Forestry Commission

Pest specific plant health response plan: Emerald Ash Borer (*Agrilus planipennis*)

Updated February 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 Emerald Ash Borer (*Agrilus planipennis*).

Scope

This contingency plan was prepared by the Forestry Commission's (FC) Cross-Border Plant Health Service in 2015 (revised 2017), and updated collectively by Forest Research in 2020, to be used at country and national (Great Britain) levels.

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.

It 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.

FC England's Forest Services will use OGB17b 'Managing Incidents in the Forestry Commission' for relevant incidents. FC Scotland 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 an incident management team 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 planipennis* in all situations where ash (*Fraxinus* species) is planted or occurs naturally, i.e. forestry, natural and semi-natural habitats, agricultural landscapes, urban environments, and parks and gardens. 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 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. planipennis*, 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 whenever the pest, or symptoms of attack by it, are observed.
- To ensure that infestations of *A. planipennis* 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 planipennis* (Fairmaire) (Coleoptera: Buprestidae), commonly known as the emerald ash borer, is a highly destructive pest of ash trees in regions where it has been introduced, including eastern North America, the European part of Russia, and more recently eastern Ukraine.

2.2. Its native range includes north-east China, Korea, Mongolia, Japan and the Russian Far East. It is now widely established across much of North America and the European part of Russia, where it is still spreading.

2.3. It occurs in parts, but not all, of the native range of ash (*Fraxinus* spp.) in both of these regions.

2.4. It can cause extensive mortality of ash.

2.5. It is officially absent from the UK.

3. Preparation

3.1. *A. planipennis* is listed as a priority quarantine pest in Schedule 1 of The Plant Health (Amendment etc.) (EU Exit) Regulations 2020/1482 and such its introduction into and movement within Great Britain is banned.

3.2. *A. planipennis* appears on the EPPO A2 list and, given the threat it poses to the native and ornamental ash population in the UK despite mitigations, it has a very high mitigated risk rating in the UK Plant Health Risk Register of 75/125.

3.3. The pest has spread from Moscow (where it is not under official control measures) and has reached Tver (155 km north-west of Moscow), Smolensk (400 km west of Moscow) and Volgograd (900 km south and east of Moscow). Spread to the north-west has slowed, which may have reduced the risk of accidental introduction via the Baltic States but spread to the south and south-west has been rapid and in July 2019 the pest was recorded for the first time from east Ukraine.

3.4 The EU has placed import restrictions on wood of ash from regions where *A. planipennis* is present (North America, Russia, China, Japan, Mongolia, North Korea, South Korea), but not for any movement within the EU. Additional legislation has been introduced for the UK through the Official Controls (Plant Health and Genetically Modified Organisms) (England) (Amendment) Regulations 2020, based on the EPPO Standard PM 9/14(1), which recommends a regulated area of no less than 100 km around outbreak areas, when pursuing a containment policy. Import requirements therefore apply to countries within 100km of outbreak areas, which now includes Ukraine, as well as Belarus and Kazakhstan. Additionally, the UK has removed the option within EU legislation to remove the bark and sapwood to a depth of 2.5 cm (point 87, option (b) of Annex VII of Regulation 2019/2072) for all countries regulated for the purposes of *A. planipennis*, due to the risk of importing wood which has not properly met the official requirements.

3.5. EPPO has undertaken a Pest Risk Assessment of the species (EPPO PRA), which indicated that the likelihood of the pest establishing in the EU and causing significant damage is high.

3.6 A statutory notification scheme (SNS) for landing consignments of solid fuel wood (firewood), which was introduced via the Plant Health (Forestry) (Amendment) (England and Scotland) Order 2016 (SI No.1167), came into force on 1 January 2017. See 'Main pathways for entry and further spread' page 34. The SNS now applies to England, Scotland and Wales under the following legislation as amended:

The Official Controls (Plant Health and Genetically Modified Organisms) (England) Regulations 2019

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

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

Legislation

3.7. A list of all the relevant legislation which might be pertinent in an *A. planipennis* outbreak is given in Appendix 3.

4. Response

Trigger

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

- a characteristic D-shaped exit hole in an ash tree or trees;
- a live or dead insect found in a consignment of wood or wood packaging material, dunnage or live plants; or
- a live or dead insect found in the wider environment (e.g. discovered by amateur entomologists).

The initial report could come from 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

4.2. 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. Country teams in Scotland and Wales will fully manage the outbreak in accordance with their own

generic contingency plans but will provide updates to the Defra Core Contingency Group for information purposes.

4.3. 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 risk group.

4.4 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 Scotland and Wales, 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.

Tactical actions on suspicion

Holding consignments and movement / planting restrictions

4.5. Until further investigation, and under a containment notice, no host or other suspect material shall leave the 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

4.6. 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

4.7. An outbreak of *A. planipennis* 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 a report

from the public of ash trees showing canopy thinning, dieback or mortality, with suspect insect galleries and damage beneath the bark (Appendix 1).

Confirmation that *A. planipennis* is present will require expert examination of samples and follow-up inspections, particularly to differentiate it from Chalara dieback of ash. Infection with *Chalara* is also characterised by foliar wilt and crown dieback. The presence of D-shaped exit holes and larval galleries under the bark are two key indicators of the presence of *A. planipennis* which are not indicators of Chalara dieback of ash.

Distinguishing EAB infestation from Chalara ash dieback

4.8. Chalara ash dieback (*Hymenoscyphus fraxineus*) is now widespread throughout the UK, and symptoms caused by this fungal disease may be confused with those of EAB infestation. In smaller ash trees and saplings, typical diamond-shaped lesions caused by the ash dieback pathogen are often visible on the main stem accompanied by dieback of branches and side shoots, although the lesions may not be easily observable on the stems of larger trees. Chalara dieback tends to cause diffuse 'tip dieback' across the periphery of the crown of larger trees, and dense clumps of foliage may be seen further down the branches as epicormic growth is produced. In North America, EAB attack more typically causes the initial dieback of one or two branches, usually on the most sun-warmed side of the tree, followed by general thinning of the crown, whilst terminal leaves may be retained on branches until they are killed. Epicormic growth becomes evident lower down the bole of the tree as it becomes heavily impacted by infestation. EAB infestation may also be indicated from woodpecker feeding activity on the stem as they predate immature beetle stages. Note however that the severity of symptoms will vary between individual trees for both Chalara dieback and EAB infestation, and so determining the presence of larvae below the bark or the characteristic D-shaped exit holes remains critical to confirm the presence of EAB.

4.9. If there is evidence of the presence of *A. planipennis* 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;

- 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

4.10. In order to confirm a suspected *A. planipennis* 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 alcohol 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 sent to Fera Science Ltd. for analysis. The address is: Fera Science Ltd., National Agri-Food Innovation Campus, Sand Hutton, York, YO41 1LZ.

Diagnostic procedures

4.11. Positive identification of *A. planipennis* is based on morphological characteristics (see factsheet in Appendix 1) and/or DNA sequencing of adults, larvae or pupae. Adults of *A. planipennis* can be identified using the keys provided in Volkovitsh *et al.* (2019) and by comparing the taxonomic keys from North America that include *A. planipennis* with the taxonomic keys for *Agrilus* species that occur in the UK and Europe (e.g. Bily 1982; Hackston, 2019). See also:

http://www.emeraldashborer.info/files/eab_id_guide.pdf

The following two documents provide further information and guidance on identification:

- Chamorro *et al.* (2013): describes and illustrates the eggs, larvae and pupae of *A. planipennis*.
- Bray *et al*. (2010) provides information on several primers for DNA sequencing and identification of *A. planipennis*. These can be sourced via a number of websites, e.g. http://www.ncbi.nlm.nih.gov/Taxonomy/Browser/wwwtax.cgi

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

Criteria for determining an outbreak

4.12. An outbreak of *A. planipennis* should be declared when a positive identification is associated with either:

a) the discovery of live or dead life-stages in ash trees; or

b) the discovery of live or dead life-stages in ash 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. planipennis* in circumstances where the adults might have had the opportunity to escape into the wider environment.

4.13. The interception of dead specimens in ash 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, at which point the criteria in 4.11 may apply.

Official action to be taken following the confirmation of an outbreak

Strategic actions on confirmation

4.14. 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 communications strategy;
- notify the Devolved Administrations and the EC; and
- inform and discuss with stakeholders.

Incident Management and Communication

4.15. In most instances where the outbreak is in woodland, parkland or the wider countryside, Forestry Commission England 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 Defra contingency plan (Defra, 2017), which will be enacted in response to a confirmed outbreak. Forestry Commission Scotland and the Welsh Government will have similar documents detailing their management of outbreaks.

4.16. The Incident Commander will set up a management structure to deliver the functions of incident management. 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

4.17. A delimiting survey should be set up as soon as possible after the first finding of *A. planipennis* to determine the geographic limits of the infested area and to demarcate a regulated area. The two elements of the delimiting survey are:

- an **intensive survey** of all ash trees 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 ash wood, derived from both small and large material, and live plants with a stem diameter ≥1.5cm; and
- **line transects** outwards to at least 10km, along which visual inspection of ash trees and branch sampling is carried out at regular intervals (e.g. every 100m) to estimate the full extent of spread. Ash trees with any signs of canopy thinning should be carefully inspected for signs of EAB. Chalara ash dieback also causes canopy thinning, although symptoms differ slightly (section 4.8), so particular inspection for the presence of EAB larval activity and D-shaped exit holes is required, employing destructive branch sampling and felling as necessary (this could be initially on a sample basis to establish the spread of the pest). 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 ash 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.

4.18. The surveys should pay particular attention to open-grown ash trees and those growing along the edges of woodlands and should include the inspection of previously cut trunks and branches, cutting residues, and naturally occurring debris showing signs of beetle activity. Samples of ash 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. planipennis,* 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 of removing two branches of 5–8cm diameter from the mid-crown of each tree 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).

4.19. Who should conduct such surveys (including tree felling and inspections) will be determined by the Incident Management Team and will depend on the location and distribution of ash 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, so it may be useful before an outbreak to have contractors identified and sufficiently trained in the required survey protocols. This will require specific call-off contracts to be in place before any outbreak occurs.

4.20. If more trees are found to be infested, the surveys should be extended so that the intensive survey covers all ash trees 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. planipennis* 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.

4.21. 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.

4.22. There is no formal survey protocol in place for surveying *A. planipennis* 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. Different methodologies have been used for assessing the spread of *A. planipennis* in North America and Russia, but in both regions, the pest has become well established and eradication is no longer viewed as an option.

Demarcated zones

4.23. A statutory regulated area should be established as soon as possible after the discovery of an outbreak of *A. planipennis*, 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 ash material should be implemented. These measures should include a prohibition on the movement of untreated ash wood (including firewood, round wood, sawn wood, wood chips, waste wood and arboricultural arisings) and plants for planting of ash. 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.

4.24. Subsequently, the size of the regulated area might need to be increased, to reflect any finds of *A. planipennis* in previously uninfested areas. Relevant parties will be informed of any changes to the regulated area via the communications lead in the Incident Management Team. These would include the stakeholders listed above in paragraph 4.15 as well as local community councils, schools, landowners and neighbours.

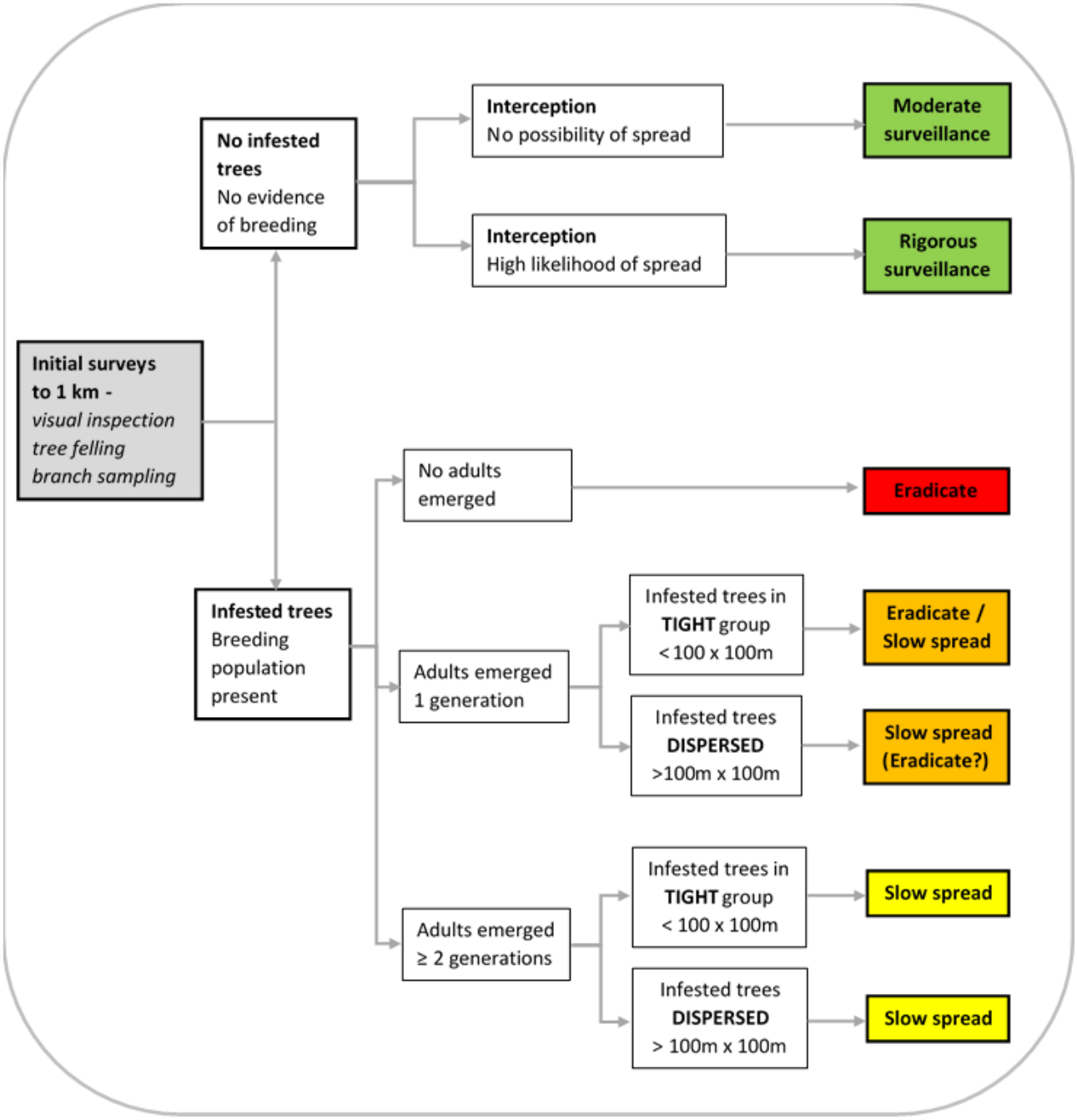
Tracing forwards / backwards

4.25. 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

4.26. 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 ash trees, and how many ash trees are present in the surrounding area. These criteria are summarised in Figure 1.

Figure 1. Management strategies for *Agrilus planipennis*



Various qualifying factors also need to be considered when deciding on the most appropriate course of action (Appendix 2), and these should be considered when using Figure 1.

Pest management procedures

Surveillance

4.27. Following an interception of EAB, if no infested ash 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, perhaps also, the use of girdled trap trees (see 4.36). These follow-up surveys will need to be repeated on an annual basis for at least 2-3 years.

4.28. If the initial delimiting surveys do not find any infested ash trees, 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 4.35. 4.36). The numbers of traps and girdled trees, and their placement, will depend on the abundance and distribution of ash in the surrounding area (see Appendix 2: Factors to consider when developing a management strategy and operational procedures). These surveys will need to be continued for at least 3 years.

Eradication

4.29. If the initial delimiting surveys detect infested ash trees, 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. planipennis* 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 ash 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 ash trees in the surrounding wider environment (Appendix 2). 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.

4.30. Actions focussed on eradication should include:

- felling and destroying (chipping/burning) all ash trees outwards to at least 400m of the infested trees, based on Mercader et al. (2009, 2012) who found that 90% of EAB larvae 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 ash trees are highly attractive to adult *A. planipennis* and if the girdled trees are treated with an insecticide such as emamectin benzoate, then the beetle's life stages are also killed (McCullough & Poland, 2016; McCullough, 2019). A series of girdled and treated trap trees spaced at regular intervals within and around the outbreak would attract and kill many 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.
- traps for adult beetles: green or purple traps baited with the host volatile (z)-3-hexanol. However, 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.

4.31. If the infested trees are found during the beetles' flight period, they must be removed and destroyed as soon as possible to limit adult emergence and dispersal (Appendix 2), 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 mid-July 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).

4.32. 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.

4.33. 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. planipennis* damage, and the bark removed from the basal 50cm of at least two branches per tree to look for galleries and immature life stages (section 4.17). 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. planipennis* material (section 4.9).

4.34. 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 ash within a radius of 400m will need to be felled and removed, as detailed above.

4.35. This process must be repeated on an annual basis for at least 4 years 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, or 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 4.46).

4.36. Traps designed to capture adult *A. planipennis* have been developed in the USA and Canada, and a network of traps across the infested and regulated area will help to monitor occurrence and spread. In the USA, either purple sticky delta traps baited with (Z)-3-hexanol or green multi-funnel traps baited with (Z)-3-hexanol are recommended. In Canada, green delta traps baited with the green leaf volatile (Z)-3-hexanol have been shown to be effective. The addition of lactone to the lures may increase their efficacy.

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. planipennis*. 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 & Polland, 2017). In contrast, the use of trap logs to detect *A. planipennis* does not seem to be effective, because the beetle prefers to attack live standing trees.

4.37. Girdled trees are more effective at detecting low and very low-density *A. planipennis* infestations 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 is 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 is 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 being highly attractive to ovipositing *A. planipennis* (McCullough, 2019).

Slowing the spread and reducing impacts

4.38. If there is evidence that a larger number of ash 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 ash trees at distances of more than 1 km from the initial focus of infestation, and these infested trees will be extremely difficult to locate. *Agrilus planipennis* 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 ash outwards

to 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 2). However, climate change and associated extremely warm summer events are likely to benefit *A. planipennis* and rates of spread may increase in such years.

4.39. The general advice (based on experience in North America) is that clear-cut areas will not ultimately prevent spread, except perhaps in the very earliest stages of an outbreak. It could also remove resistant ash genotypes which might otherwise survive. 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.

4.40. 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 ash trees, to reduce the *A. planipennis* population and slow the rate of spread (Figure 1), particularly during the flight period. In the USA, this is from late May to early July and lasts between three and six weeks (this period may be later in the cooler summer conditions of the UK). By removing only, the worst affected trees, this strategy avoids destroying ash that might be resistant to *A. planipennis* and will also help to maintain populations of natural enemies (parasitoids, predators & entomopathogens) that in the long-run may provide considerable control of the pest's population.

4.41. Under a slowing-the-spread strategy, therefore, as soon as possible after an outbreak is discovered, and at least annually thereafter, all ash trees within the known infested area should be assessed during mid to late summer for canopy thinning and dieback, e.g. by using the scale illustrated by Smitley *et al.* (2008). All trees with more than 50% canopy thinning 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 4.49). Trees that are felled should be inspected to confirm whether *A. planipennis* is present, and this information should be forwarded to Forest Research and Defra, where it will be used to help monitor spread.

4.42. Annual surveys will be required to monitor the spread of *A. planipennis*, to redefine the infested area and the boundaries of the regulated area, and to

distinguish trees impacted by EAB infestation rather than just Chalara dieback (section 4.8). Surveys of canopy thinning and branch dieback, accompanied by identification of EAB 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.

4.43. Assessing trees for canopy thinning and dieback can be based on visual, ground-based surveys, and should be accompanied by inspection for EAB activity. Girdled trees and traps (see 4.32, 4.33) 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).

4.44. Prophylactic application of chemical insecticides by injection can be effective at reducing attacks by *A. planipennis* and can also 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.

4.45. "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 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.

4.46. Likewise, four species of parasitoid wasp originating in Asia (*Spathius agrili*, *Spathius galineae*, *Tetrastichus planipennisi* and *Oobius agrili*) have been released in the USA as a means of controlling *A. planipennis* larvae (Duan et

al., 2018). However, it is not known how effective this control method would be in the UK.

4.47. 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 in a European context on wild *Fraxinus excelsior*. Such information is crucial for slowing the spread, as well as informing other work on surveying for pests such as bronze birch borer, *Agrilus anxius*.

Disposal plan

4.48. Ash trees felled to reduce *A. planipennis* 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. planipennis* life-stages, or showing signs of infestation, should be destroyed in the same way. All equipment used in the disposal of *A. planipennis*-infested trees should be thoroughly cleaned between sites to remove any wood chips in particular, as per standard biosecurity protocols.

4.49. During the *A. planipennis* flight period (May, June & July), 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, between early August and the end of April, trees need not be destroyed immediately, but they must be chipped/burned before the start of the next flying period.

4.50. 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.

4.51. 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. planipennis* 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)

4.52. 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

4.53. 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.

4.54. 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

4.55. Where eradication is unsuccessful, i.e. where new infestations continue to be found at greater and greater distances from the initial site of infestation, efforts should shift to slowing the spread of the pest and managing its impact. 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

4.56. This and other contingency plans will be reviewed on a regular basis to accommodate any significant changes in pest/pathogen 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. planipennis* 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).

4.57. 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.

5. Recovery

5.1. Eradication is unlikely to be achieved if *A. planipennis* is found in the wider environment, except under very restrictive circumstances, and therefore there is no scope for recovery to pre-outbreak conditions. Alternative species to ash could be planted to help restore woodland and urban landscapes.

5.2. Replanting with 'resistant' ash may be an option if *A. planipennis*-resistant ash can be identified and propagated. However, the resistance of any replanted trees to Chalara ash dieback would also need to be considered.

Appendix 1: Factsheet for *Agrilus planipennis*

Background information

Identity of organism and quarantine status

Species name: *Agrilus planipennis* Fairmaire, 1888 (Coleoptera: Buprestidae)

Synonyms: *Agrilus feretrius* Obenberger, 1936; *Agrilus marcopoli* Obenberger, 1930; *Agrilus ulmi* Kurosawa, 1956

Common name: Emerald ash borer

UK Risk Register Rating: Unmitigated 125/125; Mitigated 75/125

EU status: *Agrilus planipennis* is listed under the new EU Plant Health regulations (Regulation (EU) 2016/2031) as a priority pest whose introduction into and movement within all Member States shall be banned, and on the EPPO A2 List of pests recommended for regulation.

Hosts

European species known to be a host in the wider environment:

Fraxinus excelsior

European species that are potential hosts:

Fraxinus angustifolia
Fraxinus ornus

Hosts in North America:

Fraxinus americana
Fraxinus nigra
Fraxinus pennsylvanica (also a host in Russia and Ukraine)
Fraxinus profunda
Fraxinus quadrangulata
Fraxinus velutina
Chionanthus virginicus (White Fringetree) (secondary host)

Hosts in the native region in East Asia:

Fraxinus chinensis
Fraxinus lanuginosa
Fraxinus mandshurica*
(* includes *F. mandshurica* var. *japonica* & var. *rhynchophylla*)

Spurious hosts:

Juglans mandshurica
Pterocarya rhoifolia
Ulmus davidiana
Ulmus parvifolia

Spurious hosts are those that have been mentioned in the literature, but for which the evidence for supporting *A. planipennis* is unreliable. In this case two papers have mentioned these species as hosts, but neither could be accessed as of November 2019. Both papers discuss hosts in Japan, but no *Juglans, Pterocarya* or *Ulmus* has ever been recorded as a host in either the North American or European outbreaks. These hosts should not be considered in the initial surveys for *A. planipennis* should it be found established in the UK.

Otherwise, given that no *Fraxinus* is known to be totally resistant to *A. planipennis*, all *Fraxinus* species should be considered as a potential host until proven otherwise.

References for host lists: Akiyama & Ohmomo (1997), Sugiura (1999), Rebek *et al*. (2008), Baranchikov *et al*. (2014), Cipollini, D. (2015).

Ash species native to North America, especially *F. pennsylvanica*, are highly susceptible to *A. planipennis* and are usually killed within a few years. In urban areas and woodlots in the USA, up to 98-100% mortality of ash trees has been recorded (Knight et al., 2013; Kloosters et al., 2014; Steiner et al., 2019). In contrast, ash species from eastern Asia (*F. chinensis*, *F. lanuginose*, *F. mandshurica*), which have co-evolved with *A. planipennis*, are highly resistant and only attacked when severely stressed or dying (Rebek et al., 2008; Herms, 2015).

The susceptibility of European ash, particularly *F. excelsior*, is not entirely clear, but is probably intermediate between that of the North American ash species and the Asian ash species. Observations in Russia suggest that *F. excelsior* is only attacked by *A. planipennis* when it is under stress (e.g., because of drought) or when it is growing near heavily infested *F. pennsylvanica* (Straw et al., 2013; Orlova-Bienkowskaja et al., 2020). Common garden experiments in the USA, however, indicate that *F. excelsior* and other European ash species are as readily attacked and killed by *A. planipennis* as the North American species (Herms, 2015; McCullough, 2019). Young trees planted in common garden experiments outside their natural range can be more susceptible to attack than trees growing in the native region, and therefore the results of the common garden experiments need to be interpreted with some caution.

Life cycle

Larvae of *A. planipennis* tunnel beneath the bark of ash trees and feed on the cambium and outer sapwood. The tunnels disrupt the transport of water and nutrients, and effectively girdle the branches and stem, which then die above this area of infestation.

In eastern North America, the adult beetles are active from mid-May through to the end of June. The adults are 8.5-14mm long and 3.1-3.4mm wide. The body is narrow and elongate, fusiform, and metallic blue green. Most live for about three weeks, feeding on ash foliage and chewing out small, irregularly shaped pieces from around the margins of the leaves. At least a few days of feeding are required before the adult beetles mate, and 1–2 weeks of feeding can be required before the females begin to lay eggs (CABI 2015).

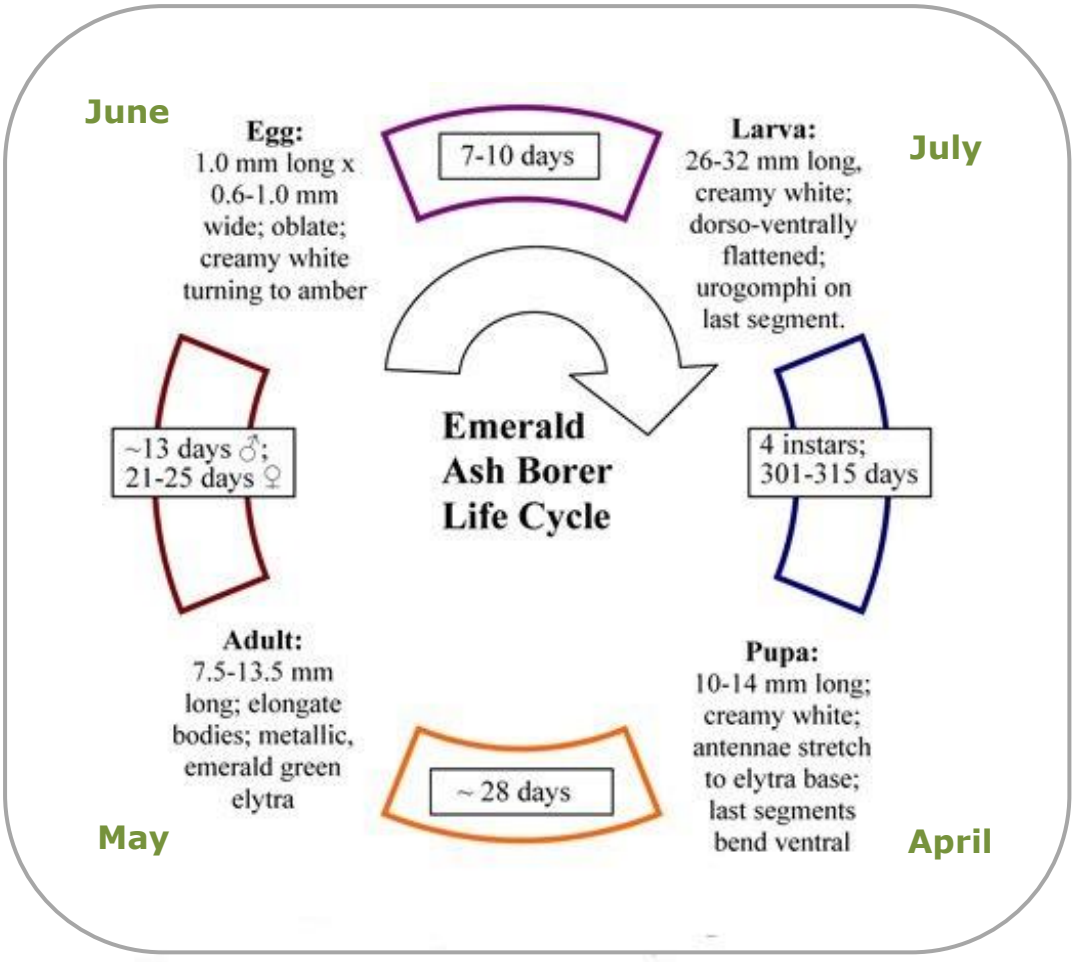


Figure 2 – typical one-year life cycle of *A. planipennis* in the eastern United States (Source: USDA emerald ash borer programme manual). In regions with a cooler climate, which includes the Moscow region of European Russia and potentially north-western Europe, many larvae overwinter twice and the life cycle may take two years.

The adult beetles emerge in May (possibly later in cooler climates) by chewing an exit hole through the bark. The exit holes produced by *Agrilus* species are D-shaped, i.e. with one flat and one curved side. Those produced by *A. planipennis* are relatively large and 3–4mm wide. The presence of D-shaped exit holes in branches and the main stem of an ash tree is an indication that the tree is infested by a species of buprestid beetle (CABI 2015).

Identification

The four life stages of *A. planipennis* are egg, larvae, pupae and adult. Eggs are usually less than 1mm long and orange coloured.

There are four larval instars. Larvae are white or cream-coloured, elongate and flattened, and the lateral margins are characteristically saw-toothed in outline. When fully developed they measure 26–32mm long.

Figure 3 – Eggs of *A. planipennis* Source: D. Cappaert, Forestryimages.org

Figure 4 - *A. planipennis* larvae Source: K. Law, USDA

Figure 5 – *A. planipennis* pupae. Source: D.B. Lyons, Canadian Forest Service

Figure 6 – Adult *A. planipennis*. Source: L. Bauer, USDA Forest Service

Pupae are naked (i.e. there is no pupal case) and are formed directly under or within the bark. As they mature, they change colour from white to the metallic green colour of the adult form.

A. planipennis are typical buprestid beetles. They have elongated, fusiform (bullet-shaped) bodies, and are a bright metallic green or purple colour. They can be identified using morphological characteristics or by DNA sequencing

There are currently nine known species of *Agrilus* established in the UK that might be confused with *A. planipennis* (Duff, 2012; Hackston, 2019). None of these are normally found in ash trees, although *A. viridis* has been recorded from *Fraxinus* species in Europe and *A. cyanescens* has been recorded from *Fraxinus ornus* (Jendek & Poláková, 2014). Any insect damage in ash that looks as though it might have been caused by an *Agrilus* species should be considered as highly suspicious and should be investigated in all cases.

Volkovitsh *et al*. (2019) provides a morphological key for distinguishing adults of *Agrilus planipennis* from adults of the larger native European *Agrilus* species. This and other taxonomic keys, along with a reference collection, can be used by experienced entomologists to confirm identification.

Damage and other typical signs of infestation are illustrated by Scarr *et al* (2002), de Groot *et al.* (2006), and McCullough *et al*. (2008). See also:

- Biology and Control of Emerald Ash Borer (Van Driesche & Reardon, 2015: https://www.fs.fed.us/foresthealth/technology/pdfs/FHTET-2014-09_Biology_Control_EAB.pdf
- Emerald ash borer information (2019): http://www.emeraldashborer.info/index.cfm
- USDA-APHIS (2018): https://www.aphis.usda.gov/plant_health/plant_pest_info/emerald_ash_b/downloads/survey_guidelines.pdf
- Canadian Food Inspection Agency (CFIA) (2019). Emerald ash borer: http://www.inspection.gc.ca/plants/plant-protection/insects/emerald-ash-borer/eng/1337273882117/1337273975030

It is difficult to distinguish canopy thinning and dieback in the early phases of *A. planipennis* infestation from the same symptoms caused by other factors, such as competition, drought stress, and disease such as Chalara dieback of ash. Consequently, reports and enquiries of possible *A. planipennis* damage require checking and verification by experts.

Distribution

Agrilus planipennis is native to north-east China, Korea, Mongolia, Japan and the Russian Far East. It has been introduced into North America and the European part of Russia (Moscow region). The outbreak in Russia is spreading and in 2019 the pest was established at Tver (155 km north-west of Moscow), Smolensk (400 km west of Moscow) and Volgograd (900 km south and east of Moscow) (Straw *et al*., 2013; Orlova-Bienkowskaja et al., 2020). Spread has been most rapid toward the south and south-west and in July 2019, *A. planipennis* was recorded for the first time from Ukraine (700 km south-west of Moscow) (Drogvalenko et al., 2019; Orlova-Bienkowskaja et al., 2020).

The current world distribution map for *A. planipennis* provided by EPPO is reproduced below. The record of *A. planipennis* in western China (Xinjiang) is recent (2016) and is probably a new introduction rather than an expansion of the pest's native range. The map includes the recent (2019) finding of *A. planipennis* in Ukraine (purple dot).

A map of the distribution of *A. planipennis* in North America is available at: http://www.emeraldashborer.info/files/MultiState_EABpos.pdf

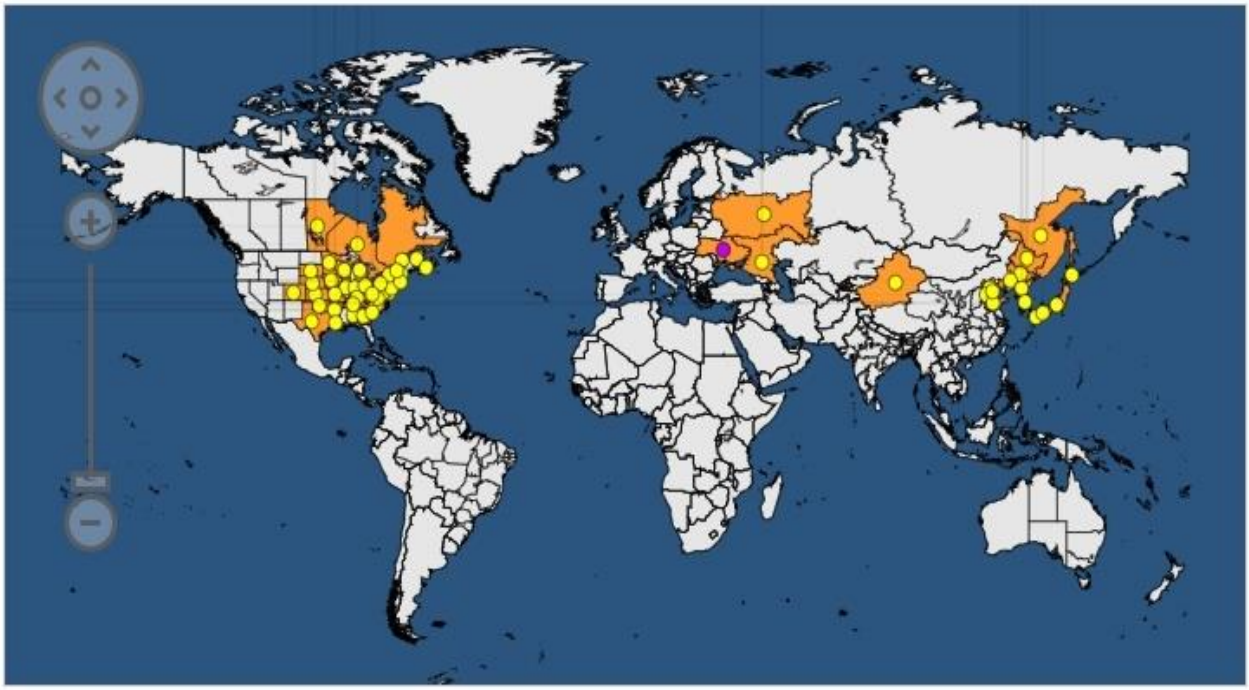


Figure 7 – World distribution of *A. planipennis* as of July 2019 (Source: https://gd.eppo.int/taxon/AGRLPL/distribution)

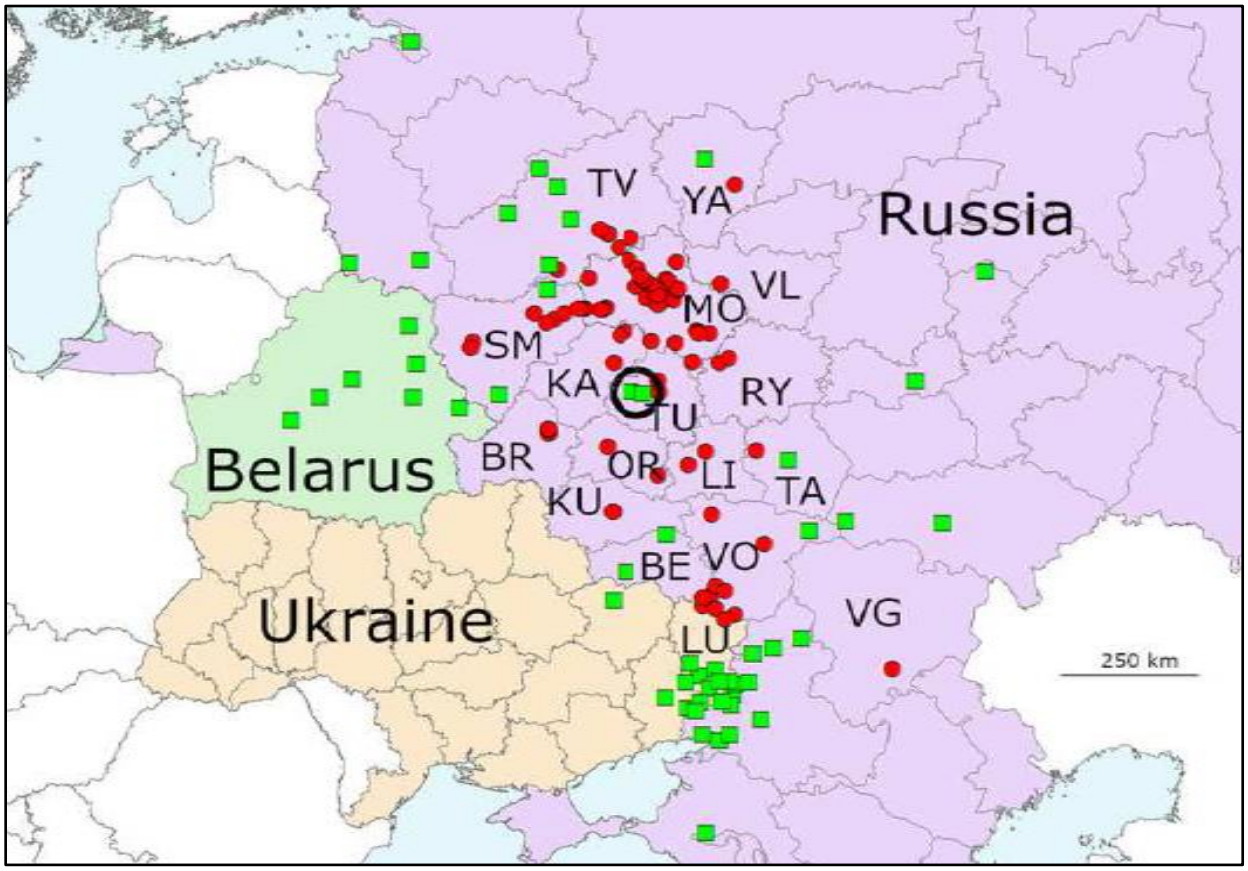


Figure 8 - Range of *Agrilus planipennis* in European Russia (R) and Ukraine (U) in 2019. The red points indicate localities where EAB was detected, the green squares indicate localities where it was not detected during surveys in 2017-2019. The black circle indicates the location of surveys of *Fraxinus excelsior* in Tulskie Zaseki Forest. (Source: Orlova-Bienkowskaja et al., 2020).

Regions: BR – Bryansk (R), BE – Belgorod (R), KA – Kaluga (R), LI – Lipetsk (R), LU – Luhansk (U), MO – Moscow (R), OR – Orel (R), RY – Ryazan (R), SM – Smolensk (R), TA – Tambov (R), TU – Tula (R), TV – Tver (R), VG – Volgograd (R), VL – Vladimir (R), VO – Voronezh (R), and YA – Yaroslavl (R).

Damage, impact and control methods

In its native range (China and other countries in East Asia) *A. planipennis* is a minor secondary pest of the local ash species *Fraxinus mandshurica* and *F. chinensis,* and only attacks severely stressed and dying ash trees. It is not particularly common and is not subject to any controls.

In contrast, in its introduced range in North America and European Russia, *A. planipennis* is highly damaging to ash, and has caused extensive and widespread mortality. Hundreds of millions of ash trees have been killed in the United States and Canada, with mortality rates of 99% observed amongst *F. pennsylvanica*, *F. americana* and *F. nigra*. In the Moscow region of Russia, *A. planipennis* has killed more than 1 million *F. pennsylvanica* along roadsides and in parks and gardens, and it has also attacked *F. excelsior*. Trees are typically killed within three to four years of initial attack.

Signs and symptoms of infestation are described in the PRA and datasheet for *A. planipennis*. They include:

- yellowing and thinning foliage
- dying branches
- dieback and mortality of whole trees
- frass-filled, sinuous larval galleries under the bark
- D-shaped exit holes 3–4mm wide
- the presence of *A. planipennis* life-stages in the trees

Figure 8 – Larval galleries of *Agrilus planipennis*. Source: A. Wagner, USDA Forest Service Agency

Figure 9 – Canopy thinning and dieback associated with *Agrilus planipennis* damage. Source: Forest Research

Figure 10 – Typical D-shaped exit hole associated with emergence of adult *A. planipennis*. Source: W. Ciesla, Forest Health Management Int.

Official control measures in North America have included large-scale sanitation felling, the use of chemical insecticides, and restrictions on the movement of plants for planting and ash wood (especially firewood). However, these measures have not prevented *A. planipennis* from spreading, and they have had little effect on the total numbers of trees killed. The aim of current management strategies in North America is to try to slow down the rate of spread and the progression of ash mortality by employing as wide a range of survey and control measures as possible. These measures include biological control through the introduction and release of four species of parasitoid wasp from the native region of *A. planipennis* in China and the Far East of Russia (Duan et al., 2018).

Some infested trees have been felled in the Moscow region of Russia, primarily for safety reasons, but otherwise no official control measures have been implemented to try to contain the outbreak or to reduce its impact. The pest is not regulated in Russia.

Main pathways for entry and further spread

A. planipennis has been shown to move along a number of different pathways. In North America, infested crating, dunnage or pallets are suspected to have been responsible for the initial introduction. *A. planipennis* then spread naturally and through human-assisted pathways, the latter including the movement of infested ash logs, firewood (identified as one of the most important long-distance pathways in North America) and nursery plants. USDA-APHIS (2018) also identifies timber, wood chips and mulch (composted and un-composted) as further potential pathways.

A. planipennis was well established in Moscow by 2003 and might have been introduced initially in the late 1990s (Izhevskiy and Mozolevskaya, 2010). Up to 2005, the rate of spread was estimated to be about 4km a year^{-1}, and subsequently it has been estimated to be 10–12km a year^{-1} (Baranchikov and Kurteev, 2012). The rate of spread between 2009 and 2013 was much greater and suggests an increase in the rate at which the outbreak was expanding, at least to the west and south (Straw et al., 2013). The current distribution of *A. planipennis* in southern Russia and Ukraine suggests that the pest is dispersing considerably faster in the south. The earlier estimates of spread are within the natural dispersal capabilities of *A. planipennis*. Even though most adult female *A. planipennis* lay their eggs within a few hundred metres of their point of emergence (Mercader et al., 2009; Siegert et al., 2010), they have the capacity to fly up to 10km over several days (Taylor et al., 2010).

The original outbreak of *A. planipennis* in Michigan, in the USA, spread initially at a rate of 10–11km a year^{-1}, primarily at that time through natural dispersal (Smitley et al., 2008). Subsequently, the *A. planipennis* outbreak in the United States has expanded at a rate of more than 20km a year^{-1} and this can only have been achieved through human-assisted movements. In North America this appears to involve particularly the transport and redistribution of firewood from infested to un-infested areas (Muirhead et al., 2006).

Information on pathways is summarised in the PRA for *A. planipennis* (EPPO 2013) and the EPPO datasheet and CABI datasheet.

The pathways covered include the importation and movement of:

- ash wood with and without bark, including round wood, sawn wood and firewood;
- ash plants for planting;
- waste wood, scrap wood and hardwood wood chips, including wood fuel;

- wood packaging material; and
- ash foliage.

A. planipennis adults can also be spread by 'hitch-hiking' in or on vehicles.

A. planipennis attacks ash trees of all ages and sizes, and larvae have been found in branches with a diameter of 1–2cm. Consequently, all ash wood, derived from both small and large material, and live plants with a stem diameter greater than 1.5cm, can contain *A. planipennis* life-stages and will need regulation. The EPPO pest risk analysis identifies all stems and branches of more than 1.5cm diameter as capable of being infested (EPPO, 2013).

Once introduced and established, *A. planipennis* can spread rapidly through natural dispersal, irrespective of any human-assisted movement. The adult beetles are strong flyers and flight mill studies indicate that the adults can travel more than 1km in a single flight, and between 10 and 20km over several days. Evidence suggests that mated females in particular fly further than males and non-mated females, which raises further concerns about spread of the pest (Taylor *et al* 2010).

Import restrictions are in place on wood of ash into the U.K: Importing and exporting wood and timber products

Statutory notification scheme for landing consignments of solid fuel wood (firewood)

The statutory notification scheme (SNS) for landing consignments of solid fuel wood (firewood) was introduced via the Plant Health (Forestry) (Amendment) (England and Scotland) Order 2016 (SI No.1167) and came into force on 1 January 2017.

http://www.legislation.gov.uk/uksi/2016/1167/contents/made

The SNS is now included in the following current legislation:

The Official Controls (Plant Health and Genetically Modified Organisms) (England) Regulations 2019

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

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

The notification scheme for firewood does not alter procedures for importers of controlled firewood imported from third countries, because these imports are already subject to advanced notification of landing requirements.

The Forestry Commission has introduced a specific requirement in respect of firewood (solid fuel wood), not previously subject to regulation, via SNS. The SNS requires imports of firewood into England and Scotland, regardless of species or country of origin, to be notified to the Forestry Commission. All relevant consignments, irrespective of size or weight must be notified.

Imports of controlled species (mainly conifers, birch, oak, ash, maple, plane and poplar/aspen) of firewood from certain third countries must already be notified in advance to the Forestry Commission. The new notification scheme extended this pre-notification requirement to all other imports of non-controlled firewood from third countries and to controlled and non-controlled imports from the EU.

The information gathered from the notifications of ash firewood into GB from EU countries and non-EU countries where EAB is not yet present and targeted inspections will provide an early warning of pathways that may need to be regulated.

During 2018/19, a total of 4,050 notified consignments of all species were received, of which 136 were inspected. Inspections are mainly undertaken using a risk-based approach, focusing on regulated species and ash from outside the EU.

The firewood import market is dominated by birch, ash, oak and alder which are declared as originating in the EU, predominately from Latvia (61%). Inspection results are relatively favourable with most of the firewood and associated WPM being compliant. 80% of the firewood notified had been kiln dried to below 20% moisture content. Sixteen out of the 136 consignments inspected were found to be non-compliant; 14 were associated with the WPM and 2 with containerised conifer kindling. No live insect activity was detected on any of the intercepted consignments.

Firewood tonnage and species from individual countries, 2018/19

Country & Species	Quantity per species (Tonnes)
Egypt	**186**
Olive wood, Olea	186

Estonia	**3,794**
Alder, Alnus	0.0
Ash, Fraxinus	1733
Ash, Fraxinus /Birch, Betula	25
Ash, Fraxinus /Oak, Quercus /Birch, Betula	25
Birch, Betula	1,888
Birch, Betula /Oak, Quercus	25
Oak, Quercus	98
France	**50**
Beech, Fagus	49
Elm, Ulmus minor	0.5
Locust Tree, Robinia pseudoacacia	0.5
Oak, Quercus	0.3
Germany	**2,572**
Alder, Alnus	72
Ash, Fraxinus	500
Beech, Fagus	1,000
Birch, Betula	500
Oak, Quercus	500
Ghana	**1585**
Wawa, T. Screroxylon	1,585
Holland	**3**
Conifer	3
Indonesia	**13**
Alder, Alnus	13
Ireland	**25**
Fir, Abies	25
Jamaica	**0.4**
Pimento	0.4
Latvia	**6,6730**
Alder, Alnus	7,714
Alder, Alnus /Ash, Fraxinus	96
Alder, Alnus /Birch, Betula	1297
Ash, Fraxinus	7,584
Ash, Fraxinus /Birch, Betula	378
Ash, Fraxinus /Birch, Betula /Oak, Quercus	146
Ash, Fraxinus /Oak, Quercus	1890
Ash, Fraxinus /Oak, Quercus /Birch, Betula	73
Ash, Fraxinus /Oak, Quercus /Birch, Betula /Alder, Alnus	48
Beech, Fagus	6
Birch, Betula	3,8701

Birch, Betula /Ash, Fraxinus /Oak, Quercus /Pine, Pinus	28
Birch, Betula /Oak, Quercus	578
Fir, Abies	100
Hornbeam, Carpinus	24
Maple/Sycamore, Acer	5
Mixed hardwoods	95
Oak, Quercus	3,019
Other*	48
Pine, Pinus	2518
Pine, Pinus/Spruce, Picea	2,898
Softwood	9
Spruce, Picea	1,042
Unknown	84
Alder, Alnus / Birch, Betula/ Poplar/Aspen, Populus	25.0
Oak, Quercus/ Alder, Alnus	25.5
Lithuania	**21,835**
Alder, Alnus	587
Alder, Alnus /Birch, Betula	964
Ash, Fraxinus	7,960
Ash, Fraxinus /Birch, Betula	264
Ash, Fraxinus /Birch, Betula /Hornbeam, Carpinus	49
Ash, Fraxinus /Birch, Betula /Oak, Quercus	97
Ash, Fraxinus /Oak, Quercus	73
Ash, Fraxinus /Oak, Quercus /Birch, Betula	50
Ash, Fraxinus /Oak, Quercus /Birch, Betula /Alder, Alnus	12
Beech, Fagus	22
Birch, Betula	9,638
Birch, Betula /Oak, Quercus	98
Birch, Betula /Unknown	25
Douglas fir, Pseudotsuga menziesii	1
Fir, Abies	49
Hornbeam, Carpinus	203
Oak, Quercus	1,563
Other*	17
Pine, Pinus	5
Pine, Pinus/Spruce, Picea	0.5
Spruce, Picea	11
Unknown	3
Ash, Fraxinus /Hornbeam, Carpinus	48
Birch, Betula /Hornbeam, Carpinus	24
Birch, Betula/ Spruce, Picea	25

Ash, Fraxinus /Birch, Betula/ Spruce, Picea	49
N. Ireland	**392**
Fir, Abies	392
Norway	**2,002**
Ash, Fraxinus	100
Beech, Fagus	200
Birch, Betula	1,502
Oak, Quercus	200.0
Poland	**4,539**
Alder, Alnus	26
Alder, Alnus /Birch, Betula	96
Ash, Fraxinus	307
Ash, Fraxinus /Beech, Fagus/Oak, Quercus /Maple, Acer	49
Ash, Fraxinus /Oak, Quercus /Birch, Betula	24
Beech, Fagus	1,002
Beech, Fagus /Oak, Quercus	49
Birch, Betula	188
Birch, Betula /Oak, Quercus	190
Birch, Betula /Oak, Quercus /Alder, Alnus	288
Birch, Betula /Oak, Quercus /Maple, Acer	360
Maple/Sycamore, Acer	257
Mixed hardwoods	75
Oak, Quercus	425
Pine, Pinus	1,108
Poplar/Aspen, Populus	59
Spruce, Picea	13
Pine, Pinus/ Poplar/Aspen, Populus	24
Portugal	**4.6**
Mixed hardwoods	0.8
Olive wood, Olea	3.8
South Africa	**303**
Camel/Giraffe thorn, Vachellia erioloba	43
Mopane, Colophospermun mopane	18
Pine, Pinus	84
Poplar/Aspen, Populus	35
Sicklebush (Dichrostachys cinerea)	16
Wattle wood, Acacia	107
Spain	**24**
Beech, Fagus	24
Ukraine	**1,423**
Ash, Fraxinus	73

Ash, Fraxinus /Oak, Quercus	26
Beech, Fagus	286
Beech, Fagus /Oak, Quercus	36
Birch, Betula	27
Conifer	1
Hornbeam, Carpinus	226
Oak, Quercus	580
Oak, Quercus/Beech, Fagus/Hornbeam, Carpinus	142
Ash, Fraxinus /Oak, Quercus /Hornbeam, Carpinus	26
Undeclared*	**4,159**
Alder, Alnus	368
Ash, Fraxinus	821
Ash, Fraxinus /Birch, Betula	96
Beech, Fagus	24
Birch, Betula	2,278
Hornbeam, Carpinus	34
Oak, Quercus	204
Pine, Pinus	312
Wawa, T. Screroxylon	20
USA	**5.7**
Hickory	4.6
Maple/Sycamore, Acer	0.0
Mesquite (Prosopis)	1.1

Appendix 2. 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 EAB 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 ash	Small numbers of ash trees in the vicinity will be easier to survey and remove but may have resulted in EAB dispersing greater distances to locate hosts. Large numbers of ash trees and blocks of ash woodland close to the outbreak site will be more difficult to survey and infested trees may be missed, but EAB 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 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-mid July	Infested trees and all other ash 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

	Outside flight period: August through to April of the following year.	demands on resources. 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 ash present in a wide range of habitats and situations, e.g. as individual trees, in hedgerows and in woodlands. Urban areas characterised by large numbers of small, private ownerships. Ash present in gardens, as street trees, in parks and other public open spaces. Nature conservation sites / SSSIs	Ash in rural areas generally easier to access and remove, but there are likely to be many more ash trees. Therefore, operations may be more challenging than liaison. More resources required to liaise with landowners in urban areas and it will be more difficult to remove ash trees from gardens, but there are likely to be fewer ash trees. Therefore, liaison may be more challenging than operations. May require special considerations in relation to retention of ash.
Ash dieback	Ash dieback (*Hymenoscyphus fraxineus*) produces similar symptoms (canopy thinning, foliage yellowing, branch dieback) to EAB infestation and may make it more difficult to locate EAB. On other hand, trees affected by ash dieback may be more susceptible to EAB, making infestation in these trees easier to detect.	Monitor the situation in Europe where EAB and *H. fraxineus* co-occur to determine whether ash dieback increases or decreases susceptibility to EAB. If ash dieback is also affecting the trees, surveys will need to be conducted particularly carefully to detect EAB, which may increase survey costs. Resources allocated to felling

		trees because of ash dieback may restrict resources available to combat EAB. Alternatively, combined efforts against ash dieback and EAB may prove to be more cost effective than dealing with the disease or pest alone.
Site conditions	Stressed ash on poor, dry sites is likely to be particularly susceptible to EAB, compared with healthy ash growing on good sites. However, although ash on good sites may be less susceptible, it may harbour cryptic infestations for longer before detection.	Surveys to detect EAB should pay particular attention to ash on poor sites, where EAB may establish more readily and its populations increase more rapidly. Detecting low density EAB infestations amongst healthy ash trees may be particularly difficult and time consuming.
Climate	Warm climate, e.g., south and SE England: most EAB complete 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. Cool climate, e.g., north England & Scotland: EAB more likely to have a 2-year life cycle; populations increase more slowly, and dispersal is less rapid and occurs over shorter distances.	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 they release beetles or become a H&S risk. Slower rates of population increase, and dispersal make it more likely that the pest can be eradicated or prevented from spreading.

Appendix 3: 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.

References

Akiyama K., Ohmomo S. (1997) A checklist of the Japanese Buprestidae. Gekkan-Mushi (Supplement 1). 67 pp.

Baranchikov Y., & Kurteev V.V. (2012) Area invaded by the emerald ash borer in Europe: no change on the western front? Conference proceedings of Ecological and Economic Consequences of Invasions of Dendrophilous Insects. Papers presented at an All-Russian and International Conference in Krasnoyarsk; 25–27 September 2012. 2012. pp. 91-94. (in Russian).

Baranchikov, Y.N., Seraya, L.G., & Grinash, M.N. (2014) All European ash species are susceptible to emerald ash borer *Agrilus planipennis* Fairmaire (Coleoptera: Buprestidae)–a Far Eastern invader. Siberian Journal of Forest Science 6, 80-85 (in Russian with English abstract).

Bily S. (1982) The Buprestidae (Coleoptera) of Fennoscandia and Denmark: Fauna Entomologica Scandinavica Vol. 10. Scandinavian Science Press Ltd

Bray A.M., Bauer L.S., Poland T.M., Haack R.A., Cognato A.I. & Smith J.J. (2011). Genetic analysis of emerald ash borer (*Agrilus planipennis* Fairmaire) populations in Asia and North America. Biological Invasions 13, 2869–2887.

CABI Invasive Species Compendium. *Agrilus planipennis* (emerald ash borer). Datasheet 3780: https://www.cabi.org/isc/datasheet/3780

Chamorro, M.L., Volkovitsh, M.G., Poland, T.M., Haack, R.A. & Lingafelter, S.W. (2013) Preimaginal stages of the emerald ash borer, *Agrilus planipennis* Fairmaire (Coleoptera: Buprestidae): an invasive pest on ash trees (*Fraxinus*). PLoS ONE 7 (e33185)

Cipollini, D. (2015) White Fringetree as a novel larval host for emerald ash borer. J. Econ. Entomol. 108, 370-375.

de Groot, P., Biggs, W.D., Lyons, D.B., Scarr, T., Czerwinski, E., Evans, H.J., Ingram, W. & Marchant, K. (2006) *A Visual Guide to Detecting Emerald Ash Borer Damage*. Canadian Forest Service, Ontario, Canada, 16 pp.

Drogvalenko, A.N., Orlova-Bienkowskaja, M.J. & Bienkowski, A.O. (2019) Record of the emerald ash borer (*Agrilus planipennis*) in Ukraine is confirmed. Insects 10. DOI:10.3390/insects10100338

Duan, J.J., Bauer, L.S., van Driesche, R.G. & Gould, J.R. (2018) Progress and challenges of protecting North American ash trees from the emerald ash borer using biological control. Forests 9, 142-159.

Duff, A.G. (Ed) (2012) Checklist of Beetles of the British Isles. Pemberley Books, Iver.

EPPO (2013) Draft Pest Risk Analysis for *Agrilus planipennis* Fairmaire, 1888. Prepared by the Expert Working Group on *A. planipennis*, 28-31 January 2013.

Haack R.A., Jendek E., Liu H., Marchant K.R., Petrice T.R., Poland T.M., & Ye H. 2002. The emerald ash borer: a new exotic pest in North America. Newsletter of the Michigan Entomological Society 47(3-4), 1-5.

Hackston, M. (2019) A key to the British species of family Buprestidae (Coleoptera). https://sites.google.com/site/mikesinsectkeys/Home/keys-to-coleoptera/buprestidae

Herms, D.A. (2015) Host range and host resistance. In: Van Driesche, R.G. & Reardon, R.C. (Eds.) Biology and Control of Emerald Ash Borer. USDA Forest Technology Enterprise Team, Morgantown, WV FHTET-2-14-09. Available at: https://www.fs.fed.us/foresthealth/technology/pdfs/FHTET-2014-09_Biology_Control_EAB.pdf

Herms, D.A., McCullough, D.G., Clifford, C.S., Smitley, D.R., Miller, F.D., Cranshaw, W. (2019) Insecticide options for protecting ash trees from emerald ash borer. North Central IPM Center Bulletin. 3rd Edition. 16 pp. http://www.emeraldashborer.info/documents/Multistate_EAB_Insecticide_Fact_Sheet.pdf

Izhevskiy S.S., & Mozolevskaya E.G. (2010) *Agrilus planipennis* Fairmaire in Moscow ash trees. Russian Journal of Biological Invasions 1, 153-155.

Jendek, E. & Poláková, J. (2014). *Host Plants of World Agrilus (Coleoptera, Buprestidae): A Critical Review.* Springer. 706 pp.

Klooster, W.S., Herms, D.A., Knight, K.S., Herms, C.P., McCullough, D.G., Smith, A., Gandhi, K.J.K. & Cardina, J. (2014) Ash (*Fraxinus* spp.) mortality, regeneration, and seed bank dynamics in mixed hardwood forests following invasion by emerald ash borer (*Agrilus planipennis*). Biological Invasions 16, 859-873.

Knight, K.S., Brown, J.P. & Long, R.P. (2013) Factors affecting the survival of ash (*Fraxinus* spp.) trees infested by emerald ash borer (*Agrilus planipennis*). Biological Invasions 15, 371-383.

McCullough, D.G., Schneeberger, N.F. & Katovich, S.A. (2008) *Pest alert: emerald ash borer.* USDA Forest Service Northeastern Area. NA-PR-02-04.

McCullough, D.G., Polland, T.M. & Lewis, P. (2016) Lethal trap trees: a potential option for emerald ash borer management. Pest Manage. Sci. 72, 1023-1030.

McCullough, D.G. & Polland, T.M. (2017) Building double-decker traps for early detection of emerald ash borer. J. Visualized Exp. 128, e55252. DOI:10.3791/55252.

McCullough, D.G. (2019) Challenges, tactics and integrated management of emerald ash borer in North America. Forestry, DOI:10.1093/forestry/cpz049

Mercader R.J., Siegert N.W., Liebhold A.M., & McCullough D.G. (2009) Dispersal of the emerald ash borer, *Agrilus planipennis*, in newly colonised sites. Agricultural and Forest Entomology 11, 421-424.

Mercader R.J., McCullough, D.G. & Bedford, J.M. (2013) A comparison of girdled ash detection trees and baited artificial traps for emerald ash borer (*Agrilus planipennis* Fairmaire) detection. Environmental Entomology 42, 1027-1039.

Mercader R.J., McCullough, D.G., Storer, A.J., Bedford, J.M., Heyd, R., Poland, T.M. et al. (2015) Evaluation of the potential use of a systemic insecticide and girdled trees in area wide management of the emerald ash borer. Forest Ecology & Management 350, 70-80.

Mercader R.J., McCullough, D.G., Storer, A.J., Bedford, J.M., Heyd, R., Siegert, N.W., et al. (2016) Estimating local spread of recently established emerald ash borer, *Agrilus planipennis*, infestations and the potential to influence it with a systemic insecticide and girdled ash trees. Forest Ecology & Management 366, 87-97.

Muirhead J.R., Leung B., van Overdijk C., Kelly D.W., Nandakumar K., Marchant K.R., & Maslaac H.J. (2006). Modelling local and long-distance dispersal of invasive emerald ash borer *Agrilus planipennis* (Coleoptera) in North America. Diversity and Distributions 12, 71-79.

Orlova-Bienkowskaja, M.J. (2013) Ashes in Europe are in danger: the invasive range of *Agrilus planipennis* in European Russia is expanding. *Biological Invasions* 15. DOI: 10.1007/s10530-013-0579-8

Orlova-Bienkowskaja, M.J. & Bienkowski, A.O. (2016) The life cycle of the emerald ash borer *Agrilus planipennis* in European Russia and comparisons with its life cycles in Asia and North America. Agricultural & Forest Entomology 18, 182-188.

Orlova-Bienkowskaja, M.J., Drogvalenko, A.N., Zabaluev, I.A., et al. (2020) Current range of *Agrilus planipennis* Fairm., an alien pest of ash trees, in European Russia and Ukraine. Annals of Forest Science (in press)

Peregudova, E.Y. (2019) The focus of the emerald ash borer *Agrilus planipennis* Fairmaire (Coleoptera: Buprestidae) in Tver, on the north-western border of the invasive range. Russian Journal of Biological Invasions 10, 258-262. DOI:10.1134/S2075111719030093.

Petrice T.R. & Haack RA. 2007. Can emerald ash borer, *Agrilus planipennis* (Coleoptera: Buprestidae), emerge from logs two summers after infested trees are cut? The Great Lakes Entomologist 40, 92-95.

Rebek, E.J., Herms, D.A. & Smitley, D.R. (2008) Interspecific variation in resistance to Emerald Ash Borer (Coleoptera: Buprestidae) among North American and Asian ash (*Fraxinus* spp.). *Environmental Entomology* 37, 242–246.

Ryall, K.L., Fidgen, J.G. & Turgeon, J.J. (2011a). Detection of emerald ash borer in urban environments using branch sampling. Natural resources Canada, Canadian Forest Service-Great Lakes Forestry Centre, Sault Ste. Marie, Ontario. Frontline Technical Note No. 111.3

Ryall, K.L., Fidgen, J.G. & Turgeon, J.J. (2011b) Detectability of the emerald ash borer (Coleoptera: Buprestidae) in asymptomatic urban trees by using branch samples. Environmental Entomology 40, 679-688.

Sargent C., Raupp M., Bean R., & Alan J. Sawyer A.J. (2010) Dispersal of emerald ash borer within an intensively managed quarantine zone. Arboriculture & Urban Forestry 36, 160–163.

Scarr, T.A., McCullough, D.G. & Howse, G.M. (2002) Forest Health Alert 3: emerald ash borer. Canadian Forest Service, Natural resources Canada, 4 pp.

Selikhovkin, A.V., Popovichev, B.G., Mandelshtam, M.Y., Vasaitis, R. & Musolin, D.L. (2017) The frontline of invasion: the current northern limit of the invasive range of emerald ash borer, *Agrilus planipennis* Fairmaire (Coleoptera: Buprestidae), in European Russia. Baltic Forestry 23, 309-315.

Siegert N.W., McCullough D.G., Williams D.W., Fraser I., Poland T.M., & Pierce S.J. (2010) Dispersal of *Agrilus planipennis* (Coleoptera: Buprestidae) from discrete epicentres in two outlier sites. Environmental. Entomology 39, 253-265.

Silk, P.J., Ryall, K. & Roscoe, L. (2019) Emerald ash borer, *Agrilus planipennis* (Coleoptera: Buprestidae) detection and monitoring in Canada. Forestry, DOI:10.1093/forestry/cpz036.

Smitley, D., Davis, T. & Rebek, E. (2008) Progression of ash canopy thinning and dieback outward from the initial infestation of emerald ash borer (Coleoptera: Buprestidae) in south-eastern Michigan. J. Econ. Entomol. 101, 1643–1650.

Steiner, K.C., Graboski, L.E., Knight, K.S., Koch, J.L. & Mason, M.E. (2019) Genetic, spatial, and temporal aspects of decline and mortality in a *Fraxinus* provenance test following invasion by the emerald ash borer. Biological Invasions 21, 3439-3450.

Straw, N.A., Williams, D.T., Kulinich, O. & Gninenko, Y.I. (2013) Distribution, impact and rates of spread of emerald ash borer, *Agrilus planipennis* (Coleoptera; Buprestidae) in the Moscow region of Russia. Forestry 86, 515–522.

Sugiura, N. (1999) The family Buprestidae in Fukushima Prefecture: the genus *Agrilus*. [Note: this online paper has been referenced by other researchers, but does not appear to be currently accessible]

Taylor R.A.J., Bauer L.S., Poland T.M., & Windell K.N. (2010) Flight performance of *Agrilus planipennis* (Coleoptera: Buprestidae) on a flight mill and in free flight. Journal of Insect Behavior 23, 128-148.

USDA–APHIS (2018) (U.S. Department of Agriculture (USDA) Animal and Plant Health Inspection Service), Plant, Pesticide Quarantine (APHIS PPQ). Emerald Ash Borer Survey Guidelines. Available at: https://www.aphis.usda.gov/plant_health/plant_pest_info/emerald_ash_b/downloads/survey_guidelines.pdf

Van Driesche, R.G. & Reardon, R.C. (2015) (Eds.) Biology and Control of Emerald Ash Borer. USDA Forest Technology Enterprise Team, Morgantown, WV FHTET-2-14-09. Available at: https://www.fs.fed.us/foresthealth/technology/pdfs/FHTET-2014-09_Biology_Control_EAB.pdf

Volkovitsh, M.G., Orlova-Bienkowskaja, M.J., Kovalev, A.V. & Bienkowski, A.O. (2019) An illustrated guide to distinguish emerald ash borer (*Agrilus planipennis*) from its congeners in Europe. Forestry, DOI:10.1093/forestry/cpz024

8. Authors and reviewers

Authors:
Daegan Inward (FR)

Nigel Straw (FR)

Reviewers:
Nick Mainprize (FC)

Dominic Eyre (Defra)