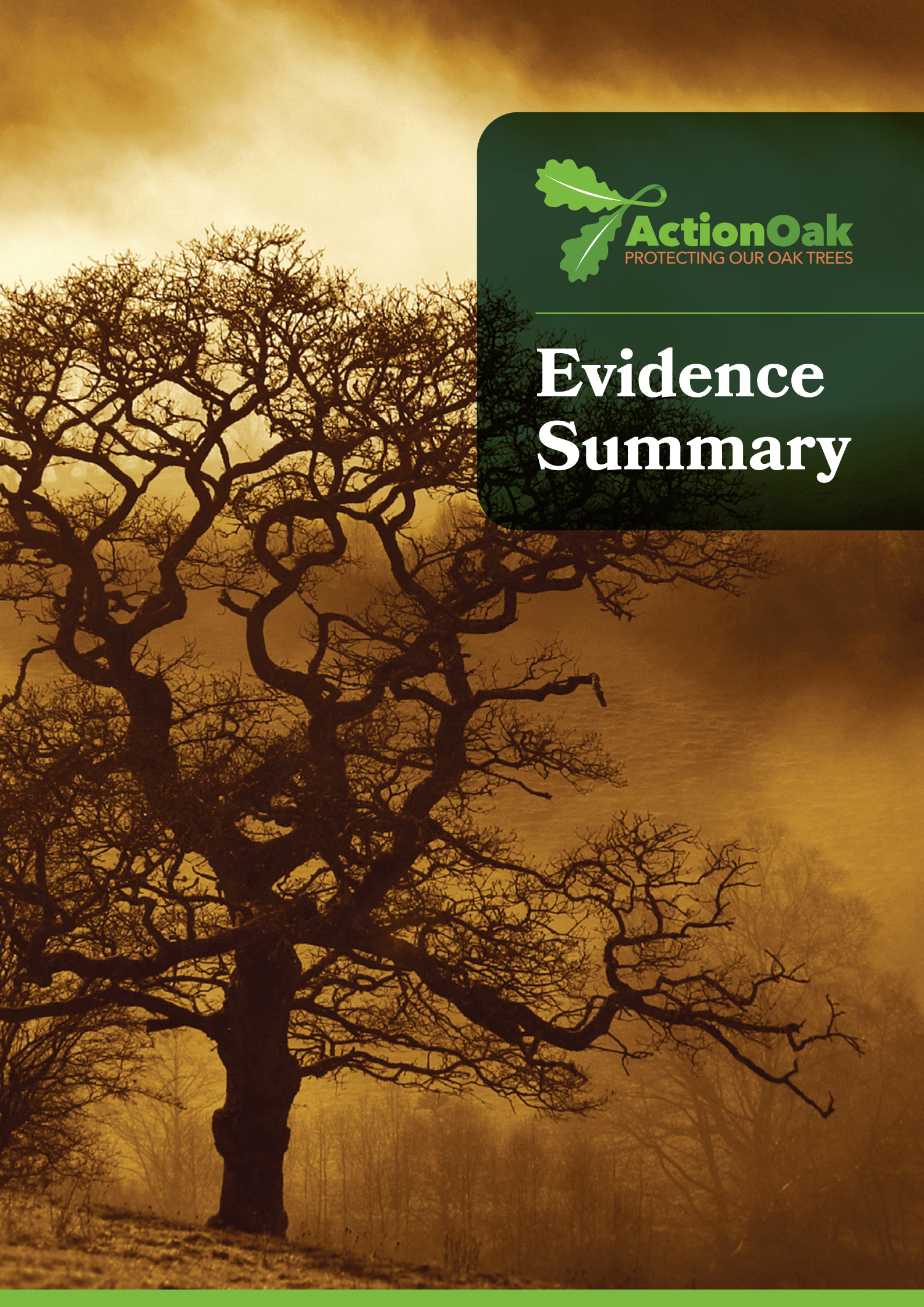

ActionOak
PROTECTING OUR OAK TREES

Evidence Summary

Confidence ratings

Data in this paper has been sourced from different organisations/publications. In order to help the reader understand the data presented a confidence rating has been applied where appropriate.

1. CR High

Based on significant evidence (e.g. recent survey, statistically sound using up to date methods, HMRC data, current industry practices; published in peer reviewed papers; recent qualitative research (interviews, focus groups etc.) with sound methodology that includes results from a number of studies in different locations with different types of people that report similar findings).

2. CR Medium

Based on incomplete or dated evidence (e.g. an estimate based on old survey data, trade association estimates, a survey result which may not be entirely representative of the whole; qualitative research from one or two case studies; published in only one or two peer reviewed papers; published in grey literature).

3. CR Low

Based on speculative or incomplete evidence (e.g. rough estimate from a single expert, or industry body lacking supporting analysis, or early result based on fast developing situation on ground, not published in peer reviewed papers, qualitative research that involves a single case or does not provide details of the sample studied or method used.

Evidence Summary:
Oak

- There are two species of oak native to Britain, *Quercus robur* and *Quercus petraea* [1]. *Q. robur* is distributed more in the south and east of England, while *Q. petraea* is more frequently found in the north and west of England, as well as in Scotland and Wales [2]. (CR Medium)
- 16% of broadleaf woodland in Great Britain is oak. It is the second most common broadleaf tree species in Britain, behind birch [3]. (CR High)
- It is estimated there are 170 million oak trees in woodlands and 2.3 million trees outside of woodlands in the UK (plus seeds and saplings) [4]. (CR Medium)
- England has more ancient native oaks than all other European countries combined [5]. Over 65,000 ancient, veteran and notable oak trees have been recorded in the Ancient Tree Inventory of which 62,000 are 'alive' [6]. (CR Medium)
- The social and environmental value of oak woodlands in Great Britain have been estimated at £320 million per year reflecting recreation, landscape, carbon sequestration, air pollution absorption and elements of biodiversity value [7]. (CR Medium)
- 98% of oak individuals sampled from Britain's native unplanted woodland possessed one of three haplotypes that suggest Iberian origin (maternal lineages from Spain and western France) [8]. (CR Medium)
- 2,300 species are known to use native oak trees. 326 of these are obligate species with 229 being highly associated with oak. For the majority of species (1,626) the data showed they used native British oak trees (*Q. petraea*/*Q. robur*) [9]. (CR High)
- In Europe, oak has over 130 species of associated insect pest [10]. (CR Medium)
- No single tree species could support a high percentage of the oak-associated species (max 28%) and mixtures of tree species are likely to be the only viable option to conserve oak-associated species [9]. (CR Medium)
- Britain represents the north-western extreme of oak distribution and as such, may contain valuable and unique adaptive variants that are worthy of conservation [10]. (CR High)
- Oak has a wide range of functional and decorative uses. It is one of few native timbers which can be used outdoors without preservative treatment, and it is widely grown for the hardwood timber market [11]. Oak wood is valued for its mechanical properties and its durable heartwood [12]. (CR High)

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Evidence Summary:
Oak Processionary Moth

Oak processionary moth (Thaumetopoea processionea)

Pest and distribution

- *Thaumetopoea processionea* (OPM: Oak Processionary Moth) is long established in mainland Europe where it is known to cause defoliation of oaks which can weaken affected trees and leave them vulnerable to other stressors [1]. (CR High)
- *T. processionea* is present in almost all European countries and also in parts of the Middle East, including Israel, Lebanon and Jordan [2,3]. (CR High)
- In 2006 it was officially confirmed that OPM, which is not native to the UK, had been found in West London [1,4,5]. (CR High)
- In the UK, *T. processionea* is established in most of Greater London and in some surrounding counties in South East England [6]. (CR High)
- Bioclimatic models forecast that most of the UK is currently less suitable for the establishment of OPM than the south-eastern part of England. These regions are expected to become highly climatically suitable for OPM establishment by 2050 and 2070 [7]. (CR Medium)

Lifecyle

- *T. processionea* is univoltine with eggs hatching in Spring (April to May). Hatching can depend on the temperatures of the preceding period and can start in March in warm weather [2,6]. (CR High)
- After emergence the caterpillar larvae pass through six instars numbered L1 to L6 and develop the uticating hairs from about L3 [8,9]. (CR High)
- From late June to early August the caterpillars retreat into the nests and moult to the pupal stage. They emerge as adult moths from about the middle of July with the latest moths emerging in late September [8]. (CR High)
- Synchrony between oak bud flushing and egg hatching appears crucial for *T. processionea* larval development. If oak budburst occurs more than 2-3 weeks after egg hatching starvation may cause mortality or hamper development of the neonate caterpillars [7,10]. (CR Medium)

Hosts

- *T. processionea* feeds on the different Quercus species that can be found across Europe and the Near East [2]. (CR High)
- *T. processionea* performance can differ between species suggesting some are more suitable hosts. *Q. petraea* was seen to be more attractive to, and more defoliated by OPM larvae than *Q. robur* and larvae performed better (grew faster and lower mortality) on *Q. petraea* compared to *Q. robur* [11,12]. (CR Medium)
- Oaks have been observed to be generally less attacked in mixtures than in pure stands, particularly mixtures associating oaks (OPM hosts) with other non-host broadleaved species [12]. (CR Medium)

- *T. processionea* has been found to have a strong spatially and temporally stable habitat preference or open woodland containing a high proportion of oak trees [13]. (CR Medium)

Dispersal Pathways

- The pathways for OPM dispersal include both natural spread and human-mediated transport [2]. (CR High)
- Males are considered strong flyers and under favourable conditions adult males can fly long distances (up to 100 km per year). Female moths fly shorter distances of between 5-20 km per year [14]. (CR High)
- Conditions can affect natural dispersal with warmer, drier weather favouring adult dispersal and survival [15,16]. (CR High)

Detection and Surveillance

- Adult moths have grey forewings, with white and grey marking, and a wingspan that can be up to approximately 30 mm [2]. (CR High)
- The caterpillar is dull, grey-brown to black with pale underside and dark head. Hairs are extremely long and pale with much shorter, almost undetectable irritating hairs. The caterpillar is around 20-30mm long [6,17]. (CR High)
- The main signs of occurrence of *T. processionea* in oak include: skeletonised remains of leaves, white silken nests at the base of lower branches, on the trunk or at the base of the trunk that turn less bright later in the season and nose-to-tail processions of the caterpillars on the branches of oak trees [2]. (CR High)
- The main methods for detecting and monitoring OPM are to search for larvae and nests on oak trees or to use light or pheromone traps to attract and capture the adult moths [18]. (CR High)
- A wide variety of commercially produced pheromone traps are available for monitoring *T. processionea*. Pheromone traps contain a lure comprising a synthetic chemical cocktail which mimics the sexual pheromone emitted by the female to attract a mate for breeding. The main types used to capture moths are delta traps and funnel traps [18,19]. (CR High)
- Results from a study show that pheromone traps were more effective at detecting *T. processionea* when placed in the upper part of the tree canopy. Funnel traps caught significantly more adult moths than delta traps [20]. (CR Medium)

Management

- In 2010 the infestation of *T. processionea* in Great Britain had reached a size that led to the decision to change from a strategy of eradication to a strategy of containment [1]. (CR High)
- Three distinct geographical zones have been defined for OPM management purposes. The established area where landowners are responsible for the management of OPM on their land, the buffer zone where an annual OPM programme is targeted led by Forestry Commission aiming to reduce pest prevalence and to prevent outward spread and the Pest Free Area (PFA). The PFA is officially designated free from the pest and covers most of the country, in this area government undertakes an extensive programme of surveillance to monitor for OPM.[21]. (CR High)
- At present there are several control methods approved for use in the UK including physical nest removal and three insecticide sprays: The bacterial biopesticide *Bacillus thuringiensis var. kurstaki* is the most targeted with the lowest non-target impacts, whilst the insect growth regulator diflubenzuron, and the synthetic pyrethroid deltamethrin are broader spectrum insecticides. Deltamethrin is highly toxic to bees and aquatic life and care must be taken when using this product near flowering plants, rivers, streams or other water bodies.[22]. (CR Medium)
- *Carcelia iliaca* is a monophagous parasitoid of *T. processionea*. The extent of its distribution in GB is unclear [23]. (CR Medium)

Impacts

- The exact impact of *T. processionea* on tree health remains relatively unknown however repeated defoliation caused by feeding caterpillars in spring increases tree susceptibility to drought and secondary pathogens [2,6]. (CR High)
- Processionary moths carry urticating setae, which cause health problems in humans and other warm-blooded animals [2,6,24]. (CR High)
- Contact with the setae releases toxins (thaumetopoein) that may elicit allergic reactions [9,25]. (CR High)
- Symptoms from contact with the setae include skin rashes, eye irritation and upper respiratory tract infections. More severe symptoms up to anaphylactic reactions have been reported [9,25,26]. (CR High)
- The setae have proven to be stable in the environment and can persist for many years [9,26]. (CR Medium)

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Evidence Summary:
Acute Oak Decline (AOD)

Disease and Distribution

- Acute Oak Decline (AOD) is a decline disease affecting both native oak species (*Q. robur* and *Q. petraea*) in Britain [1]. (CR High)
- AOD is considered a distinctive condition within the broader Oak Decline syndrome [1,2]. (CR - High)
- Decline diseases are not caused by single primary pests or pathogens but are complex syndromes. Amongst the biotic factors at least two species of bacteria (*Brenneria goodwinii* and *Gibbsiella quercinecans*) and at least one insect species (*Agrilus biguttatus*) are involved, with the bacterial species, particularly *B. goodwinii*, having a causal role in the stem lesion formation [3,4,5,6]. (CR High)
- *Rahnella victoriana* plays a secondary or 'contributory' role in development of the lesions and *B. goodwinii* gains greater fitness benefit from in vitro competitive interaction with *R. victoriana* and *G. quercinecans* (C. Brady et al. in press). Other species such as *R. variigena* may also play a role but this is unknown currently. [7 6]. (CR Medium)
- In the UK AOD is currently present in England, particularly across the Midlands and the Welsh borders [4,8,9]. (CR High)
- Similar symptoms and positive swab tests confirm the presence of AOD on a range of native oak species in continental. The distribution of AOD in Europe (based on symptom description, swab tests and photographs) includes: Austria, Belgium, France, Latvia, Netherlands, Poland and Spain [4,10,11,12]. Germany and Italy positives based on symptom description and photographs as far as is known. (CR High)

Hosts and Environment

- Most affected oaks in the UK have been over 50 years old so AOD appears to be associated with trees in their prime but it is also associated with mature and ancient oak trees. Younger affected trees that have/are weakened due to stresses have also been reported [4,8]. (CR High)
- AOD mainly affects the UK's two native oak species but cases of other oak species being affected have been found including: *Q. fabri*, *Q. ilex*, *Q. aliea var. accuserrata*, *Q. palustris*, *Q. pyrenaica*, *Q. rubra*, *Q. coccinea*, *Q. cerris* and *Q. nigra*. [1,4,8]. (CR Medium)
- A study found that at monitored and surveyed sites, trees showing symptoms occurred in localised clusters with neighbouring trees most likely to be next infected. This indicates a localised cause such as a pest or pathogen rather than a wider scale environmental effect [2,13]. (CR Medium)
- In the UK, environmental factors relating to water availability were shown to significantly influence the presence of AOD, with affected sites significantly associated with areas of low rainfall and high dry nitrogen deposition but low dry sulphur deposition [14]. (CR Medium)

Identification and Symptoms

- There are four key descriptors that identify AOD: (1) vertically arranged cracks in the outer bark from which (2) dark fluid seeps, and (3) irregularly-shaped lesions in the inner bark and/or cavities formed by rotted inner bark tissues lying behind the weeping areas outer bark, and (4) the presence of galleries of *Agrilus biguttatus* in the newest phloem and sapwood [1]. (CR High)
- A number of pests and pathogens can cause stem bleeding which makes confirming AOD by visual symptoms alone difficult. Bark samples may be needed for accurate identification [15]. (CR High)
- D-shaped exit holes made by emerging *A. biguttatus* might be present in the bark plates of affected trees [2,4]. (CR High)
- Trees may suffer from canopy dieback, but this may not occur until the tree nears death [4,15]. (CR Medium)

Forest Research, Crown copyright

External symptoms of acute oak decline

Forest Research, Crown copyright

External symptoms of acute oak decline

Tolerance

- There may be some scope for host resistance as lightly infected trees have been shown to form callus over the previous year's stem symptoms and enter remission [2]. (CR Medium)

Management

- General management advice for AOD is to leave infected trees in place and continue to monitor where there is no immediate concern for safety. However, if a limited number of trees on a site are infected and most are of the same oak species it may be prudent to fell and destroy infected individuals [15]. (CR Medium)
- Management strategies that target soil health by increasing the organic carbon around declining trees to increase pH and ammonia-oxidising bacteria (AOB) abundance might also help support declining oak trees [8]. (CR Medium)
- Good silvicultural management and care for underlying tree health may be sufficient to reduce susceptibility induced by predisposing factors such as drought, root decay and defoliation [4]. (CR Medium)
- Many cases of AOD appear to occur on locally acidic soils with low nutrient availability, low organic matter content, high levels of soil compaction, and at some sites, high levels of aluminium that may be toxic to roots and beneficial fungi and microorganisms [16]. A significant difference in the functional composition of ectomycorrhizae in AOD affected trees, which have a greater abundance of long soil exploration type ECM [17] and fewer feeder root tips [18].
- Management for promotion of well buffered, nutritionally balanced, well aerated soils with high organic matter may be a key management objective [16]. (CR Medium)
- Trees in older age classes have less capacity to counteract stresses and resume growth. Often the stands are crowded (overstocked) with large numbers of trees (excessive basal areas) that exacerbates moisture stress during drought periods and amplifies between tree competition. Stands composed of few species, particularly on poorer sites, are more susceptible [19].

Impacts

- A significant impact of AOD is tree mortality. Monitoring indicates that on average 1% of symptomatic trees on a site eventually die [4]. (CR Medium)
- Current data suggests mortality occurs longer than two years after infection [2,13], often within 3-5 years [9] (CR High)
- Mortality occurred in greatest proportions when both bleeding symptoms and exit holes were observed. Exit holes were linked to the late stage of decline. [13]. (CR Medium)
- The economic impact of AOD is expected to be very large over the medium term especially in conjunction with effects of other pests and diseases on oak [4]. (CR Medium)

A. biguttatus

- *Agrilus biguttatus* a European bark-boring beetle whose larvae feed in the vascular tissue of oak trees [20]. (CR High)

Oak bark boring beetle, Agrilus biguttatus

- *A. biguttatus* activity was apparent in almost all cases 90 per cent of trees displaying symptoms for AOD when sampled for bacterial isolations [1]. Destructive sampling to the cambial layer is required for detection and any UK reports of galleries not present may be attributable to non-detection due to incorrect sampling. (CR Medium)
- *A. biguttatus* beetles can fly several kilometres. However, their distribution seems to be restricted by cool temperatures (caused by seasonal temperature fluctuation or elevation). The beetle range might expand with a warming climate [21,22]. (CR Medium)

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Evidence Summary:
Oak Lace Bug

- Oak lace bug (*Corythucha arcuata*) is native to North America but has been in Europe since at least 2000. Initially reported in northern Italy it is now found in at least 11 countries in continental Europe [1, 6]. (CR High)
- Oak lace bug is currently absent from the UK with no recorded interceptions or outbreaks [2]. (CR Medium)
- Oak lace bug primarily feeds on oak trees but has also been found feeding on other broad-leaved tree species including sweet chestnuts, maples, hornbeam, hazels, beeches, whitebeams, limes and elms [3, 6]. (CR Medium)
- Both adults and nymphs feed on the underside of the leaves causing loss of normal colour (chlorosis) to occur on the upper surface of the leaves. The first sign of feeding damage is a stippling of small, yellow spots often concentrating around the leaf veins. Oak lace bug is likely to impact oak ecosystems in many ways, including weakening trees making them more susceptible to other pests and diseases [4,9,10]. (CR High)
- Oak lace bug has been observed to complete two to three generations per year in some locations in Europe, however, in the UK one to two generations are likely to occur. The greater number of generations each year results in an accumulative effect in causing damage to the host trees. [4,5]. (CR Medium)
- Overwintered adults take shelter in bark cracks and crevices and within the leaf litter. They can be found on the underside of leaves from April onwards. Clusters of eggs are present from early May onwards with larvae appearing later [6]. (CR Medium)

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Oak lace bug (Corythucha arcuata)

- Adult bugs are not strong fliers due to their small size but are carried by the wind over medium distances. Other factors will promote their spread including human assistance through movement of infected trees, wood products and hitchhiking on transport. [7,8] (CR High)
- There are no current biological control options that have been tested for large scale use. [2] (CR Medium)

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Evidence Summary:
Oak Longhorn Beetle

- *Neocerambyx raddei* (oak longhorn beetle) (formerly known as *Massicus raddei*) is a beetle of the subfamily *Cerambycinae* [1]. (CR High)
- Oak longhorn beetle damages the trunks of trees, mainly Quercus (*Q. liaotungensis* and *Q. mongolicus*) and chestnuts (*Castanea* spp.) [2,3]. The larvae of *N. raddei* bore into the xylem of host trees, creating galleries that reduce the transportation of water and nutrition, with infested trees displaying crown dieback [3,4]. (CR Medium)
- *N. raddei* was added to the EPPO A1 List in 2018 after suggestion by the NPPO of the United Kingdom [3]. (CR High)
- *N. raddei* is a serious pest of oak trees in China and has been reported in China, Japan, Korea, Russia, Taiwan and Vietnam [3]. *N. raddei* has not yet been reported from other continents [3,5]. (CR High)
- The pest has infested approximately 264,000 ha. of oak forests where population density is typically high, with an average of 26.5 individuals and a maximum of 156 individuals per host tree [4]. (CR Low)
- The pest requires three years to complete a single generation [6,7]. (CR High)
- Based on knowledge from other large, exotic longhorn beetles in the UK, this generation-time is likely to be longer in the UK [8]. (CR Low)
- *N. raddei* is not known as a pest across the whole of its substantial range, the reasons behind this have not yet been explored thoroughly [5]. (CR Low)
- The average pre-oviposition and oviposition periods were 4.6 and 14.8 days respectively, and a female laid on average 20 eggs during their lifespan. Adults lived about 16 days. Adults begin to mate 2-3 days after emergence, and lay eggs 2-3 days after mating [4]. (CR Medium)
- When adults emerge, many exit holes can be seen on the trunk [8]. (CR Medium)
- Establishment of *N. raddei* is likely to occur in the EPPO region and would not be limited by climatic conditions. The host status of European species in not known but *N. raddei* is believed to present a higher risk of host switch [9]. (CR Low)
- Specially designed black lights have been used to attract adult pests. A parasitoid, *Sclerodermus pupariae*, displayed parasitism of young larvae and the parasitoid *Dastarcus helophoroides* displayed parasitism of mature larvae (over 3rd instar) and pupae of the beetle [2]. (CR Medium)
- Surveys for *N. raddei* should use ethanol-baited traps placed in the tree canopy [10]. (CR Medium)

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Evidence Summary:
Oak Wilt

- Oak wilt is a destructive disease of oak trees caused by the fungus *Bretziella fagacearum* (*B. fagacearum*) - synonym *Ceratocystis fagacearum* (*C. fagacearum*), [1]. (CR High)
- Oak wilt is known to exist in many states of the Eastern USA however there are no records of spread to other continents [1,2]. (CR High)
- Over 33 species of oaks, as well as six other close relatives, are known to be susceptible to *B. fagacearum* based on artificial inoculation studies or documented natural infections [3]. (CR Medium)
- Generally, members of the red oak group are highly susceptible compared to members of the white oak section, which displays moderate-to-high levels of resistance [1,2,4]. (CR High)
- The oak wilt fungus is spread from diseased oaks to healthy trees above ground level by insect vectors or below ground level via root grafting [1,3,5]. (CR High)
- Oak wilt is identified in members of the red oak group by the rapid wilting of affected trees. Trees wilt from the top of the crown downwards and individual leaves exhibit bronzing or yellowing from tip or margins to the leaf base. In white oak, leaf symptoms are more variable. Reddish-brown to brown discoloration starts at the leaf margin and apex but is often limited to one side of the mid-rib [2,5]. (CR Medium)
- Vascular staining in the xylem of branches and main stem of moribund oaks is a less reliable symptom compared to the foliage. Diffuse bluish-grey to dark-brown discoloration in the outer sapwood occurs in red oaks. More pronounced dark brown to blackish streaks in the outer xylem are found when bark is removed from branches and stems of at least some white oak species. [2].
- Once infected, red oak species may die within 4 to 6 weeks or early in the subsequent growing season. White oaks die more slowly (2-4 years) while some highly resistant species may die over many years or recover [2,3]. (CR Medium)

Oak wilt (Bretziella fagacearum)

- In recently wilted trees, *B. fagacearum* produces fungal mats under the bark which produce infective spores. Pressure cushions around the fungal mats can cause separation of the bark from the wood, often rupturing the bark. Mats are rarely to never formed on species in the white oak group. [3,4,5]. (CR High)
- Oak wilt management includes different mechanical methods to sever roots, sanitation, and chemical application. Root disruption involves installing a trench or plow line that separates roots of healthy and infected trees. Removal of red oaks prior to sporulating mat formation (sanitation), avoidance of harvesting or pruning oaks during high-risk season and preventing movement of oak firewood are primary methods used to prevent insect transmission. Chemical application can be either preventative or therapeutic and efficacy will be specific to different oaks [6]. (CR Medium)

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Our vision

A UK where our native Oak trees are protected and flourish, both now and in the future.

Our mission

Our mission is to lead the vital work and research to protect our native Oak trees and safeguard their future.

Our values

- Protect our native Oaks for future generations.
- Be collaborative, innovative and committed in our research.
- Share findings with practitioners to grow healthier, stronger trees.
- Raise public awareness and appreciation of our native Oaks and the important role they play in our landscapes as a habitat for wildlife.

About Action Oak

Without doubt, Oaks are the UK's most iconic trees. They are a fundamental part of our landscape and cultural heritage and remain crucial to this day, supporting both biodiversity and livelihoods.

But our Oak trees are under considerable – and growing – threat from pests, diseases, human intervention and the increasing climate emergency.

Action Oak is committed to protecting these incredible trees.

Action Oak is a national intiative made up of charities, government and private landowners who have come together to protect our Oaks for future generations.

Through carrying out vital research and monitoring, we can better understand the threats and devise real solutions, so that we can safeguard the survival of our Oaks for generations to come.

Our Oaks need you

Our mission is to lead the vital work and research to protect our native Oak trees and safeguard their future.

Our mission

Our Oak trees need urgent help to protect them for the future. You can support us by:

- Donating to Action Oak
- Helping us to monitor the health of our Oak trees
- Becoming an Ambassador for Action Oak and spreading the word about our work

Learn more about the threats to our Oaks and the work of Action Oak at: www.actionoak.org

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PROTECTING OUR OAK TREES