Forestry Commission

Pest specific plant health response plan: Two-Lined Chestnut Borer (*Agrilus bilineatus*)

April 2021

Contents

1. Introduction

The purpose of pest-specific contingency plans is to ensure rapid and effective responses to outbreaks of the pests or diseases described: in this case the two-lined chestnut borer (*bilineatus*).

Scope

This contingency plan was prepared by the Forestry Commission's Plant Health Forestry Service and Forest Research in 2020.

It should be used in England in conjunction with Defra's Generic Contingency Plan for Plant and Bee Health in England (Defra 2017), which provides details of the teams and organisations involved in pest response in England, and their responsibilities and governance.

The generic contingency plan also describes how these teams and organisations will work together in the event of an outbreak of a plant health pest. The Scottish and Welsh Governments are additionally developing their own generic contingency plans for Plant Health.

Forestry Commission's Forest Services will use OGB17b 'Managing Incidents in the Forestry Commission' for relevant incidents. Scottish Forestry and the Welsh Government will develop similar documents detailing their management of outbreaks. When an outbreak becomes of UK or Great Britain (GB) wide concern, the UK Chief Plant Health Officer will form a Lead Government Department (strategic group) to co-ordinate the activities in the different countries.

This contingency plan falls into three main parts:

- official action following a presumptive diagnosis
- official action following the confirmation of an outbreak
- background information about the pest

This contingency plan covers outbreaks of *Agrilus bilineatus* in all situations where its host species are planted or occur naturally, i.e., forestry, natural and semi-natural habitats, agricultural landscapes, urban environments, and parks and gardens. It also covers situations where *A. bilineatus* is confirmed in wood or wood packaging material, dunnage, or on live plants for planting. It is designed to help government agencies anticipate, assess, prepare, respond and recover from outbreaks of the pest.

This plan will be updated following new information, lessons identified from outbreaks of this pest or response exercises other pests, or changes in policy or contact details.

Objectives of this plan

- To raise awareness in the event of an outbreak of the potential threats posed by *A. bilineatus*, and therefore, ensuring that stakeholders are aware of how to identify the pest and the symptoms caused by infestation by this pest.
- To provide guidance on steps to be taken should an outbreak occur in the UK.
- To ensure that infestations of *A. bilineatus* are managed promptly with the aim of eradicating pioneer populations or, if a population is found to be established, slowing the rate of spread and lessening its impact.
- To ensure that all relevant staff of the Forestry Commission, other Government agencies and Local Authorities are conversant with the contents of this contingency plan so that effective and immediate action is implemented.
- To ensure that good communications are put in place so that all stakeholders (including relevant media) are kept fully informed of the scale of infestation both at regional and national levels.

2. Anticipation and Assessment

2.1. *Agrilus bilineatus* (Weber, 1801) (Coleoptera: Buprestidae), commonly known as the two-lined chestnut borer, is a highly destructive North American pest of oak (*Quercus* spp.) and chestnut (*Castanea dentata*) and is commonly associated with oak mortality in the USA, making it among the most notable North American pests in the genus *Agrilus* (Muzika et al., 2000). This paper also suggests that *A. bilineatus* is a secondary species which follows in the wake of gypsy moth outbreaks and mass defoliation events.

2.2. *Agrilus bilineatus* is native to North America. It is present in Eastern and Central USA and Canada. It has been recorded from as far north as Manitoba, New Brunswick, Ontario, and Quebec in Canada to Southern states of the USA including Florida, Alabama, Louisiana, and Texas. Since 2002 there have been four reports of *A. bilineatus* in Turkey and it is believed to be established, although significant damage has not been recorded. These records are in the area close to Istanbul, not far from the border with Bulgaria.

2.3. The European Plant Protection Organisation's Pest Risk Analysis (EPPO PRA) concludes that the climate within the EPPO region is not likely to be a limiting factor for establishment and it is likely to be able to establish as a secondary pest in the EPPO region where hosts are present.

2.4. Larvae construct galleries in the phloem and outermost xylem tissues which can eventually girdle the tree leading to crown dieback and tree death. *A. bilineatus* has been reported to infest and sometimes kill healthy trees, but generally it appears to be a secondary pest preferring to infest trees already weakened by other stress events (Muzika et al., 2000). In North America, widespread outbreaks have frequently followed periods of severe drought, defoliation, ice storms and late spring frosts. Sweet chestnut affected by diseases such as *Cryphonectria parasitica* may also be more susceptible. Historically high levels of tree mortality have been attributed to *A. bilineatus* and it has been noted as being one of the principal factors contributing to the mortality of weakened oaks in Eastern North America.

2.5. *Agrilus bilineatus* is officially absent from the UK and EU.

2.6. Most *Agrilus* species, can be transported in live plants as well as wood products such as logs, firewood, solid wood packaging, lumber, bark, and wood chips (Meurisse et al., 2018). For live plants, such as nursery stock, there are not always external signs of infestations during the first year of infestation (e.g., no exit holes). For wood products, *Agrilus* individuals would be most likely to complete development in items with some bark (e.g., logs and dunnage), given that *Agrilus* larvae feed in the cambial region and immature larvae need bark to complete their development. Also, bark would be required for those individuals that pupate in the outer bark. However, it is possible for some individuals that would have constructed pupal cells in the outer sapwood, that bark is not required.

3. Preparation

3.1. *Agrilus bilineatus* is listed as a provisional quarantine pest in Annex 2A of The Plant Health (Phytosanitary Conditions) (Amendment) (EU Exit) Regulations 2020/1527. There is a Defra proposal for it to be regulated during early 2021 on all hosts and pathways into the UK. *Agrilus bilineatus* is not known to occur in the UK, and therefore it is proposed to regulate the pest as a “plant pest not known to occur in any part of the United Kingdom”. By including *A. bilineatus* on this list, it will be regulated on all hosts and pathways. See Appendix 2 for specific requirements.

3.2. *A. bilineatus* was added to the EPPO Alert list in 2018 and moved to the EPPO A2 list in 2019.

3.3. All oak and chestnut species are considered as being potential hosts for *A. bilineatus* in the EPPO region. Although mainly a secondary pest in North America, there is concern that *A. bilineatus* could have a much greater impact in the EPPO region if there are differences in the susceptibility of native European *Quercus* species and *C. sativa* compared to North American host species.

3.4. In its native range, *A. bilineatus* attacks *Castanea dentata* and a wide range of *Quercus* species including *Q. robur* (pedunculate oak, a native species in the UK) and *Q. rubra* (red oak, a common ornamental in the UK). It is therefore a potential threat to all *Quercus* species in the UK and to *Castanea sativa* (sweet chestnut).

3.5. Due to the potential risk that *A. bilineatus* poses to oak and sweet chestnut in the UK, it has a very high unmitigated risk rating in the UK Plant Health Risk Register of 100/125 and an identical mitigated rating of 100/125. This is because the risk register has not taken account of the proposed UK legislation, which when introduced in January 2021 will reduce the risk of the pest arriving in the UK and hence lower the mitigated risk rating.

Legislation

3.7. A list of all the current relevant legislation which might be pertinent in an *A. bilineatus* outbreak is given in Appendix 4.

4. Qualifying statement

4.1. Agrilus bilineatus was added to the EPPO Annex 2 list of pests and diseases that require regulation, and where possible are to be eradicated, because of its potential impact on native European oaks and sweet chestnut. The risk posed by *A. bilineatus* to oak trees and sweet chestnut in Europe is based, however, on observations at only three locations in the USA, where apparently heathy *Quercus robur* were attacked and killed (Haack, 1986; Petrice & Haack, 2014). The concern clearly is that *Q. robur*, and by inference other European oak species and sweet chestnut, might be inherently more susceptible to attack by *A. bilineatus*, and therefore more likely to be killed, compared with North American oak species, in a similar way that North American species of ash are more susceptible to emerald ash borer (EAB, *Agrilus planipennis*) compared with Asian ash species, and European birch is extremely susceptible to bronze birch borer (*Agrilus anxius*). On this basis, and from a precautionary perspective, EPPO concluded that *A. bilineatus* was a serious threat and should be regulated (EPPO, 2019).

4.2. It is important to note, however, that *Q. robur* is present and alive at many sites in North America where *A. bilineatus* is also present, without any apparent detrimental effects (EPPO, 2019). In Turkey, the only country in Europe where *A. bilineatus* has been recorded, four isolated adult beetles were found between 2002 and 2018, but there is no indication that oak trees or sweet chestnut in the area are suffering additional ill health. Therefore, the impact of *A. bilineatus* on European oaks and sweet chestnut may not be as great as initially feared.

4.3. From a precautionary perspective, however, and until more data become available, it makes sense to prepare a contingency plan to deal with an outbreak of *A. bilineatus*, assuming the worst-case scenario. The plan can then be adjusted as new information becomes available, and the Incidence Management Team may decide to alter the approach to outbreak management on the basis of any new information, including that gained during initial surveys. Unfortunately, though, compared with EAB and other better-known *Agrilus* pest species, there is less information available relating specifically to *A. bilineatus*, especially on dispersal and rates of spread, and patterns of infestation in attacked trees. On the other hand, *A. bilineatus* is very closely related to EAB and the two species share many aspects of their biology and behaviour. Consequently, the contingency plan for *A. bilineatus* follows very closely the contingency plan that has been written for EAB. There are differences between the two pest species and where these are likely to influence surveillance and monitoring, for example, and the approach to management (eradication or slowing spread), then these issues are highlighted in the relevant sections.

4.4. One important difference between *A. bilineatus* and EAB is that whilst EAB is the only *Agrilus* species that might be found in ash trees in the UK, there are several native and established species of *Agrilus* that are commonly found in oak and potentially sweet chestnut. This makes verifying attack by *A. bilineatus* much more difficult, with consequences for confirming an outbreak and for surveillance and monitoring. The presence of D-shaped exit holes and sinuous larval galleries under the bark (typical of *Agrilus* species in general) are not sufficient in the case of *A. bilineatus* to indicate infestation solely by this species and confirming the presence of the pest requires either the capture of an adult beetle and its verification by specialist entomologists, or molecular identification of the immature stages of the pest (larvae and pupae). Many of the assumptions in the EAB contingency plan were based on the ease of identification, allowing surveys to be carried out rapidly and for demarcated areas to be set up quite quickly. However, surveys will be less straightforward and will take longer for *A. bilineatus* (e.g., there is likely to be a two-week minimum lag between finding a larva and identifying it through molecular barcoding).

5. Response

Trigger

5.1. The key indicators that would trigger a response are findings or reports of:

- a live or dead adult beetle found in the wider environment (e.g., discovered by an amateur entomologist) and confirmed to be *A. bilineatus*; or

- the discovery of *A. bilineatus* life-stages in oak, sweet chestnut or a related hard-wood tree species in the outdoor environment in the UK; or
- a live or dead insect found in a consignment of wood or wood packaging material, dunnage, or live plants, which was confirmed to be *A. bilineatus*.

The initial report could come from amateur entomologists, nursery owners, arboriculturists, woodland owners or managers, professional survey staff (FC, APHA, etc), members of the public or government officials.

Official action following a presumptive diagnosis

Strategic actions on suspicion

5.2. In England, a duty officer from FC England or the Animal & Plant Health Agency (APHA) will act as a point of contact for incidents, and it is their job to assign a response officer to incidents when they occur. Similar arrangements are expected to be in place for Scotland and Wales. The response officer investigates and reports back to the Defra Core Contingency Group, which is an 'ad hoc' group put together in response to a notification, and which is usually chaired by the Chief Plant Health Officer. Scotland will fully manage the outbreak in accordance with their own generic contingency plan but will provide updates to the Defra Core Contingency Group for information purposes.

5.3. The response officer will gather information including the: location, likely origin, host or commodity, level of damage, extent of outbreak and chance of spread. The Core Contingency Group will comprise plant health officials and specialists from the Defra's Plant Health Risk Group (PHRG).

5.4. Based on the information fed back to the Core Contingency Group in England, they will decide upon the alert status given (black, amber or red), which will determine the level of response as described in the Generic Contingency Plan for Plant and Bee Health in England (Defra 2017). In England, the Core Contingency Group can advise on alert status and the appropriate response. The Core Contingency Group will nominate the control authority (e.g., Forestry Commission), and the control authority will then appoint an Incident Commander who will set up an Incident Management Team.

Tactical actions on suspicion

Holding consignments and movement / planting restrictions

5.5. Until further investigation, and under a containment notice, no host or other suspect material shall leave the potentially infested site. Local operations associated with tree management will be halted until the suspected case is investigated. The extent of the site under containment will be determined by the Incident Management Team.

Preliminary trace forward / trace backward

5.6. If the finding can be linked to any traded plants or wood, tracing forwards and backwards to identify suspect material will be conducted and, if the pathway is known, to identify other potentially contaminated stock or sites. This will include suppliers of plants, wood and wood products, propagators, and wholesalers.

Confirming a new outbreak

How to survey to determine whether there is an outbreak

5.7. An outbreak of *A. bilineatus* might be detected as a result of surveys carried out following an interception of live or dead life stages in wood or wood packaging material, dunnage or an imported plant, but more likely, an outbreak would be detected through general surveillance or following the capture of an adult beetle, or a report from the public of wilted foliage on scattered crown branches of host trees in late summer (Haack & Acciavatti, 1992). The wilted foliage turns brown and remains attached for several weeks or even months. Such branches will not produce new foliage in subsequent years (Haack & Petrice 2019). In the UK however such damage is also associated with drought stress and so careful investigation is needed to rule out more likely causes of decline than *A. bilineatus*.

5.8. Confirmation that *A. bilineatus* is present will require expert examination of samples and follow-up inspections. The presence of D-shaped exit holes approximately 5 mm wide and larval galleries under the bark are two key indicators of the possible presence of *A. bilineatus.* However, other *Agrilus* species are present in the EPPO region with similar body sizes and hosts, and D-shaped exit holes on *Quercus* and *Castanea* are not characteristic of only *A. bilineatus*. Therefore, adult specimens or molecular diagnosis of immature stages are the only reliable ways to identify the pest.

5.9. If there is evidence of the presence of *A. bilineatus*, then follow-up inspections in line with ISPM 6 (guidelines for surveillance) should gather information about:

- likely origin of the pest and, if a consignment of plants or plant products including wood and wood products is suspected to be the origin of the outbreak, details such as other destinations that the plants or plant products have been delivered to.

- geographical location and ownership of the affected site, including any other abiotic factors which might influence the outbreak, e.g., public access, transport routes, etc. Include detailed maps.
- hosts infested at the site (species, variety, development stage, etc.), and an estimate of the abundance and distribution of potential hosts in the surrounding area.
- when and how the pest was detected and identified (including photographs of symptoms).
- level of pest incidence and, where appropriate, life stages present.
- extent and impact of damage (including part of host affected).
- recent import or movement of host plants or host plant products into and out of the affected site.
- movement of people, products, equipment, and vehicles, where appropriate.
- accessibility to the site for machinery to remove trees.
- relevant treatments applied to host plants that may affect development of symptoms, or detection and diagnosis of the pest.
- history of the pest at the site or place of production, or in the area; and
- likely biodiversity impacts of any control measures, including any duty of care obligations under the Natural Environment & Rural Communities (NERC) (2006) Act.

These surveys should be conducted by an FC Plant Health/Tree Health Officer or an APHA inspector depending on the location.

Sampling

5.10. To confirm a suspected *A. bilineatus* detection, it is important that a sample of the insect and the infested plant/wood material be collected for expert identification. Adult specimens are most useful for rapid identification, but any life stages present should be collected. A representative sample of the infested plant or wood product should be obtained (along with a sample of any *attached* foliage and bark, if present, to help confirm the identity of the infested material), and these samples should be either:

a. triple-wrapped and sealed in robust plastic bags; or

b. double-wrapped in robust plastic bags and the bags placed inside a secure box or vial and sent immediately and securely to the Tree Health Diagnostic & Advisory Service at Forest Research for diagnosis. Suspect insects should be preserved in pure ethanol or propylene glycol (to preserve the DNA) and sent in a similar manner. The samples must be accompanied by information about the date when the samples were collected, the location (address, postcode, GPS) and contact details of the person collecting the samples. The address is: Tree Health Diagnostic & Advisory Service, Forest Research, Alice Holt Lodge, Gravel Hill Road, Wrecclesham, Farnham, Surrey, GU10 4LH.

c. samples collected by APHA's PHSI staff should be packaged as per points a or b above and sent to Fera Science Ltd. for analysis. The address is: Fera Science Ltd., York Biotech Campus, Sand Hutton, York, YO41 1LZ.

Samples should only be removed from the site by trained individuals using safe and appropriate equipment and operating according to biosecurity guidelines.

Diagnostic procedures

5.11. Positive identification of *A. bilineatus* is based on morphological characteristics (see factsheet in Appendix 1) and DNA sequencing of adults, larvae, or pupae. Adults of *A. bilineatus* can be identified by comparing the taxonomic keys from North America that include *A. bilineatus* (Fisher, 1928) with the taxonomic keys for *Agrilus* species that occur in the UK and Europe (Bily 1982; Hackston, 2019; Volkovitsh *et al.* 2019).

See also Emerald Ash Borer *Agrilus planipennis* Fairmaire (Coleoptera: Buprestidae): a guide to identification and comparison to similar species (Parsons, 2008), for a short key to the more common American *Agrilus*, including *A. bilineatus*: http://www.emeraldashborer.info/documents/eab_id_guide.pdf.

Criteria for determining an outbreak

5.12. An outbreak of *A. bilineatus* should be declared when a positive identification of the insect is associated with either:

a) the discovery of live or dead life-stages in oak trees or sweet chestnut the wider environment; or

b) the discovery of live or dead life-stages in oak or chestnut wood, waste wood, chips, or plants for planting, and from which adults have (or might have) emerged; or

c) the capture of live adults of *A. bilineatus* in circumstances where the adults might have had the opportunity to escape into the wider environment.

5.13. The interception of dead or live specimens in wood, waste wood, chips or plants for planting would not automatically trigger an outbreak response, but should be followed up with a trace forward and backward exercise, possibly resulting in a local survey of trees and woodlands to provide further information about the location of specimens, numbers of individuals etc.

Official action to be taken following the confirmation of an outbreak

Strategic actions on confirmation

5.14. On positive confirmation, the following actions should be initiated to:

- notify Westminster Ministers and senior Defra and Forestry Commission officials.
- set up regular Lead Government Department (LGD) meetings to make key decisions about the outbreak, such as the movement of resources, funding and whether eradication should be continued, and to keep partners aware of the current status, actions and possible future requirements, and to agree a communication strategy.
- notify the Devolved Administrations EPPO and the International Plant Protection Convention IPPC; and
- inform and discuss with stakeholders.

Incident Management and Communication

5.15. In most instances where the outbreak is in a woodland, parkland or the wider countryside in England, the Forestry Commission is likely to appoint an Incident Commander and an incident management team. APHA would take the lead for outbreaks in private gardens and plant nurseries. In Wales the Welsh Government, with Natural Resources Wales's support, would take the lead in woodland situations. Forestry Commission England's Forest Services will work to the Generic Contingency Plan for Plant and Bee Health in England (Defra, 2017), which will be enacted in response to a confirmed outbreak. Scottish Government/Scottish Forestry and the Welsh Government and Natural Resources Wales will have similar documents detailing their management of outbreaks.

5.16. The Incident Commander will set up a management structure to deliver the functions of incident management. The scale of the outbreak will determine the size and nature of the management structure. Identification of and liaison with key stakeholders is a crucial part of this process. An example list of such stakeholders would include, but not exclusively: ICF, Confor, Scottish Government, Welsh

Government, Natural Resources Wales, Environment Agency, Natural England and other members of the Defra Group, SEPA, Forest Research, Woodland Trust, National Trust, Country Land & Business Association, Scottish Land & Estates, Royal Horticultural Society, National Farmers' Unions and local councils.

Surveillance to delimit the outbreak

5.17. A delimiting survey should be set up as soon as possible after the first finding of *A. bilineatus* to determine the geographic limits of the infested area and to demarcate a regulated area. Ultimately the IMT will need to determine the size of both the infested zone and the overall demarcated zone. The two elements of the delimiting survey are:

- an **intensive survey** of all oak trees and sweet chestnut outwards to at least a 1km distance from the first tree(s) found to be infested, or where adults appear to have escaped into the wider environment. This should include all oak and chestnut wood, derived from both small and large material, and live plants with a stem diameter ≥ 2 cm: and
- **line transects** outwards to at least 10km, along which visual inspection of oak and sweet chestnut trees and destructive sampling of suspect branches (i.e., recently dead crown branches still holding foliage) is carried out at regular intervals (e.g., every 100m) to estimate the full extent of spread. The branch material will need to be inspected closely for the presence of *A. bilineatus* larval activity and D-shaped exit holes, and samples taken for molecular diagnosis. The finding of an adult beetle would provide more direct evidence of infestation. Trees may need to be felled to obtain branch material.

  Using transects will indicate spread of the pest from the point of the outbreak, but the number of transects needed and their orientation will depend on the distribution of oak and sweet chestnut within the 10km zone. This will need to be determined on the ground (to include garden and hedgerow trees) and using available data from the National Forest Inventory, and if in Scotland, the Native Woodland Survey of Scotland. Additional trapping and surveillance may also be conducted in the wider environment, beyond the 10km zone, to help determine whether the detected population is isolated, or whether additional populations may be present.

5.18. The surveys should pay particular attention to open-grown oak trees and sweet chestnut and those growing along the edges of woodlands (Dunn, Kimmerer & Nordin 1986b), and should include the inspection of previously cut trunks and branches, cutting residues, and naturally occurring debris showing signs of beetle activity. Samples of oak and chestnut trees showing canopy thinning and dieback should be felled, and the bark removed to look for galleries and immature life stages. Branches from the southerly (sun-warmed) sides of the trees are often colonised preferentially. Apparently healthy trees might also be infested with *A. bilineatus,* and these will therefore also require checking for the presence of the pest. This should be approached in a standardised manner, e.g., by following the Canadian Forest Service procedure for EAB of removing two branches of 5–8cm diameter from the mid-crown and peeling the bark from the first 50cm above the base of the branches to look for larval galleries (Ryall *et al*., 2011a, b; Silk *et al*., 2019). ***

(*** *a different branch sampling protocol may be required for A. bilineatus, depending on how frequently it attacks apparently healthy trees and its typical distribution within infested trees*.)

5.19. The agency responsible for conducting such surveys (including tree felling and inspections) will be determined by the Incident Management Team and will depend on the location and distribution of oak and chestnut in the area. However, it would be useful to determine (and inform) in advance those agencies and staff likely to be required to conduct the surveys, to optimise their response-time when needed. Canopy sampling will require specialist tree-climbers. This will require specific call-off contracts, which the Forestry Commission has in place for England.

5.20. If more trees are found to be infested, the surveys should be extended so that the intensive survey covers all oak trees and sweet chestnut out to at least 1km from the new infested trees, and the line transects extend a full 10km from the new infested trees. This process should be continued to provide a preliminary assessment of the infested area and should be repeated in subsequent years to monitor the spread of *A. bilineatus* and to update the boundaries of the infestation and regulated area. A survey on such a scale will be a huge commitment of resources, and advanced planning should reflect this.

5.21. Reporting on the outbreak should be done through regular situation reports. The frequency of these will be determined by the Incident Management Team and will be used as the basis for informing ministers, stakeholders, and the media.

5.22. There is no formal survey protocol in place for surveying *A. bilineatus* in the UK, and the methodology described above should therefore be viewed as a first version based on the guidance available. It might well require modification and refinement in future.

Demarcated zones

5.23. A statutory regulated area should be established as soon as possible after the discovery of an outbreak of *A. bilineatus*, to help minimise spread of the pest within the infested area, and to prevent human-assisted transport to areas outside the infested area. An initial regulated area of at least a 50km radius around the infested trees will need to be established, within which measures to prevent the movement of potentially infested oak and sweet chestnut material should be implemented. These measures should include a prohibition on the movement of untreated oak and chestnut wood (including firewood, round wood, sawn wood, wood chips, waste wood and arboricultural arisings) and plants for planting of oak and sweet chestnut. The prohibition should prohibit the movement of such material from the infested area to the rest of the regulated area, and from the regulated area to regions outside the regulated area.

Tracing forwards / backwards

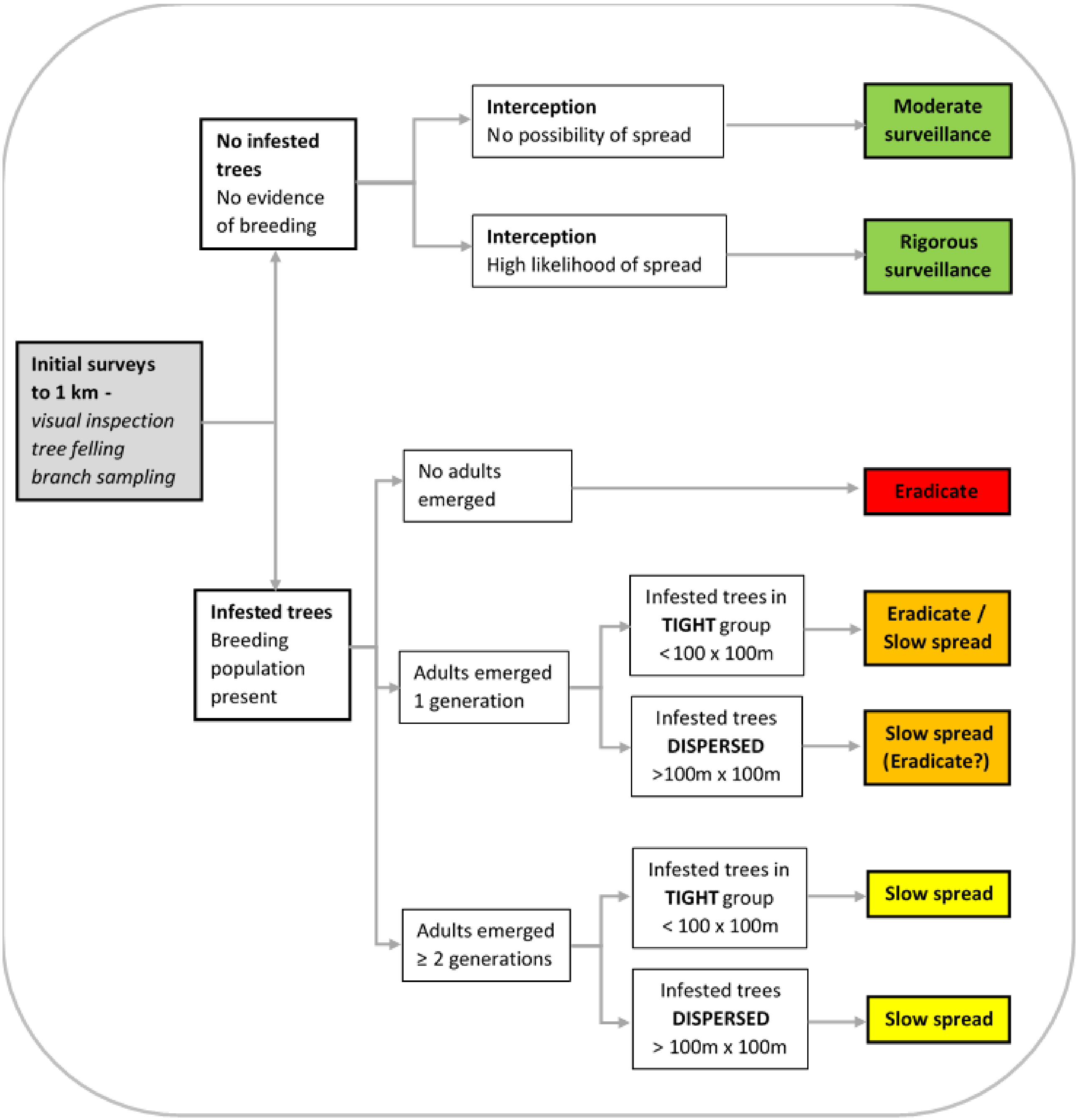
5.24. Depending upon the confirmed pathway(s) of entry, tracing forwards and backwards to identify suspect material will be conducted to identify other potentially contaminated stock or sites.

Management strategy

5.25. The management response will be directed towards either (1) eradication or (2) slowing the spread of the pest and reducing its impact, depending on how many trees are found to be infested, whether adult beetles have emerged, how many generations the pest may have completed, the distribution of the infested oak and sweet chestnut trees, and how many oaks and sweet chestnut are present in the surrounding area.

These criteria are summarised in Figure 1; note however that this was initially developed for EAB and may require subsequent modification for *A. bilineatus*.

Figure 1. Management strategies for *Agrilus bilineatus (*based on the approach for *Agrilus planipennis* and which based on findings during an outbreak may need to be refined for *Agrilus bilineatus*).



Various qualifying factors also need to be considered when deciding on the most appropriate course of action (Appendix 3), and these should be considered when using Figure 1.

Pest management procedures

Surveillance

5.26. Following an interception of *A. bilineatus*, if no infested host trees are discovered during the initial delimiting survey and there is no evidence of breeding and there appears to have been no possibility of spread, then the subsequent management strategy is best served by a moderate programme of surveillance (Figure 1), consisting of annual repeat surveys of the original 1km intensive survey zone, combined with trapping for adult beetles and the use of girdled trap trees (see 5.39). These follow-up surveys will need to be repeated on an annual basis for at least 2-3 years.

5.27. If no infested host trees are found during the initial delimiting surveys, but there is a high likelihood that adult beetles have spread into the wider environment, then a more rigorous programme of surveillance will need to be put in place (Figure 1). This should involve repeating the intensive surveys outwards to 1km and the line transect surveys to 10km in the following and subsequent years, and the establishment of a network of traps and girdled trap trees (sections 5.37, 5.38). The numbers of traps and girdled trees, and their placement, will depend on the abundance and distribution of hosts in the surrounding area (see Appendix 3: Factors to consider when developing a management strategy and operational procedures). These surveys will need to be continued for at least 3 years.

Eradication

5.28. If infested host trees are detected during the initial delimiting surveys, then the decision either to attempt eradication or concentrate on slowing the spread of the pest and reducing its impact, will depend on whether adult *A. bilineatus* have emerged from the infested trees and how long the beetles have been present (Figure 1). Where no adult beetles have emerged, or if only one generation of beetles has emerged and their ability to spread appears to have been limited, then eradication may be possible and management should focus on this objective. An infestation confined to a small group of trees in an area where there are generally few host trees is more likely to be eradicated than an infestation affecting a larger number of trees dispersed across a wider area, especially if there are large numbers of other host trees in the surrounding wider environment (Appendix 3). Determining how many generations of beetles may have emerged and how far they might have spread will require detailed examination of the infested trees by entomology specialists familiar with wood-boring and bark-feeding insects.

5.29. Actions focussed on eradication should include:

- felling and destroying (chipping/burning) all host trees outwards to at least 400m of the infested trees. This is based on Mercader et al. (2009, 2016) who found that 90% of *A. planipennis* larvae (the assumption is that this is also likely to apply to *A. bilineatus)* were found within 100m of the point where adults emerged in newly established satellite populations, 98% of larvae were found within 200m, and only a very small number of larvae (<1%) were found up to and beyond 400m from the point of adult emergence.
- the use of lethal trap trees: girdled oak trees are potentially attractive to adult *A. bilineatus* and if the girdled trees are treated with an insecticide such as emamectin benzoate, then the beetle's life stages are also likely to be killed. The use of emamectin benzoate would depend on approval being granted for its use in the UK – it is not currently (January 2021) approved. (There have been anecdotal reports from tree care professionals in the USA claiming that emamectin benzoate is very effective for controlling *A. bilineatus* for three years, however no actual test results have been published to date for *A. bilineatus)*. A series of girdled and treated trap trees spaced at regular intervals within and around the outbreak could attract and kill a large number of beetles and their offspring. Trees that are girdled but which are not treated with insecticide could also be used, but these untreated trap trees would have to be felled and destroyed soon after the adult flight and oviposition period.
- except for *A. planipennis*, limited attention has been placed on developing effective traps for *Agrilus* monitoring and surveying programs. *A. bilineatus* adults have been captured on purple, yellow and green sticky traps (Petrice & Haack, 2014), as well as in green funnel traps coated with fluon to increase slipperiness (Petrice & Haack, 2015). The green colour is assumed to mimic green foliage, whereas purple is believed to have a similar reflectance as tree bark. Attraction to a specific trap depends on the species concerned, the sex of the beetles, as well as the place where the trap is placed in the tree (Petrice & Haack, 2015). In a study by Rutledge, (in review) targeting *A. anxius* on birch and *A. planipennis* on ash, many adults of the non-targeted *A. bilineatus* were also captured, with significantly more captured on purple traps than on green traps. However, this may be explained by the difference in trap type (green funnel vs. purple prism) and trap location (green in mid-canopy vs. purple at base of crown), and therefore direct comparisons are difficult. In the study by Petrice & Haack (2014) where all traps were similar in type, more females of *A. bilineatus* were captured on purple,

followed by yellow, green, and white, respectively. Males of *A. bilineatus* did not show a significant preference for colour and placement. In recent surveys in declining oak forests all species of *Agrilus* developing on oaks in France (i.e., *A. angustulus*, *A. biguttatus, A. curtulus, A. graminis, A. grandiceps, A. hastulifer, A. laticornis, A. obscuricollis, A. olivicolor* and *A. sulcicollis*) have been trapped in green funnel traps coated with fluon, which were significantly more attractive than similar purple traps for all species (Sallé, unpublished data).

Note that traps are less effective when populations are low and, generally, they are more useful for monitoring rather than as a means of reducing the population.

- traps designed to capture adult *A. planipennis* have been developed in the USA and Canada, and if the same or similar traps also work for *A. bilineatus*, then a network of traps across the infested and regulated area will help to monitor occurrence and spread. In the USA, purple sticky delta traps baited with (Z)-3-hexanol and green multi-funnel traps baited with (Z)-3-hexanol are recommended for EAB, and in Canada, green delta traps baited with the green leaf volatile (Z)-3-hexanol have been shown to be effective for *A. planipennis*. The addition of lactone to the lures may increase their efficacy. However, *A. bilineatus* may not respond to these plant volatiles in the same way as *A. planipennis*, because it attacks different tree species. More research is required to determine which volatiles, if any, are attractive to *A. bilineatus*.

- traps need to be placed in a sunny, exposed position (normally on the south-western side of trees) to catch the maximum number of *A. bilineatus*. Free-standing 'double-decker' traps have been shown to be more effective at catching adults of *A. planipennis* when populations are low compared with single traps placed in trees (McCullough & Poland, 2017). In contrast, the use of trap logs to detect *A. bilineatus* does not seem to be effective (EPPO, 2019), as the beetles are most attracted to stressed host trees prior to mortality (Dunn *et al*. 1986b).

- girdled trees are likely to be more effective at detecting low and very low-density *A. bilineatus* populations, compared with artificial traps that capture the adult beetles, although the difference between girdled trees and trapping decreases as the pest population increases (Mercader *et al.*, 2013). Girdling should be carried out in spring or early summer by removing a 15-20cm band of outer bark and phloem around the base of the tree and followed by felling and debarking in the autumn or winter to detect larval galleries. The trees must be felled and destroyed before the start of the next flight period. Small or medium-sized trees (10-20cm DBH) are optimum in terms of being easier to girdle and inspect, whilst still likely to be highly attractive to ovipositing *A. bilineatus*. Phloem-girdled white oak trees (*Q. alba*), which are not widely present in GB, have been shown to remain attractive to *A. bilineatus* for longer than xylem-girdled trees which died quite rapidly (Dunn *et al*. 1986b). The adults are attracted to volatiles being given off by the stressed trees, and so girdled trap-trees may prove more effective at attracting insects than a purely visual trap.

- Emamectin benzoate, a systemic insecticide administered by trunk injection, has demonstrated three years of control in the USA against both *Agrilus* larvae and leaf feeding *Agrilus* adults (Herms et al., 2014; McCullough et al., 2011; Smitley et al., 2010). Using emamectin benzoate, it is reported that girdling ash trees 2–3 weeks after insecticide injection, created lethal trap trees that were attractive to *A. planipennis* adults (McCullough et al., 2016). There have been anecdotal reports from tree care professionals in the USA claiming that emamectin benzoate is very effective for controlling *A. bilineatus* for three years, however no actual test results have been published to date for *A. bilineatus.*

5.30. If the infested trees are found during the beetles' flight period (May-August), they must be removed and destroyed as soon as possible to limit adult emergence and dispersal (Appendix 3), although not without allowing sufficient investigation to determine how long the beetles have been present and where they might have spread. Outside the flight period, from the end of August through to April, trees can be felled and removed at any time, although sooner is better than later and all of the infested trees must be cleared and destroyed prior to the start of the next flying period (i.e., before the beginning of May).

5.31. A clear policy of who will carry out and pay for tree felling and removal, whether it is the responsibility of the landowner or occupier, the local authority, or FC, APHA or Defra, will need to be established by the Lead Government Department as soon as practicably possible after the outbreak is discovered and before tree felling commences. The removal of host plants will typically remain the responsibility of the occupier or other person in charge of the premises. Contact information for the Arboricultural Association with their register of qualified tree surgeons and ConFor (Confederation of Forestry Industries) will be provided to enable landowners to identify qualified operatives to carry out removal work. In exceptional circumstances, the removal of trees may be carried out by the PHSI or FC.

In the case of private householders, officials may agree to organise the felling and removal of host trees and shrubs, with responsibility for payment of costs remaining with the occupier or other person in charge, or for it to be undertaken by the relevant local authority which will be responsible for determining whether to accept responsibility for the costs of the work or seek recovery. Exceptionally, officials may, in the interests of speed, have to arrange for the work to be carried out and bear the cost, where possible seeking recovery after the event.

5.32. Trees should be cut as close as possible to ground level and the trunks and branches cut into sections of a size that can be easily handled, turned over and examined by inspectors before disposal. The outside of the logs and cut ends must be examined for any signs of *A. bilineatus* damage, and the bark removed from any dying or recently dead stems and branches to look for immature life stages, which may then be distinguished from native *Agrilus* species by molecular methods. The condition of the phloem provides an indication of whether it is still a viable feeding and breeding resource; decayed and dry phloem is not suitable, and live insects will be typically found in phloem which retains some moisture and is not fully degraded. The location of each infested tree should be recorded, so that the spatial distribution of infestation can be mapped, and samples of infested material or suspect material should be retained for examination in the laboratory. Samples must be transported within three layers of containment and the laboratory facility receiving the samples must hold a licence for working on *A. bilineatus* material (section 5.12).

5.33. In the following year, intensive surveys and trapping from 400m to 1km (i.e., from the edge of the clear-felled area to the boundary of the designated infested area), and trapping and systematic surveys outwards to 10km, need to be repeated to confirm there has been no further spread, or, if more infested trees are discovered, to redefine the infested area and the boundaries of the regulated area. If more infested trees are discovered, then these and all other host trees within a radius of 400m will need to be felled and removed, as detailed above.

5.34. This process must be repeated on an annual basis for at least 4 years (i.e. two generations of the pest with an expected 2-year life cycle) after the last infested trees have been removed and there have been no further signs of breeding, at which point the infestation may be declared as eradicated, <u>or</u> it may continue for a longer or shorter period depending on whether newly infested trees continue to be found and the pest continues to spread, in which case a change of policy from eradication to slowing the spread may be required (section 5.56).

Slowing the spread and reducing impacts

5.35. If there is evidence that a larger number of trees have been attacked over a wider area, e.g., an area larger than 100 x 100 m, and more than one generation of adult beetles has emerged and dispersed (Figure 1), then eggs are likely to have been laid into trees at distances of more than 1 km from the initial focus of infestation, and these infested trees will be extremely difficult to locate. Natural dispersal through adult flight has not been studied for *A. bilineatus*. However, information is available for *A. planipennis,* which is a reasonable proxy, demonstrating that it is a strong flyer capable of making long-distance flights of more than 1km (Haack *et al.*, 2002). In flight-mill experiments in the laboratory, individual adult females have been shown to fly 9-10km over a period of several days (Taylor et al., 2010), and in an intensive quarantine area in the USA, Sargent *et al*. (2010) recorded an average dispersal distance per year of 1.4km. Consequently, once more than 1-2 generations of the adult beetles have emerged, clear-felling oak and sweet chestnut outwards to a distance of 400m, or even to 1km, is very unlikely to result in eradication or prevent further spread.

Note that rates of spread may be less in areas with a cooler climate, such as northern England and Scotland (Appendix 3). However, climate change and associated extremely warm summer events are likely to benefit *A. bilineatus* and rates of spread may increase in such years.

5.36. The general advice (based on experience in North America) for *A. planipennis,* is that clear-cut areas will not ultimately prevent spread, except perhaps in the very earliest stages of an outbreak. In addition, cutting large numbers of infested or potentially infested trees reduces the resources available locally to the pest, and therefore might stimulate spread further afield.

5.37. Therefore, if the infestation is more extensive and more than one generation of adult beetles has emerged and dispersed, the management programme should focus on monitoring and the phased removal of the worst affected oak trees, to reduce the *A. bilineatus* population and slow the rate of spread (Figure 1), particularly during the flight period. In the USA, this extends over 10-12 weeks, from the beginning of May until the end of August (EPPO, 2019). The peak in flight activity occurs in May or June.

5.38. The strategy for slowing the spread of *A. planipennis* is based on felling and destroying the most heavily infested ash trees (trees with more than 50% canopy thinning and dieback) to reduce the pest population, but at the same time leaving those trees that are less severely affected and which might in the end prove to be resistant to the pest. This strategy is unlikely to work for *A. bilineatus*, because there is a wide range of factors that can cause canopy thinning and dieback in oak and *A. bilineatus* may not necessarily be present and confirming the presence of the beetle is much more difficult. Unless an adult beetle is found, the presence of *A. bilineatus* can only be confirmed by molecular analysis, and without confirming that *A. bilineatus* is present, it will be hard to justify felling large numbers of oak trees and sweet chestnut.

In addition, even if *A. bilineatus* is found to attack healthy oaks and sweet chestnut, there is no information on whether a proportion of oak trees or chestnuts might be resistant to the pest, and how readily this resistance might be expressed. European oak trees have co-evolved with a number of *Agrilus* species and may prove relatively resistant to *A. bilineatus* attack. Consequently, there is less certainty in the case of *A. bilineatus* that all trees in poor condition need to be felled and that trees with fewer symptoms are indeed resistant.

5.39. A different strategy will therefore need to be employed for *A. bilineatus*, involving (1) identifying trees with suspect canopy thinning or dieback; (2) taking samples of suspicious material; (3) analysing the samples in the laboratory using molecular techniques: (4) felling and destroying those trees that are confirmed by the laboratory analysis to contain *A. bilineatus*. Inevitably, this will be a slower process than that for *A. planipennis*, but it will need to be instigated as soon as possible after an outbreak is discovered and carried out at least annually thereafter. Trees subsequently confirmed to be infested should be felled and the material chipped to less than 1.5cm in three dimensions and/or burned. (Note that burning should not normally exceed 10 tonnes per 24-hour period, according to Environment Agency and SEPA regulations, and a specific dispensation will be required if larger quantities of material is required to be burnt: section 5.53).

5.40. Annual surveys will be required to monitor the spread of *A. bilineatus*, to redefine the infested area and the boundaries of the regulated area, and to distinguish trees impacted by *A. bilineatus* infestation. Surveys of canopy thinning and branch dieback, accompanied by identification of *A. bilineatus* activity within the trees, are best carried out during mid or late summer, although surveys at other times of the year can be useful for identifying heavily infested trees. Trees marked up in the summer may be felled during autumn or winter.

5.41. Assessing trees for canopy thinning and dieback can be based on visual, ground-based surveys, and should be accompanied by sampling for *A. bilineatus* activity. Girdled trees and traps (see 5.38, 5.39) could also be used to detect the presence of beetles in areas outside the known infested area, which would provide advance warning that regular surveys and tree removal might soon be required. Grids of small (15-20cm DBH) girdled trap trees at a density of 2-3 per km^2 combined with trapping and treating trees with emamectin benzoate (≤1% of trees), reduced the rate of population increase and ash decline significantly at the advancing front of the *A. planipennis* invasion in the USA, although the rate of spread remained about the same (Mercader *et al.*, 2015, 2016; McCullough, 2019).

5.42. Prophylactic application of chemical insecticides by injection might prove useful in certain situations for reducing attacks by *A. bilineatus and* might provide some control of the pest in trees at an early stage of attack by the pest. Insecticides are used in the USA and Canada to protect ash trees in urban areas from *A. planipennis*, and to buy time and spread the costs of removing infested trees.

5.43. "Revive" (containing emamectin benzoate), an insecticide applied by trunk injection, is approved for use in Portugal, Spain and Switzerland, but is not currently approved in the UK. Defra will consider possibilities for off-label approvals for products that are registered in the EU. Comprehensive guidance on types of insecticides used in the USA to control *A. planipennis,* and on the timing of insecticide application at different stages of the lifecycle, are given in "Insecticide options for protecting ash trees from emerald ash borer" (Herms et al., 2019). In Canada, the preferred insecticide for controlling *A. planipennis* is "TreeAzin", which is based on azadirachtin, a natural insecticide derived from the neem tree. This and other insecticide products may be of use in the future should any of them become registered for use in the UK. ***

(*** There is no evidence of these insecticides being used to control *A. bilineatus*, but it is assumed they would provide similar levels of control as that for *A. planipennis*).

5.44. Natural enemies may also provide a degree of control. Several natural enemies of *A. bilineatus* have been reported in the literature, including both parasitoids and predators. Some of the larval parasitoids include species in the genera *Atanycolus* (Braconidae), *Leluthia* (Braconidae), *Phasgonophora* (Chalcididae), *Spathia* (Braconidae), and *Wroughtonia* (Braconidae) (Chapman, 1915; Chittenden, 1897a; Cote & Allen, 1980; Haack et al., 1981; Hopkins, 1892; Petrice & Haack, 2014). It is also reported that a species of *Trichogramma* has been reared from an *A. bilineatus* egg (Chapman, 1915). Similarly, some of the larval and pupal predators were species of *Adelocera* (Elateridae), *Cymatodera* (Cleridae), *Phyllobaenus* (Cleridae), and *Tenebrioides* (Trogossitidae) (Cote & Allen, 1980; Dunbar & Stephens, 1976; Haack et al., 1981). Various bird species also feed on *A. bilineatus* adults and within-tree life stages (Cote & Allen, 1980; Dunbar & Stephens, 1976). European species of *Agrilus* which utilize oak trees are known to have a variety of natural predators and parasitoids.

5.45. The opportunity to conduct research on surveying methodology alongside the management/monitoring work should be taken where possible, given the current lack of information on surveying for this species either in a USA or European context. Such information is crucial for slowing the spread.

Disposal plan

5.46. Trees felled to reduce *A. bilineatus* infestation should be destroyed within the infested area by chipping to less than 1.5cm in three dimensions, and/or burning (section 4.29). Firewood, round wood, sawn wood, wood chips, waste wood and debris found to contain *A. bilineatus* life-stages, or showing signs of infestation, should be destroyed in the same way. All equipment used in the disposal of *A. bilineatus* infested trees should be thoroughly cleaned between sites to remove any wood chips in particular, as per standard biosecurity protocols.

5.47. During the *A. bilineatus* flight period (May-August), all felled trees within the infested area should be processed and destroyed as soon as possible after they have been inspected, within a maximum of one week. Outside the flight period, from September to April, trees need not be destroyed immediately, but they must be chipped/burned before the start of the next flying period.

5.48. It is preferable to burn infested material on site, within the infested area, but material chipped to 1.5cm could be moved off-site to processors outside the infested area if destined for immediate destruction, e.g., as biomass, and it is covered securely during transport or is shipped in sealed containers. Additional restrictions may be imposed on a case-by-case basis, especially during the insect's flight period.

5.49. For previous plant health outbreaks in England, Forestry Commission England has put in place framework incineration contracts with prior agreement from the Environment Agency, allowing it to exceed the 10 tonnes per day limit. Such contracts might be required in the event of an *A. bilineatus* outbreak. Site-by-site burning agreements with the Environment Agency or SEPA would be good practice, whether seeking approval to exceed 10 tonnes per day or not. (Check with the Environment Agency for current details: https://www.gov.uk/guidance/d7-waste-exemption-burning-waste-in-the-open)

5.50. Landowners need to ensure that any clearance complies with Habitat Regulations. If needed, permissions can be sought to undertake emergency activities e.g., felling. Further information may be obtained from Natural England or the FC (the latter being the lead authority for all forestry activity).

Public outreach

5.51. It is crucial to have public support for the management programme and to help with general surveillance. Engaging the public will require the provision of timely, balanced and accurate information about monitoring and control. It can also provide opportunities for the public to participate in monitoring and reporting suspect trees using the reporting tool Tree Alert. The voluntary tree health surveillance network Observatree could also be deployed. Information, subject to available budget, can be made available through public meetings, newspapers, radio, TV, publicity materials, the internet, social media, and face-to-face contact. It should be targeted locally, especially within the infested and regulated areas and, where appropriate, regionally and nationally. Owners and managers of any affected land must be rapidly informed about a detection, educated about the risk posed by the pest, and provided with appropriate guidance regarding any possible statutory activities likely to be carried out on the land. It would be helpful to prepare a summary of such key information in advance.

5.52. It is important to provide information on the location and size of the infested and regulated areas, statutory and voluntary responsibilities, indications of changing or enlarging distribution, management options, pathways by which the pest might have arrived and could be dispersed, the prospects for GB forestry and the host species more generally, and what people can do to help, especially in terms of monitoring. Managing this level of public engagement will require a central administration office capable of handling many enquiries and able to provide general and specific information. Liaison with communications and press teams from other countries will be required for cross-border outbreaks.

Review measures in the cases of prolonged official action

5.53. If continuing action is required within the demarcated area over a prolonged period, a review of the management programme should be undertaken regularly (e.g. annually) to determine the success and cost effectiveness of the measures in the longer term. This review will involve consultation with stakeholders and should include:

- evaluation of the effectiveness of current measures.
- evaluation of the economic impact and cost effectiveness of continuing existing measures.
- consideration of further measures to eradicate or slow the spread of the pest.
- consideration of statutory obligations and impact on import and export procedures.
- consideration of alternative approaches or the cessation of statutory action; and
- consideration of the impacts on biodiversity from control methods.

Criteria for declaring / change of policy and reviewing the contingency plan

5.54. This and other contingency plans will be reviewed on a regular basis to accommodate any significant changes in pest distribution, dispersal, refinement of surveillance techniques, legislation changes or changes in policy. When and if policy makers in the country or countries affected deem that eradication is no longer a viable option, there will be a move towards slowing the spread of the pest and reducing its impacts. The criteria for determining such a break point for *A. bilineatus* would be the number of trees infested, the distribution of the infested trees, the overall size of the pest population, the resources needed to eradicate or manage the outbreak, or a combination of these. However, this will be determined by the policy makers in the country or countries affected. Further details can be found in the Defra generic contingency plan (Defra, 2017).

5.55. In circumstances where official action is no longer considered appropriate, stakeholders should be consulted, and a timetable and mechanism agreed for the removal of official measures and for the dissemination of information on managing the pest as appropriate.

The plan should only be re-consulted upon if significant new information is presented, which affects the approach to the management of an outbreak.

6. Recovery

6.1. Eradication is unlikely to be achieved if *A. bilineatus* is found in the wider environment, except under very restrictive circumstances, and therefore there is no scope for recovery to pre-establishment conditions.

Alternative species to *Quercus* and *Castanea* could be planted to help restore woodland and urban landscapes, but whether this is necessary will depend on the impact that *A. bilineatus* has on oak and chestnut populations in the UK.

7. Appendices

Appendix 1. Pest background information

Source: EPPO Global Database, EPPO PRA

Identity of organism and quarantine status

Species name: *Agrilus bilineatus* (Weber, 1801)

Synonyms: *Buprestis bilineata* Weber 1801; *Agrilus flavolineatus* Mannerheim (1837); *Agrilus bivittatus* Kirby (1837); *Agrilus aurolineatus* Gory (1841)

Common name: Two-lined chestnut borer

Risk rating: Unmitigated risk High – 100 out of 125; Mitigated risk 100 out of 125

EU status: *Agrilus bilineatus* – On EPPO A2 list of pests recommended for regulation as quarantine pests (September 2019).

UK status: *Agrilus bilineatus* – Regulation planned for introduction during 2021 (see Appendix 2)

Hosts

Despite its common name, the two-lined chestnut borer is principally a pest of oak. In North America, *A. bilineatus* attacks *Castanea dentata* (Fagaceae) and numerous species of *Quercus* (Fagaceae). It will probably attack any of the oaks (Fisher, 1928). Complete development of *A. bilineatus* in *Q. robur* (pedunculate oak) has been documented several times in Michigan (Haack, 1986; Petrice & Haack, 2014). There is no information on the host status of *C. sativa* in North America as this species is not widely planted there (because of its susceptibility to *Cryphonectria parasitica*). See the EPPO PRA for a list of genera and species of *A. bilineatus* on which larvae can develop.

Life history

Throughout its range, *A. bilineatus* usually completes its life cycle in a single year, although some individuals can require two years (Cote & Allen, 1980), which may be attributed to slower larval developmental rates in vigorous hosts, populations that occur where summers are cool and short, or individuals that develop from eggs that were laid in late summer (Chamorro et al., 2015). In the absence of further evidence or modelling, *A. bilineatus* would be expected to complete its life cycle in two years throughout the UK, with the potential exception of the very warmest areas. Even then it would be expected to vary between one and two-year cycles depending on the summer. Larvae must experience an extended cold period before they pupate and transform to adults, as is common in many *Agrilus* species that develop in temperate latitudes (Chamorro *et al.*, 2015; Reed *et al.*, 2018).

Identification

Eggs

The eggs of *A. bilineatus* are oval, creamy white when first deposited, becoming reddish and then tan as they mature (Chapman, 1915). Eggs are about 1–1.2 mm long, 0.5–0.8 mm wide and 0.3 mm thick (Chapman, 1915). Eggs can be laid singly, or in clusters, with most clusters containing 2–4 eggs (Chapman, 1915; Haack & Benjamin, 1982).

Group of eggs laid in the lab on an oak stick wrapped with ribbon to simulate back cracks.

Courtesy: Deborah L. Miller, USDA Forest Service.

Larvae

Larvae are elongate, legless, creamy white to yellowish and dorsoventrally flattened. The head is dark brown (Petrice & Haack, 2014). There are ten abdominal segments, with the last segment terminating in two brown urogomphi (projections found on the terminal abdominal segment of immature stages) (Chamorro *et al.*, 2015; Petrice & Haack, 2014). The presence of urogomphi is characteristic of *Agrilus* larvae (Burke, 1917). *A. bilineatus* has four larval instars (Chapman, 1915; Cote & Allen, 1980; Haack & Benjamin, 1982). On emergence from the egg, first-instar larvae measure 1–1.5 mm, while fourth instars reach 18–24 mm (Chapman, 1915). Morphological characters of the urogomphi might be able to be used. There does not seem to be an appropriate key available at present to distinguish *A. bilineatus* from some other *Agrilus* species, such as the *Quercus*-infesting European species *A. sulcicollis* (Petrice & Haack, 2014), which has become established in North America.

Fourth instar larva and galleries in cambial region of Northern pin oak, *Quercus ellipsoidalis* (Pine County - St. Croix State Park in Minnesota, USA).

Courtesy: Steve A. Katovich, USDA Forest Service.

Pupae

Pupae, 6–10 mm in length, are creamy white at first, becoming darker as the adult forms (Chapman, 1915).

Adults

Adults are elongate and can vary from 5 to 13 mm in length depending on the condition of the host in which they developed (Haack & Acciavatti, 1992). The head of *A. bilineatus* is bronzy green in colour while the thorax and abdomen are mostly black with a greenish tinge (Horn, 1891; Fisher, 1928). There is a yellow stripe along each side of the thorax and along the centre of each elytron. These stripes are very characteristic of this species as no other *Agrilus* species colonizing oaks in Europe has such stripes. The abdomen has a shiny appearance. Females tend to be more robust than males. However, the main distinguishing character between the sexes is presence of a central groove along the second abdominal sternite on males and the lack thereof on females.

Adult *Agrilus bilineatus,* Ottawa (US)

Courtesy: Eduard Jendek

More photographs are available at:
https://www.insectimages.org/search/action.cfm?q=agrilus+bilineatus
https://gd.eppo.int/taxon/AGRLBL/photos

Table 1. Details on morphology and development time (EPPO, 2019)

Stage	Colour/shape	Size	Duration
Eggs	Creamy white to golden brown, oval-shaped	1 mm long, 0.5 mm wide, 0.3 mm thick (Chapman, 1915).	10-14 days
Mature larvae	Creamy white to yellowish	18-24 mm long	About 10 months (for the 4 larval instars)
Pupae	Creamy white	6-10 mm long	9-12 days
Adults	Bronzy green head, black, greenish tinge with two stripes on the prothorax and elytra. These stripes are very characteristic as no other *Agrilus* species colonizing oaks in Europe have such stripes.	5-13 mm long	8-38 days

Distribution

Agrilus bilineatus is native to North America. It is present in Eastern and Central USA and Canada. It has been recorded from as far north as Manitoba, New Brunswick, Ontario, and Quebec in Canada to Southern states of the USA including Florida, Alabama, Louisiana and Texas. Since 2002 there have been four reports of *A. bilineatus* in Turkey and it is believed to be established, although significant damage has not been recorded. These records are in the area close to Istanbul, not far from the border with Bulgaria.

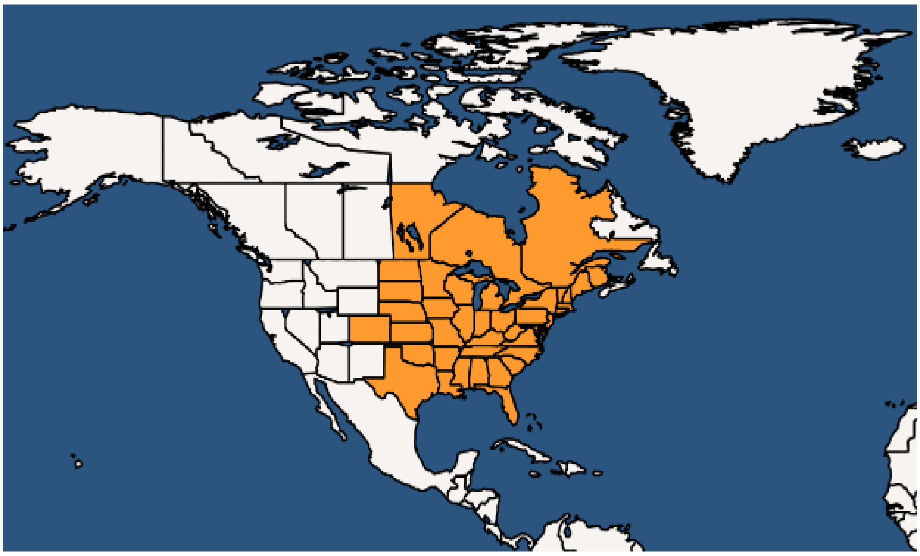


Figure 1. Distribution map of *A. bilineatus* in North America. States where *A. bilineatus occurs* are shaded orange.

Source: EPPO (2019)

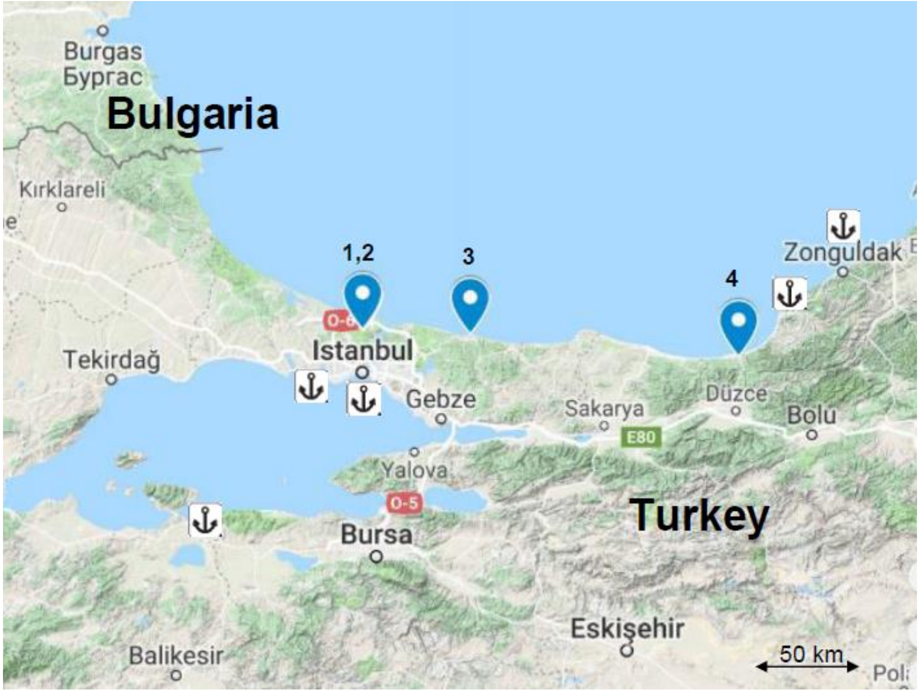


Figure 2. Reports of *A. bilineatus* in Turkey. Location 1 and 2 (2013 and 2016), location 3 (2018) and location 4 (2002).

Source: EPPO (2019)

Damage impact and controls

All oak and chestnut species are considered as being potential hosts for *A. bilineatus* in the EPPO region. The impact in the EPPO region may be different from the impact observed in North America, because of potential differences in the susceptibility of European native *Quercus* species and *C. sativa* compared to North American host species.

A. bilineatus is usually present at low population levels in the North American forests where it breeds in weakened host trees. However, following severe oak defoliation and drought, it has the capabilities of increasing in numbers rapidly and bringing about large-scale oak mortality (Dunbar & Stephens, 1976). *A. bilineatus* has been one of the major contributors to oak mortality in North America (Dunbar & Stephens, 1976).

The pest attacks both the trunk and the branches of its hosts, and during outbreaks it apparently attacks both healthy and weakened trees. Several stress factors make trees more attractive and more susceptible to attack. Attack usually begins in the crown of the tree and proceeds downward along the bole in each succeeding year of infestation (Haack & Benjamin, 1982).

Pedunculate oak (*Q. robur*) is one of the two oak species most widely distributed in Europe and the UK. *Quercus robur* is the only native European tree species for which there is data on susceptibility to *A. bilineatus*. On the Michigan State University (MSU) campus (Haack RA, unpublished data) and at two MSU Experimental Forest genetic test sites, where *Q. robur* was inter-planted with native *Q. alba* and *Q. rubra* trees (Haack, 1986), *A. bilineatus* is reported to have infested and killed healthy *Q. robur*. *A. bilineatus* also readily attacked *Q. robur* trees in Michigan that were artificially girdled to induce stress, and among these trees, *A. bilineatus* attacked trees showing less evidence of stress compared to *A. sulcicollis* (Petrice & Haack, 2014). At other sites in the USA, however, *Q. robur* is present and is alive even though *A. bilineatus* is also present (EPPO, 2019).

The potential impact of *A. bilineatus* depends on susceptibility of *C. sativa* and European *Quercus* host species. An *Agrilus* species may infest only weakened trees (of host species that have co-evolved with it) in its area of origin but may infest and kill apparently healthy trees of other species in the same host genus in new areas where they are introduced, as has occurred for *A. planipennis* on ash in North America (Herms *et al.*, 2015) and is shown by the susceptibility of European *Betula* species to the North American *A. anxius* (Miller et al., 1991; Nielsen et al., 2011). Therefore, all *Quercus* species in Europe and *C. sativa* need to be considered as potentially at high risk, until further information on host susceptibility becomes available.

The potential impact would also depend on other stress factors. Trees already stressed by pests and diseases such as *Thaumetopoea processionea* (oak processionary moth), acute oak decline, *Dryocosmus kuriphilus* (chestnut gall wasp), *C. parasitica* (sweet chestnut blight) will be at risk. Trees are also likely to become more stressed in future due to increased extreme weather events, and therefore more vulnerable to attack. Moreover, considering that, together with temperature, the frequency and duration of severe droughts are expected to increase in the future years because of climate change, the impact of wood boring insects (such as *A. bilineatus*) is likely to be more important in the future (Sallé *et al.*, 2014).

A. bilineatus could kill isolated trees as well as large groups of trees. This would have an impact on wood production yields. Moreover, damage would decrease timber quality because of the larval gallery systems and because of subsequent colonization by secondary pests. The aesthetic value of ornamental oaks in parks, public gardens and as street trees would also be impacted. More generally, this pest could have an impact on the landscape if trees are already stressed on a large scale by other factors.

Main pathways

Bark and wood-infesting insects, including most *Agrilus* species, can be transported in live plants as well as wood products such as logs, firewood, solid wood packaging, lumber, bark, and wood chips (Meurisse *et al.*, 2018). For live plants, such as nursery stock, there are not always external signs of infestations during the first year of infestation (e.g., no exit holes). For wood products, *Agrilus* individuals would be most likely to complete development in items with some bark (e.g., logs and dunnage), given that *Agrilus* larvae feed in the cambial region and immature larvae need bark to complete their development. Also, bark would be required for those individuals that pupate in the outer bark. However, it is possible, for some individuals that would have constructed pupal cells in the outer sapwood, that bark is not required.

Appendix 2. Import controls

A. bilineatus is not known to occur in Great Britain, and therefore regulating it under GB legislation from 2021 (planned introduction Summer 2021) as a Plant pest not known to occur in any part of Great Britain under Insects, mites and nematodes, at all stages of their development, is proposed and has been agreed by the UK's Plant Health Risk Group. By including *A. bilineatus* on this list, it will be regulated on all hosts and pathways as follows:

Regulated material

Relevant material, originating in third countries, which may only be brought into the Great Britain if specified requirements are met.

(1) *Item*	*(2)* *Description of relevant material*	*(3)* *Requirements*
	Wood of *Castanea* and *Quercus* other than in the form of: —chips, sawdust, shavings or —wood packaging material, except associated controlled dunnage, but including wood which has not kept its natural round surface, originating in Canada, The USA and Turkey.	The wood must be accompanied by: (a) an official statement that it originates in an area* which, in accordance with the measures specified in ISPM No. 4, is known to be free from *Agrilus bilineatus* Weber and is not within 100 km of a known outbreak of *Agrilus bilineatus* Weber. (b) is bark-free, and has undergone an appropriate heat treatment to achieve a minimum temperature of 56 ℃ for a minimum duration of 30 continuous minutes throughout the entire profile of the wood, or (c) an official statement that it has undergone appropriate ionizing irradiation to achieve a minimum absorbed dose of 1 kGy throughout the wood. Where the phytosanitary certificate

		includes the official statement referred to in paragraph (b), there must also be evidence of that heat treatment by a mark "HT" put on the wood or on any wrapping in accordance with current usage and on the phytosanitary certificate. * The name of the area(s) must be included in the phytosanitary certificate under the heading "Additional declaration"

Justification

Currently there are no requirements for wood of *Castanea* from Canada, the USA or Turkey. There are measures for wood of *Quercus* from the USA in relation to oak wilt; these will mitigate against some of the risk from *A. bilineatus* but do not completely mitigate the risk. For example, the PFA for oak wilt partially overlaps with the range of *A. bilineatus* but not completely. The option to remove 2.5 cm of outer sapwood has not been included as the USA and Canada cannot reliably do this for ash so would be unable to do this reliably for *Quercus* and *Castanea*. The option to debark and heat treat has been slightly altered to 'bark-free'. This option is simple and unambiguous and easy to check during inspections. Evidence for *A. planipennis* shows that debarking removes around 99% of larvae with heat treatment adding extra assurance. The EPPO standard PM 10/8(1) disinfestation of wood with ionizing radiation states that 1 KGy is a lethal dose for wood infesting insects. Canada and Turkey are not covered by any requirements for wood of *Quercus*. Current measures are not sufficient to prevent the introduction of *A. bilineatus*.

(1) *Item*	*(2)* *Description of relevant material*	*(3)* *Requirements*
	Wood in the form of chips obtained in whole or part from *Castanea* and *Quercus* originating in Canada, the USA and Turkey.	The wood must be accompanied by: (a) an official statement that it originates in an area* which, in accordance with the measures specified in ISPM No. 4, is known to be free from *Agrilus bilineatus* Weber and is not within 100 km of a known

		outbreak of *Agrilus bilineatus* Weber. * The name of the area(s) must be included in the phytosanitary certificate under the heading "Additional declaration"

Justification

There are currently measures for wood chips of *Quercus* from the USA, but these measures are not sufficient to prevent the introduction of *A. bilineatus.* The EPPO PRA considers that only a PFA is sufficient and this is the only option offered in relation to *A. planipennis*. There are no measures for wood chips of *Quercus* from Canada or Turkey and no measures for wood chips of *Castanea*.

(1) Item	*(2) Description of relevant material*	*(3) Requirements*
	Isolated bark and objects made of bark of *Quercus* originating in Turkey.	The isolated bark must be accompanied by: (a) an official statement that it originates in an area* which, in accordance with the measures specified in ISPM No. 4, is known to be free from *Agrilus bilineatus* Weber and is not within 100 km of a known outbreak of *Agrilus bilineatus* Weber. * The name of the area(s) must be included in the phytosanitary certificate under the heading "Additional declaration"

Justification

Isolated bark of *Castanea* is prohibited from all Third countries. Isolated bark of *Quercus* other than *Quercus suber* is prohibited from Canada, Mexico and the United States. Q. suber is distributed around the Mediterranean. It is not found in Canada, the USA or Turkey.

(1) *Item*	(2) *Description of relevant material*	(3) *Requirements*
	Plants, other than plants in tissue culture, pollen or seeds, including cut branches with or without foliage of *Castanea*, and *Quercus* intended for planting, originating in Canada, The USA or Turkey.	The plants must be accompanied by: an official statement that they have been grown throughout their life in an area* established by the national plant protection organisation in accordance with ISPM No. 4 as an area that is free from *Agrilus bilineatus* Weber and is not within 100 km of a known outbreak of *Agrilus bilineatus* Weber. * The name of the area(s) must be included in the phytosanitary certificate under the heading "Additional declaration"

Justification

Plants of *Castanea* and *Quercus* with leaves are prohibited (Annex VI Regulation (EU) 2019/2072). However, *A. bilineatus* could move in dormant trees so this does not mitigate the risk. The current requirements for plants of *Quercus* from the USA are for PFAs for Oak wilt; the distributions of oak wilt and *A. bilineatus* overlap but are not identical. There are no further requirements for *Quercus* from Canada or Turkey. Therefore, specific requirements for plants for planting of *Castanea* and *Quercus* in relation to *A. bilineatus* are required.

Notifiable material originating in third countries, other than the European Union

Wood, except wood packaging material, where it—

(a) has been obtained in whole or in part from one of the following order, genera or species—

(i) *Quercus* L., including wood which has not kept its natural round surface, originating in Canada, the USA or Turkey except wood in the form of casks, barrels, vats, tubs or other coopers' products or parts thereof including staves and where there is documented evidence that the wood has been processed or manufactured using a heat treatment to achieve a minimum temperature of 176°C for 20 minutes.

(ii) *Castanea*, including wood which has not kept its natural round surface, other than sawdust or shavings, originating in Canada, the USA or Turkey.

Isolated bark and objects made of bark, where it—

(a) has been obtained in whole or in part from one of the following order, genera or species—

(i) *Quercus* L., originating in Turkey.

Appendix 3. Factors to consider when developing a management strategy and operational procedures

Qualifying Factor	Influence/effect	Management response/ implications
Number of infested trees	A small number of infested trees close together can be dealt with more quickly and there is less chance that the beetles will have spread. A greater number of infested trees scattered across a large area is more likely to be associated with *A. bilineatus* having been present for >2 generations and having spread to a much wider area.	A small, concentrated population is more likely to be eradicated than a larger, more dispersed population.
Abundance & distribution of host trees	Small numbers of host trees in the vicinity will be easier to survey and remove but may have resulted in *A. bilineatus* dispersing greater distances to locate hosts. Large numbers of host trees and blocks of oak or woodland close to the outbreak site will be more difficult to survey and infested trees may be missed, but *A. bilineatus* may not have needed to disperse as widely.	Surveys will need to cover a wider area, but it should be possible to inspect & remove trees more quickly and to fell outward to distances >1 km. Eradication is more likely to be successful if detection is early. Greater input to survey work required and more intensive monitoring. Larger numbers of trees will need to be felled within 400m, which will increase costs and require more time. Less chance of successful eradication.
Time of year / flight period	Flight period: May-August	For eradication purposes, infested trees and all other host trees within 400m will need to be felled and destroyed immediately to reduce emergence and dispersal. Survey work will also need to be completed

		as quickly as possible to delimit the outbreak and this, and tree felling, will place acute demands on resources.
	Outside flight period: August through to April of the following year.	Trees do not need to be cut & destroyed immediately, giving more time for surveys, investigations, and delimiting the outbreak, but all infested trees must be removed & destroyed before the start of the next flight period (i.e., before May).
Land use / ownership	Rural areas characterised by fewer, larger landholdings, and oak present in a wide range of habitats and situations, e.g., as individual trees, in hedgerows and in woodlands.	Host trees in rural areas are generally easier to access and remove, but there are likely to be many more trees. Therefore, operations may be more challenging.
	Urban areas characterised by large numbers of small, private ownerships. Oak present in gardens, as street trees, in parks and other public open spaces.	More resources are required to liaise with landowners in urban areas and it will be more difficult to remove host trees from gardens, but there are likely to be fewer oak trees. Therefore, liaison may be more challenging than operations.
	Nature conservation sites / SSSIs	May require special considerations in relation to retention of host trees.
Site conditions	Stressed oak on poor, water-stressed sites is likely to be particularly susceptible to TLCB, compared with healthy oak growing on good sites. However, although oak on good sites may be less susceptible, it may harbour cryptic infestations for longer before detection.	Surveys to detect *A. bilineatus* should pay attention to oak on poor sites, where *A. bilineatus* may establish more readily and its populations increase more rapidly. Conditions such as Acute Oak Decline and Armillaria (honey fungus) may make trees more attractive and susceptible to *A. bilineatus.* Detecting low density *A. bilineatus* infestations amongst healthy host trees may be particularly difficult and time consuming.

Climate	Warm climate, e.g., south and SE England: most *A. bilineatus* complete their life cycle in 1-year in the US, favouring rapid population increase, and this may be the case in the warmest areas of England. There remain uncertainties however about the influence of the cooler summers typical in the UK. Warmer conditions increase dispersal during the flight period.	Rapid population increase and spread means that eradication is less likely to be achieved, and it may be more difficult to slow the spread of the pest. Surveys will have to be carried out over larger areas to account for the greater capacity for dispersal. Infestation will develop more rapidly, and trees will succumb more quickly, increasing the pressure to remove trees before beetles emerge or trees become a H&S risk.
	Cool climate, e.g., north England & Scotland: *A. bilineatus* is more likely to have a 2-year life cycle; populations increase more slowly, and dispersal is less rapid and occurs over shorter distances.	Slower rates of population increase, and dispersal, make it more likely that the pest can be eradicated or prevented from spreading.

Appendix 4. Relevant legislation

Domestic:

The Waste Management Licensing (Scotland) Regulations 2011

The Environmental Permitting (England and Wales) Regulations 2010

Natural Environment and Rural Communities Act 2006

The Plant Health (Official Controls and Miscellaneous Provisions) (England) Regulations 2019 *

The Official Controls (Plant Health and Genetically Modified Organisms) (England) (Amendment) Regulations 2020

Plant Health Act 1967

Forestry Act 1967

* These new regulations replace the previous Plant Health (Forestry) Order 2005 and Plant Health (England) (Amendment) Order 2015. Similar legislation has been introduced for Scotland and Wales.

The Official Controls (Plant Health and Genetically Modified Organisms) (Wales) Regulations 2020;

The Plant Health (Official Controls and Miscellaneous Provisions) (Scotland) Regulations 2019.

The Plant Health (Amendment etc.) (EU Exit) Regulations 2020
These Regulations are made in exercise of the powers conferred by the European Union (Withdrawal) Act 2018 (c. 16) to address failures of retained EU law to operate effectively and other deficiencies arising from the withdrawal of the United Kingdom from the European Union.

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