without stature).

20 I am concerned with trees in the highway environment; replacement with h-chestnut is not a satisfactory solution in terms of tree reliability and or long-term safety.

21 Lime and oak.

22 Mixed.

23 The scheme (private landowner) in which I was involved in chose to replant Scarlet Oak.

24 Pterocarya fraxinifolia.

Appendix 9 continued: Respondents' comments for question thirteen.

25 Sweet Chestnut.

26 Platanus orientalis minaret and Ginkgo Biloba.

27 Maples.

28 I would usually give applicants the information and choice of replacement species.

29 Have not changed tree planting policies. Will not change until conclusive evidence as to long-term effect of leaf miner.

30 Every council is only planting Pyrus chanticleer, no matter what they are felling. They are too scared to plant big trees.

31 Aesculus indica appears not to be affected and is used for all replacements.

32 It depends on the location. Alternative Aesculus spp planted is Aesculus flava.

33 English Oak.

34 Aesculus indica or flava or a diff genus altogether.

35 Tilia spp.

36 Yellow buckeye and A. indica

37 Forest-type trees which are key tree species for this area: Oak, Scots pine, Silver birch.

38 Fagus sylvatica and Quercus robur.

Appendix 9 continued: Respondents' comments for question thirteen.

39 Ash and other natives dependant on soil but Carnea is more resistant to leaf miner and Indian HC seems resistant to most of the current pathogens.

40 Sweet chestnut.

41 As I am sure you are aware after reading the forestry commissions articles on Pseudomonas syringae PV Aesculi No alternative Chestnut species shows any signs of resistance. In fact Aesculus x carnea and the sterile form of Chestnut that produces no Cankers 'Baumanii' are highly susceptible.

42 Aesculus x carnea.

43 (Hang on... AFAIA Leaf miner of Horse Chestnut and BC of Horse chestnut affect, err, Horse Chestnut. (OK, and other Aesculus). So ALL other genera have known resistance, no??)

44 Hornbeam, London Plane and Turkish Hazel.

45 Depends on location and customer preference.

46 A. indica.

47 Sorbus aria and Castanea sativa.

48 Platanus x hispanica.

49 This question is ambiguous. Known resistance to what, bleeding canker? There are no trees with resistance to Phytophthora that I'm aware of.

50 Castanea sativa.

Appendix 9 continued: Respondents' comments for question thirteen.

51 Planting native species in rural areas and natives and ornamentals in urban areas.

52 Not been asked to as yet.

53 We've used walnut & lime but the selection of these was primarily lead by the client's choice & desires.

54 Not my area but conversation with London Tree Officers and those in Reading and Wokingham indicates replanting with alternative species, especially sweet chestnut (Castanea sativa).

55 If space allows either horse chestnut, red horse chestnut or English oak. If not then smaller species like birch and hawthorn.

56 Lime, Oak, Field Maple and Hornbeam.

57 Tilia and Quercus spp.

Appendix 10: Respondents' comments for question fourteen.

1 Historically (in the past million years) the horse chestnut has probably grown here, why should it not do so again

2 They are a successful species in our environment, and have become enmeshed in our culture.

3 Part of English heritage-conker games! Large impressive trees

4 How?

Appendix 10 continued: Respondents' comments for question fourteen.

5 Although a non-native species it is firmly held as an important and well-loved tree amongst people in the UK. It would be sadly missed if allowed to die out.

6 Safeguarded is a strong word but certainly reasonably practicable steps should be taken. Regardless of technical and scientific opinion most people recognise and associate Horse Chestnuts (conkers) with their childhood. They are too established in the landscape for the arboricultural industry et al to 'turn' against them.

7 The tree has been in the UK for 500 years so I don't regard it as non-native - the ecology of the environment will have adapted considerably to the tree during this time. Also, the tree is culturally important.

8 Major part of existing landscape and have heard that Phytophora is becoming more commonly identified further south.

9 Would be a shame to loose the species from the country whether it's native or not.

10 Landscape and historic qualities.

11 If possible - but also maybe just nature that they die and another Aesculus spp. will become dominant

12 These trees provide significant visual, amenity and historic value to our urban and rural countryside alike, and have become to be associated as one of the great British landscape trees, and must therefore be safeguarded. We cannot allow another Dutch Elm episode to further disfigure our historic landscape.

13 For a species as prolific in our countryside, and even vital a certain childhood game, without a doubt.

Appendix 10 continued: Respondents' comments for question fourteen.

14 Well yes and no. As an ecologist I prefer to promote only native species. However some non-native trees have become an ingrained part of our countryside aesthetic and culture (conkers). Horse chestnut is one of these species that merits saving.

15 Although a prominent feature in the landscape I believe it is more important to ensure continuation of native species such as oak, which are also showing symptoms of decline. The ease of propagation and relative speed of growth for horse chestnut will ensure its survival even through continual infestation of recent disorders. The fact that they can be produced readily from seed also guarantees genetic variation, which in itself provides a degree of protection. This is clearly illustrated with the elm. As this predominantly reproduced vegetatively the species suffered from DED due to the majority of trees being colonial. Genetic diversity is essential for natural defenses against pest and disease.

16 Focusing on amenity trees - with climate change and change in species ranges what is/isn't native becomes blurred. We have to plant what is robust and likely to cope with change. So native isn't necessarily an important distinction, especially in towns or designed landscapes, which are inherently man made. More important is the place in the landscape of these trees and the public's interaction with them.

17 Regardless of being non-native the safeguarding of the species / genus is important etc.

18 Well used and naturalised species too frequent to allow to disappear from our landscape.

19 Horse chestnuts are an important amenity tree in urban / estate plantings and much loved by the public.

Appendix 10 continued: Respondents' comments for question fourteen.

20 Kids love them and they provide a spectacular flower display and are fast growing providing quick impact. Also they are attracting a varied insect and microbe population, which may be seen as having some benefit to our biodiversity.

21 We have a great tradition of plant collecting in this country that should not be discounted. Whilst I believe the Horse Chestnut gets planted in a lot of inappropriate locations, I consider it an important part of our landscape heritage.

22 Non-native trees make an important contribution diversifying amenity tree planting.

23 Iconic and naturalized.

24 As an Arboricultural Officer dealing with protected trees I am only prepared to allow felling and replacement when a tree is virtually standing dead. An infestation by "leaf miner" would not be an acceptable reason to fell a tree - it is an aesthetic problem to which a control method may be found.

25 They have become a traditional tree.

26 Important component of historic parkland and should be conserved where of landscape significance.

27 Strict definition of 'native' or 'non-native' is too narrow for the purpose of setting conservation targets. Horse Chestnut is 'native' in the public mind, which is what counts, and among the tree species is one of the most referenced in our culture.

28 Although 'non-native' it is a significant tree in our landscape.

Appendix 10 continued: Respondents' comments for question fourteen.

29 WHATEVER SPECIES IT IS, IF THE AMENITY VALUE IS HIGH THEN THE TREE SHOULD BE SAFEGUARDED AS MUCH AS REASONABLY POSSIBLE.

30 Stupid not to.

31 They still attribute to the amenity of the area in which they grow.

32 Native or non-native is irrelevant, the majority of the public like a good-looking big tree and love conkers.

33 Not really sure what you mean by "safeguarded".

34 Although they are non-native, they are still very much part of our green heritage and hold high amenity value.

35 HC is a beautiful tree and with the history of conkering it would be a great loss to lose this species from the UK. All trees have a right place regardless of them being non-native. Moreover, HC is naturalised in the UK.

36 Along with a number of species, HC could arguably be described as native by now.

37 If we can, imagine having to fell them all. Any decent tree cover is better than none.

38 While non-native, is has been naturalised in this country for some time and should be safeguarded for cultural reasons.

39 It is a weak species and should be marginalised to parks where optimum conditions can be maintained.

Appendix 10 continued: Respondents' comments for question fourteen.

40 This tree has a significant history in UK and Ireland and is one of the most significant trees from children's perspective (conkers). Effort should be made to retain these trees where possible.

41 Britain's urban trees are diverse and all are worthy of safeguarding, whether native or not. The amenity they provide is what needs protecting/safeguarding.

42 There are many significant avenues, open spaces and parklands where Horse chestnut is a key species to the setting of these areas.

43 Although not a native, it is one of the most widely known trees in the UK by the public.

44 Safeguarded in what way?

45 As a significant amenity tree it should be protected where it is practical to do this.

46 Horse Chestnuts in some areas form a major part of both the rural and urban treescape.

47 It is a naturalised tree that supports a great variety of species and has a part of our history and culture.

48 Because some of the public wish for this.

49 All adds to our biodiversity.

Appendix 10 continued: Respondents' comments for question fourteen.

50 The Horse Chestnut is such an attractive tree in the landscape when in flower. It is of interest to children, with some arboriculturists gaining their first experience of tree climbing and the natural world from looking for "conkers". It would be a real shame if the Horse chestnut were to disappear from the British landscape.

51 Horse chestnuts have an established place within the landscape and are attractive trees. They also provide the fruit for the well-known game conkers.

52 Yes. It is naturalised, generally well thought of by the public and we have too few trees to let them go.

53 This tree has made its self-part of the nations heritage.

54 It all depends on what you mean by 'native' (Sycamore? Scots Pine outside Scotland? Domestic Apple?) and what you mean by 'Safeguarded'. Sensible precautions, yes, major expense No. There are, after all more important issues. (Count the square miles of rain forest destroyed since I started filling this in).

55 Safeguarded means little, attempts should be made to resolve the problem but the level of resource allocation is probably the issue.

56 Depends on the tree, its historical, cultural and aesthetic attributes and situation. Each tree must be assessed on its merits.

57 Why allocate disproportionate funds trying to fight nature, only likely to slow the decline rather than eradicate it, Local authorities do not have sufficient budgets as it is for Arboriculture, funds should be concentrated on planting alternative species.

Appendix 10 continued: Respondents' comments for question fourteen.

58 They are beautiful trees and should be safeguarded if possible.

59 Important amenity species. And think of the conker championships...

60 An attractive ornamental but of very limited ecological value.

61 It is always difficult to justify the huge cost of trying to preserve one species but the Horse Chestnut is certainly held with high affection by most British people even if they only associate it with Conkers!!!

62 Would be a shame to lose chestnuts like we lost Elm. Chestnuts are a familiar and long standing part of our landscape.

63 Has been naturalised for centuries, is part of the landscape and national culture, especially for children. Also one of the few trees most lay people can recognise.

64 Indigenous tree since Roman times, stately tree deserves preserving.

65 Not native.

66 Although this depends on the contribution of the species to the environment, landscape, biodiversity etc. Horse Chestnut clearly significantly affects designed landscapes and it's loss/diminished contribution will have a significant negative effect but also has, in my opinion, significant social value, being amongst the 'lay-persons' most important/recognisable trees and if it were lost, I fear that it would only serve to further distance particularly younger generations but society as a whole from the natural environment.

67 It's a well established part of the landscape. There is nothing wrong with non-native species in the correct context.

Appendix 10 continued: Respondents' comments for question fourteen.

68 Good question. Horse chestnut has been with us for 400 years. It would a shame to lose it.

69 Non-native but firmly ingrained in the British countryside and the nation's psyche.

70 Not as a matter of course but you do sometimes get some nice specimens, which should be protected.

71 Reasonable measures.

72 All worth a try, seems like no one is active in trying so far but with D.E.D. history?

Appendix 11: Respondents' comments for question fifteen.

1 I think that in you dissertation, you may wish to discuss how you could have better posed the questions. Critical analysis is an important part of HE work and I as a questionnaire completer was left feeling unsure - on occasion - as to exactly what you were asking or weather I could give an accurate answer. Good luck with it.

2 No

3 We have been asked to consult on the presence of BBC 3 times, which we identified only once. The other times the bark was stained caused by water weeping from a pocket further up. Media attention to southern cases may be scare mongering owners who value their mature tree.

Appendix 11 continued: Respondents' comments for question fifteen.

4 In my opinion many trees with HCBC are being felled too early into the disease, and could be monitored for a while until in a condition requiring removal.

5 In my experience leaf minor is evident in nearly all Aesculus - with secondary infections appearing in only the weakest specimens - feel they are all vulnerable to extinction unless Leaf minor can be controlled.

6 I have pondered whether the current cold winter will do anything to moth populations, and if so the effect this would have on leaf infestations from minors?

7 Many people are reacting way too early to manage P. syringae infestation of trees. Some trees have shown a natural resistance and this may play a part in selective recovery of the fitter specimens. Selective reproduction will do the rest. Otherwise invest more £'s in research and do nothing until we have a more effective answer with the results of the research taken on board.

8 Sorry, not much help, I have seen a lot of leaf minor, but due to current advice, that it will not harm the tree in the long term, it is difficult to propose a sensible management plan.

9 The severe cold this winter may have knocked out the leaf miner problems until 2011.

10 I really don't see the leaf miner as so much of a problem, the early season leaves are unaffected and the trees maintain vigour. It will be interesting to see if this problem does escalate over the next few years or if nature finds a way of regulating herself as she often does.

Appendix 11 continued: Respondents' comments for question fifteen.

11 If you would like to contact me I may be able to help. I was a mature student at Writtle in 93-96; so always glad to assist, as I have not forgotten the help I received on major projects etc. by local authority officers and owners of HONS nurseries.

12 As a contractor, I rarely encounter clients who are prepared to spend money or enquire about managing the health of a Horse Chestnut. They want to know either if it is dying or not, if it is structurally safe or not. In most instances, trees in London left to their own devices seem to be pulling through. Those that don't usually have an additional factor to contend with, e.g. water table alteration, compaction. Requests for crown reductions are common, I am unsure whether the resultant defoliation and leaf removal helps, or whether the works simply add stress to the tree.

13 I am very worried about limbs falling from large trees that otherwise don't look too badly infected. I've talked to other arboriculturalists about this and they aren't noticing it. Maybe we've been unlucky but...

14 We have chosen to let the trees fight the infection, with a monitoring program, and will only remove dead and dangerous trees in high target areas.

15 We've monitored our Hc over the years and seen that mild symptoms of Bleeding canker can vanish.

16 Clearer guidelines on management and recommended replanting should be provided to local authorities.

Appendix 11 continued: Respondents' comments for question fifteen.

17 I have been testing H/chestnut for Phytophthora as this disease is evident in various species on my patch (oak, lime, Norway maple, beech) in the case of H/chestnut the tests proved negative in most cases thus implicating pseudomonas. Infection with Pseudomonas ,Guignardia, Cameraria, leave the tree in a stressed weakened state opening them up to secondary infection. Felling is always the final option when a tree is stone dead or has a secondary infection such as Armillaria taking the trees position into consideration (roadside).

18 I only deal with TPO's and planning applications, I do not deal with Council tree stock. I will forward the email to the other AO's in BwDBC.

19 We have been trying to leave the chestnuts alone in private gardens, to see what will happen. Better to fell them when they die, and pruning may not be helping the energy store of the trees. Haven't seen much secondary flushing recently, like there was a couple of years back!

20 We should expect greater incidence with hotter summers, although the current freeze should help control re-emergence of leaf miner this year.

21 Emphasises the need to maintain a rich variety of species.

22 A very useful research project you are undertaking as the information currently available is limited. I do hope that you get a good response to your questionnaire as the resulting information could prove to be very useful in both the short and long-term management of Horse chestnut trees.

23 Some of the questions I had to fill in were not relevant but had to proceed to the next question!

Appendix 11 continued: Respondents' comments for question fifteen.

24 Education is the key; species selection, appropriateness and location selection, as well avoidance of heavy management where unnecessary etc.

25 Budget is always an issue in tree Management. Also we looked at using Admire but other factors then kick in as in effects to worms, bees etc. I feel we have to stay up with research and training and try to make a difference, I have used decompaction in 2 local parks to mitigate Mature Oaks that have been lost, as I was afraid we would lose more our declining chestnuts are in the main street trees with little scope, maybe we need a national forum. J Barrell is lobbying the FC so it would be ideal.

26 Cameraria ohridella generally looks bad and raises concern with tree owners and the general public, however the horse chestnuts across the district all recover with a green flush of leaves each year before the leaf minor gets going again. I am yet to see a horse chestnut, which has died through the effects of the leaf minor alone.

27 There is an Indian Horse Chestnut (Aesculus indica) planted within a local horse chestnut rich area, which seems entirely unaffected.

28 The answer to every question in every questionnaire ever written should rightly be 'It depends'. Tick boxes don't allow for shades of grey. A few points - I live in the Marches, between Wales & England - Postally we're in the W Midlands but I work as much (more??) in Wales. Also in the SW and the S (and anywhere else if someone pays!) Q 4 & 6 - Define 'infest' and 'infect' - do you mean a couple of leaf mines / a single patch of staining in a tree? Or wholesale early leaf browning / large bark lesions with entire branches or whole trees dying?? But more power for setting this up! Good Luck!

Appendix 11 continued: Respondents' comments for question fifteen.

29 'Bleeding' has been seen in chestnuts for many years and not fully elucidated. I think this is still very much the issue. It is not being accurately identified and implications of it are still not fully discussed.

30 One of our main concerns is the secondary infection of bacterial canker lesions causing structural failure of principle limbs. We have had a few occasions of this, and this area needs to be monitored closely for health and safety reasons. Good luck with your research.

31 I recommend not planting A. hippocastanum (and other susceptible). Bleeding canker has been a severe problem in this area for at least 10 years but appears to be possibly a bit less active at present, and some trees do seem to get over it. Will the recent severe cold make a difference to Leaf Miner this year? Possible not!

32 We have little problems with Guignardia in our area and have certainly not found it has added to the decline of many trees. We have found that some trees seem to be able to cope with the Bleeding Cankers but others decline very rapidly especially in dry years. We have seen it develop over the last 10 years or so.

33 What about climate change?

34 Personally I think the horse chestnut will go the way of the elm. My own experience is that mature horse chestnut once felled are replaced by other species but more importantly horse chestnut trees (at least in the Reading and Wokingham area) that are under 3 metre are being removed and replaced. Makes sense really. Why leave in a tree that will provide problems for the next 100 years when they are at a stage when removal is quick and cheap. Once we have a small population left say in 20-40 years time then these will probably be protected against further decline.

Appendix 11 continued: Respondents' comments for question fifteen.

35 Good luck with the dissertation!

36 An article on local TV showed a soil injection and decompression to be affective in helping situation.

Appendix 12: Dissertation approval form.

Writtle College
A partner of the University of Essex

UNDERGRADUATE DISSERTATION APPROVAL FORM 2009-10

Please note: The Deadline for receipt of completed forms is Friday 13th November 2009

Note 1:

Full registration on the dissertation module is dependant on this form being signed and dated by an agreed supervisor. One copy of this form should be kept by the supervisor. The original copy should be returned to the student to be placed in the dissertation appendix. **(There is no need to include the other forms such as EC1, EC2, risk assessment, etc, in the dissertation appendix as this form is sufficient).**

Note 2:

A student would normally continue with the research question/working title which was covered in the Research Methods module. If the objectives are radically changed, or a new research question is chosen, a new dissertation proposal must be submitted to the supervisor (on form APC-D1).

Student name: Rupert Ellingham

Research question/Working title: The extent + severity of C. ohridella + P. syringae on Aesculus species, + the success of managment techniques used to mitigate these problems in the UK.

Supervisor: Charlotte Power
Andy Boorman

The following documentation relevant to the above research question/working title, has been seen and verified by me:

Research Proposal	☑	✓ to be entered
Ethics Committee (EC1)	☑	
Resources Approval (from Head of School)	☐	✓ or N/A, to be entered
Ethics Committee – Research involving people (EC2)	☑	
Ethics Committee – Animal welfare (AW1)	☐	
COSHH	☐	
Fieldwork Hazard Assessment	☐	
Risk Assessment	☐	

Student Signature: R Ellingham Date: 10/10/09

Dissertation Supervisor (signed): Date: 10/10/09

Sept 2009 SF014