Department
for Environment
Food & Rural Affairs

Rapid Pest Risk Analysis (PRA) for:

Xylella fastidiosa

February 2020

(update of 2014 UK PRA and 2017 climate appendix)

Summary and conclusions of the rapid PRA

This rapid PRA shows:

Xylella fastidiosa is a plant-pathogenic bacterium which infects a very wide range of plants. It is already heavily regulated to reduce the likelihood of it entering the UK. In some host species, impacts can be severe and the plant or tree can be killed rapidly. Other hosts have latent infections, or may remain asymptomatic (but still be capable of spreading the disease) for several years before succumbing to the bacterium. *Xylella fastidiosa* is native to the Americas, but has been spread to countries elsewhere in the world, including parts of Europe. There are several subspecies of *X. fastidiosa*, which have different host ranges. *Xylella fastidiosa* is vectored by a number of xylem-feeding hemipteran insect species, including some which are widespread in the UK. At least parts of the UK are likely to prove suitable for *X. fastidiosa* to establish, but it is unclear what levels of damage it may be able to cause to plants in the UK. If an outbreak were to occur in the UK, the greatest impacts are expected to be social (though the assessment of potential social impacts is made with medium confidence, while confidence in potential economic and environmental impacts is low, indicating the uncertainty about the magnitude of direct impacts which might occur in the UK). Leaf scorches and other symptoms could be visible on amenity trees causing public concern, impacts on horticultural businesses could be severe, and this is already a high-profile pest in the media. Other impacts could occur due to the response required to keep the UK free of *X. fastidiosa*, reputational damage to the UK, and potential restrictions on exports if eradication were to be unsuccessful. However, substantial uncertainties remain about many key aspects of *X. fastidiosa*, and it has not proved possible to quantify the risk to the UK with any degree of confidence.

Risk of entry

Three pathways were assessed for entry. Entry of *X. fastidiosa* on **plants for planting** was considered to be **moderately likely** with **medium confidence**. Plants infected by *X. fastidiosa* may be asymptomatic for long periods which raises the threat of this pathway. In mitigation against the risk of movement in planting material, there are extensive legislative measures in place to reduce the likelihood of infected plants for planting from entering the UK, and the legislation is continually being reviewed in response to new information. For example, there is a list of at least 14 hosts in the EU which have been infected by more than one subspecies of *X. fastidiosa*, and many of these infected hosts have been reported from more than one location within Europe. Six host species or genera are recognised as higher-risk hosts in the EU Commission Implementing Decision 2015/789 (as amended), and these hosts are subject to additional requirements before they can be moved in trade due to such risk factors. Subsequent developments (such as a new EFSA opinion or further interceptions/outbreaks) highlight there is an evolving risk situation in relation to such hosts.

Movement on cut flowers, fruit and vegetables, etc., were assessed as part of the pathways of movement of infectious vector insects. Entry with **infectious adult vectors** is considered to be **unlikely**, but this is with **low confidence** as there are many uncertainties. Entry with **infectious immature vector insects** is considered **very unlikely**, again with **low confidence**.

Several other pathways were discussed but not formally rated. For some, there was a lack of critical information meaning no sensible assessment of the risk could be made. Other pathways were considered extremely unlikely, but were mentioned for completeness.

Risk of establishment

The assessment of establishment is highly uncertain, as there are few data about the actual climatic (or other) requirements of *X. fastidiosa*. Distribution records from locations at the edges of the native range are scarce and scattered, and are likely to indicate where surveys have been conducted, rather than delineating the true extent of the bacterium's range. There have been several attempts at modelling, but the basic data underlying many models is scarce, lacking or assumed. A suitable vector insect, *Philaenus spumarius*, is native to the UK and widespread, thus *X. fastidiosa* would be able to spread.

Establishment both outdoors and under protection in the UK is considered **likely** as there have been recent findings of *X. fastidiosa* in locations with relatively cool summers, similar to the UK. Winter temperatures in the UK are not considered to be limiting as *X. fastidiosa* is known to be present in parts of North America with much colder winters than the UK experiences. Due to the many uncertainties remaining, the assessment for **establishment outdoors was made with low confidence**. **Establishment under protection has a medium confidence** rating, as the temperatures are higher and there have been findings in protected cultivation elsewhere in Europe.

Economic, environmental and social impact

Impacts in the current range of *X. fastidiosa* differ greatly. Very large impacts have been seen on hosts such as olive trees in Apulia (southern Italy) or citrus in Brazil, and this assessment is made with high confidence. Pierce's disease, caused by *X. fastidiosa*, causes significant impacts on grapevine in southern California (partly due to a highly efficient vector species) and elsewhere. There are reports of leaf scorch diseases, which may be due to reasons other than infection with *X. fastidiosa*, on trees in northern US states. Most reports are on street trees in urban areas and while a third or more of trees in certain areas may be "affected" by *X. fastidiosa*, it isn't clear what level of actual impacts this equates to. Therefore impact on trees in more temperate areas such as north-eastern states of the USA is considered to be medium, with low confidence. Impacts in areas with relatively low summer temperatures (similar to those in the warmest parts of the UK) are not known as no data could be found from these locations, other than that *X. fastidiosa* had been detected. **The overall impact rating for *X. fastidiosa* in its current range is large, but this has only medium confidence as the impacts vary so much in the current range.**

The potential economic impact of *X. fastidiosa* as a plant pathogen in the UK is highly uncertain, mainly due to the cooler UK summers compared to summers in most parts of the current distribution. It is possible that over many years, impacts directly due to infection by *X. fastidiosa* could occur in the UK, as the cooler temperatures could lead to very long latent periods before symptoms become apparent. However, due to the complete lack of data on impacts from areas with cooler summer temperatures, it is just not known what the direct impact of *X. fastidiosa* may be in the UK. Additionally, this PRA is relatively short-term (based on the situation in the next 5-10 years), but potential impacts could occur over a much longer timeframe. Modelled impact data are available for vineyards, but for other UK hosts, impact data applicable to the UK ornamental use of common host plants are not available (e.g. in the UK, olives and citrus are mostly grown as ornamentals and not for fruit production).There are also indirect factors which will cause economic impacts if *X. fastidiosa* were to be found in the UK. UK exports could be affected, as *X. fastidiosa* is a pest of quarantine concern to many countries. Confidence in UK plants could be reduced and reputational damage incurred to the UK plant industry as a whole. The measures legally required in response to any outbreak currently involve host clearance in the infested zone and stringent requirements which must be met before movement of plants can occur within the demarcated area. If detection of an outbreak were to be delayed for any reason, it is possible that *X. fastidiosa* could have spread beyond the initial location. As a result, eradication measures would have to take place over a much wider area, affecting more locations and businesses. Taking account of existing knowledge and the current scenario, it is more cost effective to continue to exclude *X. fastidiosa* from the UK in the short term than it would be to eradicate it or mitigate its impacts in the longer term.

Overall, potential **economic impacts** in the UK are considered to be **medium**, with **low confidence**. Potential UK impacts are primarily considered to be due to possible export restrictions on UK plants, reputational damage to UK plant health and biosecurity and, in the shorter term, the implementation of statutory requirements for eradication required to maintain UK freedom from *X. fastidiosa* (and prevent longer-term impacts if it were to establish). The magnitude of direct impacts of *X. fastidiosa* on host plants in the UK has very high uncertainty.

Potential **environmental impacts** in the UK are considered to be **small**, but with **low confidence**. While impacts in the immediate vicinity of an outbreak would be very high in the event of eradication measures being undertaken, they will be localised (unless the outbreak has spread significantly, or *X. fastidiosa* is detected in multiple locations). As this PRA assesses impacts at a national scale, environmental impacts in the 5-10 year time frame of this PRA were therefore assessed as small. As stated in economic impacts, it is unclear what the long-term direct impacts of *X. fastidiosa* might be on hosts in the UK, as summers here are cooler than in any part of the current range where impacts have been seen.

Social impacts in the event of a UK outbreak are considered to be **large**, with **medium confidence**. This rating is given due both direct and indirect potential social impacts. Direct social impacts could occur if branch dieback occurred on street or other amenity trees, necessitating pruning, or even felling and replanting. However, it is uncertain to what extent such amenity trees might be affected by symptoms requiring such management in the UK climate. Indirect impacts would be due to clearance of infected plants and other hosts in the immediate vicinity of infected plants, which would cause local concern, especially if the outbreak were detected in an urban or suburban location. Nurseries within a 5 km radius could have significant financial losses due to the restrictions on movement of many plants, possibly leading to job losses or even closure of some businesses. The very high profile of *X. fastidiosa* and the possibility of significant media attention, especially if picked up by mainstream publications, could add further to the social impacts.

Endangered area

For an area to be considered “endangered”, the pest must be able to establish and be capable of causing economically important loss (ISPM 05, ISPM 11). As the potential impacts of *X. fastidiosa* in the UK have such high uncertainty it is not currently possible to identify particular areas of the UK which might suffer important economic losses. Therefore, identifying specific areas in the UK which are considered endangered has not been possible due to this uncertainty. This does not mean that the UK is not at risk of impacts from *X. fastidiosa*, rather it is a reflection of the high levels of uncertainty surrounding key aspects of the PRA. The whole of the UK could be considered at risk from indirect impacts of reputational damage, export restrictions, action required to eradicate an outbreak to maintain UK freedom from the pest, losses to nurseries especially near any outbreak site, and significant concern among members of the public due to the high media profile of *X. fastidiosa*. Direct impacts are most likely to cause symptoms in warmer areas, e.g. the south coast and urban heat islands such as London. Vineyards in the UK are a rapidly expanding sector (especially in the south of England), and these may be vulnerable to impacts caused by *X. fastidiosa*.

Risk management options

Statutory controls for preventing entry, and the measures which would be taken in the event of any outbreak, are detailed in the Defra contingency plan (Eyre & Parkinson, 2019). Good sourcing practice and biosecurity by individual businesses will help to reduce the risk to the UK. As this is a quarantine listed organism, non-statutory controls are not appropriate.

Key uncertainties and topics that would benefit from further investigation

There are many uncertainties remaining with this PRA.

The factors affecting the establishment of *X. fastidiosa* are particularly unclear. There is a lack of laboratory evidence to back up the predictions that different subspecies respond differently to different temperatures. While climate is assumed by most modelling to be a major limiting factor for establishment, it is possible that other interactions of *X. fastidiosa* with its environment are equally limiting. For example, differing host preferences and/or host specificities of each subspecies and/or sequence type may limit the ability of *X. fastidiosa* entering the UK to transfer to a host in the wider environment. Differing competency and mobility of vectors may affect the potential rate of spread and establishment.

The key uncertainty affecting this risk analysis is to do with the UK climate and how *X. fastidiosa* might respond to the cooler UK summers compared to the conditions in most parts of its current range. The interaction between *X. fastidiosa* and potential host plants may affect the risk of establishment or impacts. Evidence collected during this PRA suggests establishment of *X. fastidiosa* is likely, at least in the warmer parts of the UK. However, it remains uncertain the extent to which direct impacts will be apparent in this country, and how severe they would be. Longer-term impacts are also highly uncertain. *Xylella fastidiosa* has only recently been recorded in locations where the summer temperatures are broadly comparable to warmer parts of the UK, and so the long-term impacts are not known. Additionally, this PRA considers impacts in the next 5-10 years, when no significant changes to climatic conditions have been assumed. Potential impacts over time-scales longer than 5-10 years were not assessed, but the scale of impacts would be expected to be affected by warmer climatic conditions.

Images of the pest

Leaves of *Quercus robur* showing scorching and bands of colours caused by *Xylella fastidiosa*. © John Hartman, University of Kentucky, https://Bugwood.org

Is there a need for a detailed PRA or for a more detailed analysis of particular sections of the PRA? If yes, select the PRA area (UK or EU) and the PRA scheme (UK or EPPO) to be used.

Xylella fastidiosa is a high-profile organism in the UK and the rest of Europe and as such there is a lot of ongoing research covering this pathogen. This means that new information is being published regularly, and more is expected in the future, e.g. outcomes from the BRIGIT[1], POnTE[2] and XF-ACTORS[3] projects amongst others, as well as specific research

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[1] https://www.jic.ac.uk/brigit/ (accessed December 2019)
[2] https://www.ponteproject.eu/ (accessed December 2019)
[3] https://www.xfactorsproject.eu/ (accessed December 2019)

topics on *X. fastidiosa* within networks such as Euphresco[4] or projects undertaken by Scotland's Plant Health Centre[5]. While this PRA, in conjunction with the updated 2019 EFSA opinion, presents current information, it is only to be expected that both will rapidly become out of date as new developments are reported. However, at the time of writing, a more detailed PRA is not appropriate (especially given the availability of the 2018–2019 EFSA documents which are comprehensive). Rather, consideration should be given to updating this PRA frequently, in whole or in part, as significant new information becomes available.

No	✓				
Yes		PRA area: UK or EU		PRA scheme: UK or EPPO	

Given the information assembled within the time scale required, is statutory action considered appropriate / justified?

Xylella fastidiosa is a high profile pest species with a very broad host range. It has had very high impacts on a number of hosts in countries both in its native and introduced ranges. There are high levels of uncertainty over the magnitude of direct impacts *X. fastidiosa* may have in the UK. While high uncertainty remains, both direct and indirect impacts to the UK are possible from *X. fastidiosa*. Continued statutory action is warranted to prevent introduction of this pest and give the best opportunity to facilitate early eradication in the event it is detected, to protect against potential impacts. Continued review of the legislation in response to the risk situation will help assess whether additional requirements are needed (e.g., in response to entry pathways identified as high risk).

Yes Statutory action ☑

No Statutory action ☐

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[4] https://www.euphresco.net/projects/portfolio (accessed February 2020)
[5] https://www.planthealthcentre.scot/projects (accessed February 2020)

Stage 1: Initiation

1. What is the name of the pest?

Xylella fastidiosa (Bacteria, Xanthomonadaceae).

This pathogen is the causal agent of a number of named plant diseases including citrus variegated chlorosis, olive quick decline syndrome, peach phony rickettsia, Pierce's disease of grapevine and several different named leaf scorch diseases.

There are currently six named subspecies of *X. fastidiosa*, of which the first three are well-described. The remaining three are less well studied, and their status is uncertain. However, all six names are in current use in the literature to a greater or lesser extent.

(i) *Xylella fastidiosa* subsp. *fastidiosa* (validly accepted subspecies name)
(ii) *Xylella fastidiosa* subsp. *multiplex* (validly accepted subspecies name)
(iii) *Xylella fastidiosa* subsp. *pauca* (a well-described subspecies, though the name has not been validly published and so has yet to be formally accepted)
(iv) *Xylella fastidiosa* subsp. *morus* (not yet validly named, and may be a strain resulting from genetic recombination between the subspecies *fastidiosa* and *multiplex* (Marcelletti & Scortichini, 2016))
(v) *Xylella fastidiosa* subsp. *sandyi* (not yet validly named, and may be a strain resulting from genetic recombination between the subspecies *fastidiosa* and *multiplex* (Marcelletti & Scortichini, 2016))
(vi) *Xylella fastidiosa* subsp. *tashke* (not yet validly named, and no reference strains are available)

This PRA will largely be carried out for *X. fastidiosa* as a species, but for certain sections, the assessment will be carried out separately for the first three subspecies listed here (i–iii). The information about the remaining subspecies (iv–vi) is scarcer, the taxonomy is uncertain and it is unlikely that a useful assessment of the risk posed to the UK by any of these three subspecies can be made at this time.

2. What initiated this rapid PRA?

Xylella fastidiosa is native to the Americas. It was first detected causing disease in olive in Europe in the Apulia region of Italy in 2013 (Saponari *et al.*, 2013). There had been previous European interceptions on imported coffee plants and other hosts. As a result, a UK PRA was produced in 2014 (Parkinson & Malumphy), and a very detailed EFSA Opinion was published in 2015, updated in 2018 (EFSA, 2018a). In 2017, a new appendix to the UK PRA assessing the potential climatic suitability of the UK for *X. fastidiosa* was published (Baker, 2017), and in 2019 an updated EFSA Opinion was published summarising a great deal of new information. As the situation continues to develop rapidly, it was considered appropriate to also update the UK PRA with the latest information available.

It must be understood that the situation with *X. fastidiosa* continues to evolve rapidly, especially in Europe. Therefore, this PRA must be regarded only as an assessment of the risk to the UK at the time of writing. It is almost certain this PRA will require updating again as more information becomes available.

3. What is the PRA area?

The PRA area is the United Kingdom of Great Britain and Northern Ireland.

Stage 2: Risk Assessment

4. What is the pest's status in Regulation (EU) 2016/2031[6] and its associated implementing regulations, including Commission Implementing Decision (EU) 2019/2072[7], and in the lists of EPPO[8]?

Xylella fastidiosa is one of the priority pests identified in the Commission Delegated Regulation (EU) 2019/1702[9]. *Xylella fastidiosa* is also included in Commission Implementing Decision (EU) 2019/2072 under Annex II, part B (that is, a Union quarantine pest known to occur in the Union territory).

Xylella fastidiosa is also the subject of emergency EU measures: Commission Implementing Decision (EU) 2015/789/EU, as regards measures to prevent the introduction into and the spread within the Union of *Xylella fastidiosa* (Wells *et al*.). There have been numerous amendments to 2015/789. In order to see the currently applicable regulations, the latest consolidated version of the legislation should be consulted via a search on https://eur-lex.europa.eu. The mitigations discussed later on in this PRA are based on the legislation in force in December 2019.

Xylella fastidiosa is on the EPPO A2 list of pests recommended for regulation as quarantine organisms.

Cicadellidae (non-European) which are "known to be vectors of *Xylella fastidiosa*" are Union quarantine pests, listed in 2019/2072 under Annex II, part A. Four example species are named (*Draeculacephala minerva*, *Graphocephala atropunctata, Homalodisca vitripennis* (also on the EPPO A1 list) and *Xyphon fulgida* (under its synonym *Carneocephala fulgida*)), but the listing makes it clear these are examples and other vectors are also covered. A list of non-EU Cicadomorpha vectors is provided by EFSA

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[6] http://data.europa.eu/eli/reg/2016/2031/oj

[7] http://data.europa.eu/eli/reg_impl/2019/2072/oj

[8] https://www.eppo.int/ACTIVITIES/quarantine_activities

[9] http://data.europa.eu/eli/reg_del/2019/1702/oj

(2019b), and at the time of writing this is as complete a list as current information allows. It is, however, possible that additional hemipterans will be identified as vectors in the future as research into *X. fastidiosa* continues.

5. What is the pest's current geographical distribution?

Xylella fastidiosa is considered to be native to the Americas (Fig. 1). Different subspecies are thought to have evolved in different parts of the Americas: *X. fastidiosa* subsp. *fastidiosa* in Central America, *X. fastidiosa* subsp. *multiplex* in North America, and *X. fastidiosa* subsp. *pauca* in South America (EFSA, 2018a). All three of these well described subspecies have also been detected in parts of Europe (see Table 1 and discussion later in this section). The first verified European detection was in 2013, in Italy. However, it is unclear how long *X. fastidiosa* may have been present, undetected, in Europe. A surveillance programme was started in Corsica, France, in the summer of 2015 at the time of the first detection of *X. fastidiosa* in that region (Soubeyrand *et al.*, 2018). Using the data from this work, epidemiological models were constructed. Depending on the model, Soubeyrand *et al.* (2018) suggest that *X. fastidiosa* may have been present in Corsica since 2001, or even 1985 or earlier. More data, especially results from sampling wild plants, are required to test which model (and hence which putative date of introduction) most closely reflects reality.

Figure 1. Global known distribution of *Xylella fastidiosa* as of autumn 2019. Sources: EFSA, 2018a and EPPO GD, 2019.

Table 1: Distribution of the three main *Xylella fastidiosa* subspecies.

Continent	***Xylella fastidiosa* subsp. *fastidiosa***	***Xylella fastidiosa* subsp. *multiplex***	***Xylella fastidiosa* subsp. *pauca***
North America: (EFSA, 2018a)	**Mexico** **USA**	**USA**	*No records*
Central America: (EPPO GD, 2019)	**Costa Rica**	*No records*	**Costa Rica**
South America: (EFSA, 2018a; EPPO GD, 2019)	**Brazil**	**Argentina** **Brazil** **Paraguay**	**Argentina** **Brazil** **Ecuador**
Europe: (EFSA, 2019a)	**Spain (Balearic Islands)**	**France** **Italy** **Portugal** **Spain**	**France** **Italy** **Spain (Balearic Islands)**
Africa: (EFSA, 2018a)	*No records*	*No records*	*No records*
Asia: (EPPO GD, 2019)	**Israel** **Taiwan**	*No records*	*No records*
Oceania: (EPPO GD, 2019)	*No records*	*No records*	*No records*

There have been records of *X. fastidiosa* in additional countries of unknown status, where the sub-species involved was/were not determined.

- **Canada** (Goodwin & Zhang, 1997; Turnquist and Clarke, 1992).
- **Iran**: Grapevine and almond orchards in a number of locations (Amanifar *et al.*, 2014).
- **Puerto Rico** (EPPO GD, 2019).
- **Venezuela** (Hernandez & Ochoa Corona, 1997).

Within Europe, *X. fastidiosa* demarcated areas subject to containment measures are in **France** (Corsica), **Italy** (specified parts of Apulia) and **Spain** (the Balearic Islands) (EU Commission, 2019). Demarcated areas which are subject to eradication measures are in specified regions within: **France** (Provence-Alpes-Côte d'Azur (PACA)); **Italy** (Apulia and Tuscany); **Portugal** (Norte); and **Spain** (Valencia and Madrid) (EU Commission, 2019).

European findings linked to imported plants have occurred in the **Netherlands** on plants from Costa Rica and Honduras (*X. fastidiosa* subspp. *fastidiosa* and *pauca*) (Bergsma-Vlami *et al.*, 2015); Saxony, **Germany** (subsp. *fastidiosa*); and **Switzerland** (subspp. *sandyi* and *pauca*), but all three counties now have an official status of *X. fastidiosa* as absent (EPPO GD, 2019). **Belgium** detected *X. fastidiosa* on olive trees at a wholesaler, but the findings were classified as interceptions as the trees had been recently imported from Spain, there was evidence that they were infected before arrival and no vectors were detected (Belgian NPPO, unpublished data 2018). There has been a recent finding in a physically closed glasshouse near Rome, **Italy** (EUROPHYT outbreaks database

November 2019, unpublished data). No demarcated area was established, as all the plants in the affected lot have been destroyed and movement of all specified plants has been halted.

Of the three other potential subspecies, *X. fastidiosa* subsp. *morus* is only known from the USA (samples from California, Kentucky and Washington D.C.) (Nunney *et al.*, 2014). *Xylella fastidiosa* subsp. *sandyi* was first described from the southern USA (Schuenzel *et al.*, 2005), has been intercepted in Europe on plants from Latin America, and isolated from an ornamental plant growing in the wider environment in France (Denancé *et al.*, 2017). *Xylella fastidiosa* subsp. *tashke* is only known from the USA, from the south-west of the country (Randle *et al*., 2009).

6. Is the pest established or transient, or suspected to be established/transient in the UK/PRA area?

Xylella fastidiosa has not been detected in the wider environment in the UK.

There has been one confirmed UK interception, on *Coffea arabica* plants originating from Costa Rica in 2015. The affected plant was destroyed by burning, and other plants from the same batch were followed up but there were no more findings of infected plants.

7. What are the pest's natural and experimental host plants; of these, which are of economic and/or environmental importance in the UK/PRA area?

Xylella fastidiosa has been reported from a very wide range of hosts, and the number of plant species which have been shown to be infected is constantly increasing. However, the pathogenicity of *X. fastidiosa* to many of these hosts has not been demonstrated. For many plant species, infections are either asymptomatic or mild (slight stunting) (Purcell & Saunders, 1999; Costa *et al.*, 2004; Wistrom & Purcell, 2005).

North American reports have suggested there is host specificity within different strains of *X. fastidiosa* (Schuenzel *et al.*, 2005; Randle *et al.*, 2009; Nunney *et al.*, 2014). *Xylella fastidiosa* subsp. *pauca* from *Coffea* did not infect *Citrus* after artificial inoculation, and *vice versa* (Almeida *et al.*, 2008; Nunney *et al.*, 2012). Even within subspecies, there is evidence of host (or vector) specialisation. Below the level of subspecies, *X. fastidiosa* is classified by sequence type, abbreviated to ST followed by a number to differentiate them. Harris & Balci (2015) examined *X. fastidiosa* subsp. *multiplex* infections of street trees in Washington, D.C. The results suggested host specificity within a given ST, for example, *Quercus* infections were all caused by *X. fastidiosa* subsp. *multiplex* ST-9, while *Ulmus* infections were mostly caused by ST-41 and only one sample out of the 20 tested was caused by ST-9 (Harris & Balci, 2005).

Hosts susceptible worldwide

A list of hosts known to be susceptible to *X. fastidiosa* worldwide is maintained by EFSA, though it must be emphasised that the impact of the bacterium on many of the listed plant species is not known. At the time of writing this PRA, the most recent version was published in 2018 (EFSA, 2018b), but it is highly likely that the EFSA list will be updated again in the future. A brief overview of the EFSA (2018b) document follows, but for more details, or to have the latest information, it is recommended that the most recent EFSA host plant list is consulted.

EFSA (2018b) categorised the host records in 5 classes. The classes are constructed to take into account the robustness of the detection method reported, from A (most robust detection of *X. fastidiosa* and the category which was most selective) to E (all host records, regardless of detection method, i.e. the most inclusive category). For *X. fastidiosa* as a whole, there were 563 records in total (category E), of which 312 records fulfilled the criteria for category A (EFSA, 2018b).

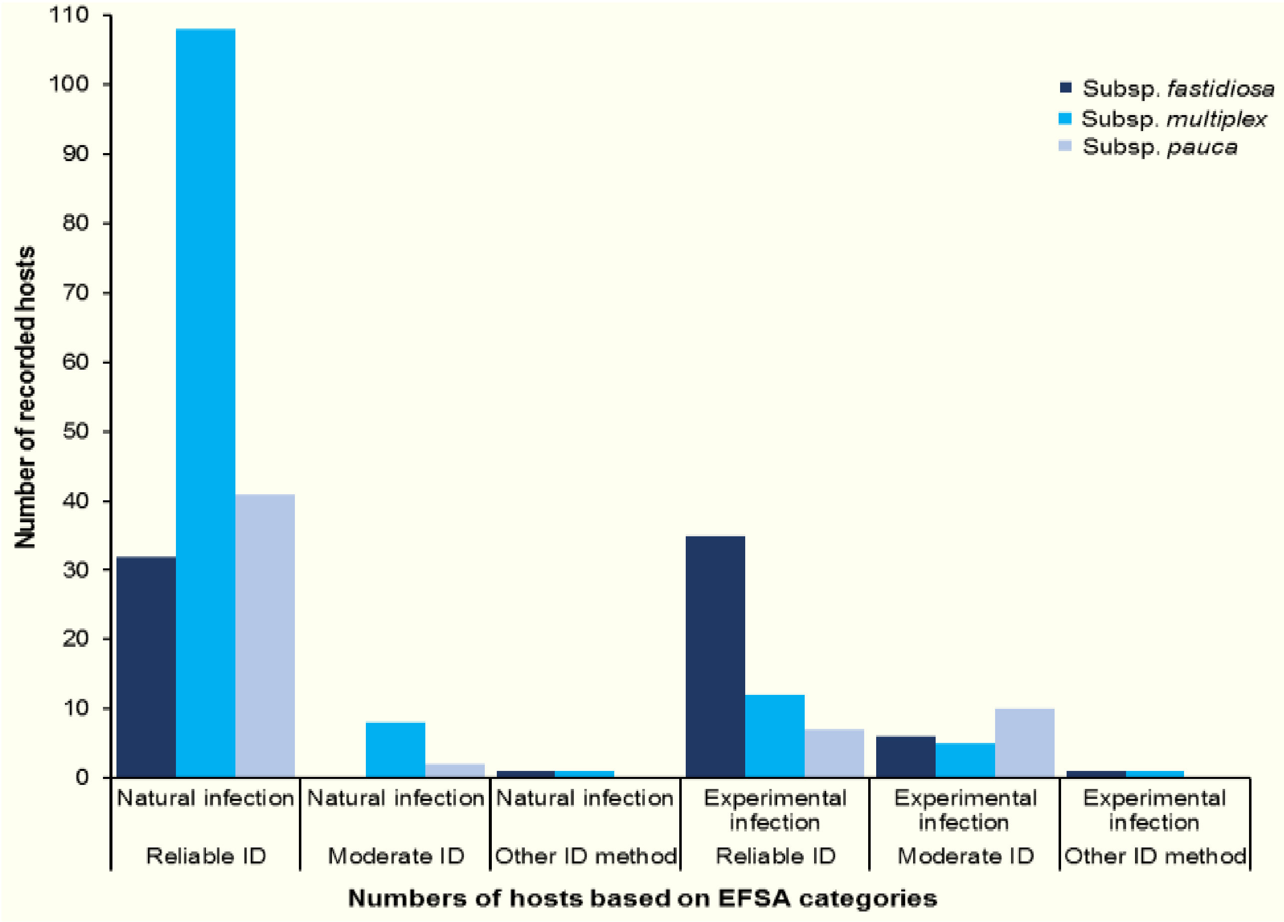

Figure 2. The number of recorded host species of three subspecies of *Xylella fastidiosa*, divided by whether the host was identified through natural or experimental infections (N.B. some host species occur in both natural and experimental categories), and with an indication of the robustness of the method used to identify the pathogen. Based on data from EFSA (2018b).

From the EFSA host database (2018b), the number of hosts by subspecies was extracted and is shown in Fig. 2: the categories used in the graph equate to EFSA's categories A, C and E (there were no new hosts categorised only as B or D for these three subspecies). The majority of *X. fastidiosa* subsp. *multiplex* hosts have been identified through natural infections, and this subspecies has the most recorded hosts overall. Of the three subspecies covered in detail here, *X. fastidiosa* subsp. *pauca* has the fewest recorded hosts globally (combining natural and experimental host records) (all data from EFSA, 2018b).

There are many hosts on the global list for which infections have not (yet) been detected in Europe. A number are of relevance and importance to the UK, of which three are briefly mentioned here. *Quercus robur* (common oak or English oak), is very widely grown in the UK and an iconic tree species. *Rubus* sp. (raspberries, blackberries, etc.), are important crops in the UK, especially in areas such as Herefordshire, Kent or Tayside. *Vaccinium* sp. (blueberries) are a crop which is expanding in importance in many areas of the UK.

Hosts naturally infected in Europe

The latest list of hosts found to be susceptible to *X. fastidiosa* in the EU can be found here https://ec.europa.eu/food/plant/plant_health_biosecurity/legislation/emergency_measures/xylella-fastidiosa/susceptible_en (last accessed June 2019). The list is separated into hosts susceptible to each of the three subspecies known to be present in the EU (*fastidiosa, multiplex* and *pauca*), as well as hosts susceptible to all three subspecies.

Hosts considered to be highly susceptible to multiple subspecies of *Xylella fastidiosa* include *Coffea* (coffee), *Lavandula dentata* (French lavender), *Nerium oleander* (oleander), *Olea europaea* (olive), *Polygala myrtifolia* and *Prunus dulcis* (almond). The hosts in this list are treated as high risk plants in the EU emergency measures 2015/789 (as amended). These six hosts were identified as higher-risk as they have been infected by more than one subspecies of *X. fastidiosa* and have been infected in more than one geographical location. However, there are eight other examples of hosts which have been found to be susceptible to multiple subspecies of *X. fastidiosa* in Europe, for example *Helichrysum stoechas* (everlasting flower) or *Rosmarinus officinalis* (rosemary).

Many hosts are of economic, environmental or social importance to the UK. A very small selection of hosts known to have been infected in the EU (as recorded on the EU host plants database), are listed below. The selection was based on hosts considered to be of particular importance to the UK (though not all these hosts may show severe symptoms).

SUSCEPTIBLE TO *X. FASTIDIOSA* SUBSP. *FASTIDIOSA* IN EUROPE:

- *Juglans regia* (walnut). Widespread ornamental plantings, also of environmental importance and there is some UK nut production.
- *Vitis vinifera* (grapevine). Wine production is a rapidly growing industry in the UK. Data on the number of registered vineyards from the Food Standards Agency (FSA)

Vineyard Register[10] are available: all vineyards over 0.1 ha must be registered, and all commercial vineyards must be registered, regardless of their size. There were 522 registered UK vineyards according to the most recently available 2017 list. However, much of the vineyard data on the FSA website is for 2015 and earlier, and vineyards are a rapidly growing sector in the UK.

More recent data on UK vineyards are available online from other sources. Englishwine.com[11] cites the Wine Standards Board as the source of their data. These data demonstrate there has been a substantial increase in the total area of planted vineyards in the UK in recent years, and are shown in Fig. 3. The number of registered vineyards has undergone a similar increase, englishwine.com stating that in 2018 there were a total of 672. An infographic from another website, winegb.co.uk[12] (citing Wine GB/Wine Intelligence as the sources of the data) states there were 658 commercial vineyards in 2019, which is broadly comparable to the englishwine.com data, especially given englishwine.com includes hobby vineyards. When it comes to hectares under vine, though, winegb.co.uk has a much higher estimate of the total area, stating that in 2019 there were 3579 ha. Though winegb.co.uk also state that 3 million vines were planted in the UK in May 2019, these plantings seem unlikely to account for over 1000 ha increase in planted area in one year (i.e., comparing the englishwine.com area data for 2018 with the winegb.co.uk data for 2019).

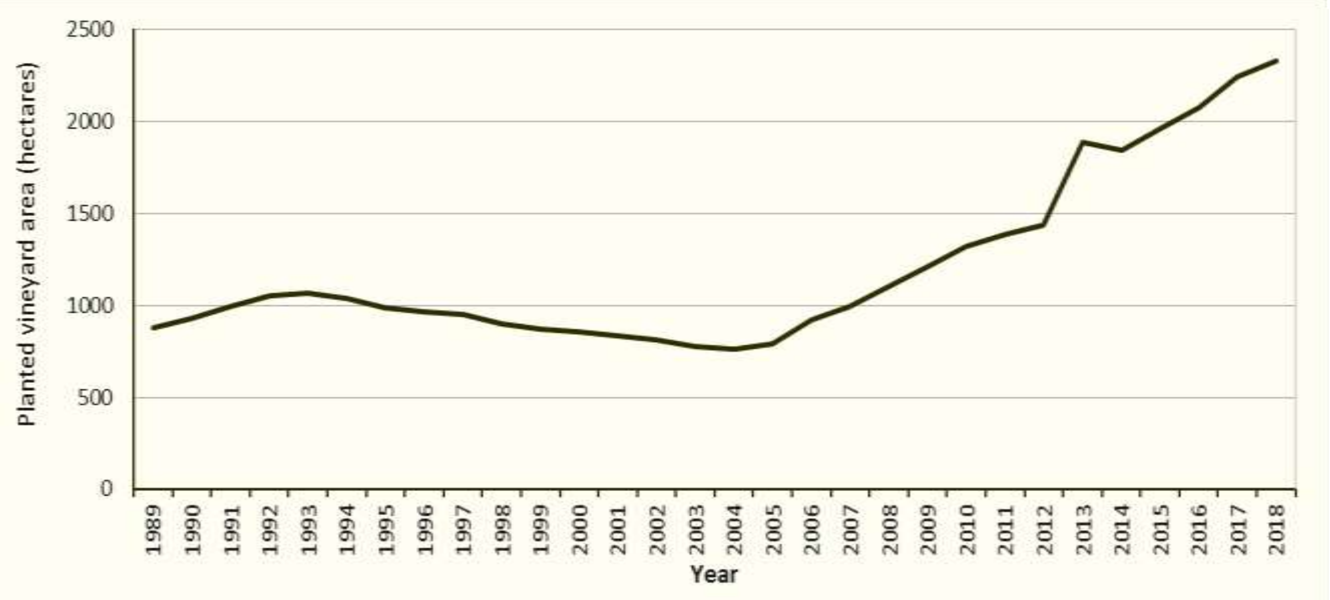

Figure 3. Total vineyard area in the UK over time (includes hobby and abandoned vineyards). Data source: http://www.englishwine.com/vineyards.htm (which states the source of their data is the Wine Standards Board of the Food Standards Agency). Accessed December 2019.

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[10] https://www.food.gov.uk/business-guidance/uk-vineyard-register (accessed December 2019)

[11] http://www.englishwine.com/vineyards.htm (accessed December 2019)

[12] https://www.winegb.co.uk/wp-content/uploads/2019/10/infographics-WineGB-Julia-marketing-2019-a5-brochure-v2-update-Sep-2019-single-pages.pdf (accessed December 2019)

SUSCEPTIBLE TO *X. FASTIDIOSA* SUBSP. *MULTIPLEX* IN EUROPE:

- *Acer pseudoplatanus* (sycamore). Though non-native, this species is naturalised in the UK and is very common.
- *Lavandula* spp. (lavender). Grown in many gardens as an ornamental, there are also a number of farms cultivating lavender commercially.
- *Prunus* spp. (plums, cherries, ornamental almond (*P. dulcis*), etc.). Includes orchard crops, ornamentals and trees in the wider environment. UK orchard production data are available for two species of *Prunus* fruits.
  Plums: in 2017, the planted area was 640 ha which produced 8.0 thousand tonnes of fruit. 2018 provisional figures are 620 ha which produced 8.7 thousand tonnes (Horticultural Statistics, 2019).
  Cherries: in 2017, the planted area was 731 ha which produced 6.5 thousand tonnes of fruit. 2018 provisional figures are 756 ha which produced 3.6 thousand tonnes (Horticultural Statistics, 2019).
- *Rosa canina* (dog rose). Mostly a host in the wider environment, where leaves, flowers and rosehips are all important sources of food for a variety of animals.
- *Rosmarinus officinalis* (rosemary). Commonly grown garden herb.

SUSCEPTIBLE TO *X. FASTIDIOSA* SUBSP. *PAUCA* IN EUROPE:

- *Laurus nobilis* (bay). Commonly grown ornamental.
- *Olea europaea* (olive). Commonly grown ornamental, though at least one site in the UK is attempting to grow trees for commercial fruit harvest.

8. Summary of pest biology and/or lifecycle

This section is based on material presented in EFSA (2018a) unless otherwise stated.

Xylella fastidiosa is a bacterium which occurs in the foregut of hemipteran insects and can be transmitted to the xylem vessels of host plants during feeding. Symptoms are due to the xylem being blocked by both bacterial biofilms and by tyloses (part of the plant defence mechanism, involving cellular outgrowths which extend into adjacent xylem vessels) and thus symptoms can often mimic water stress. The bacteria usually move through the plant via the xylem vessels, but in some hosts infections may remain more localised. Disease caused by *X. fastidiosa* is due to a complicated interaction between many factors, including the host, bacteria, vector(s), environmental conditions, availability of alternative hosts, etc.

There is little evidence that *X. fastidiosa* can be seed transmitted. EFSA (2015) reports on four published studies, which have only studied seed transmission in one host species (*Citrus sinensis*, sweet orange). One paper did report seed transmission, but other, more recent, studies have not demonstrated the occurrence of any seed transmission of *X. fastidiosa* in *C. sinensis* (EFSA, 2015).

Xylella fastidiosa is vectored by xylem-feeding hemipteran insect vectors in the suborder Auchenorrhyncha (Cicadomorpha), which includes insects commonly known as spittlebugs/froghoppers, leafhoppers, sharpshooters and cicadas. Current information, e.g. EFSA (2018a) suggests that any Cicadomorpha which feed on xylem are potential vectors, but this is an over-simplification. All such insects have the potential to imbibe *Xylella fastidiosa* when feeding on infected plants, but only insects where the bacterium is able to persist and multiply in the foregut, forming a microfilm, are vectors. It isn't currently possible to predict accurately which insect species are potential vectors (EFSA, 2019b). Evidence of actual transmission is only available for a subset of xylem-feeding Cicadomorpha. Details about vector species (or potential vector species) can be found in section 10 of this PRA and EFSA (2019b), while mechanisms of transmission are covered in this section. Vectors acquire *X. fastidiosa* by feeding on xylem of an infected plant (including asymptomatic plants), and the vectors can immediately transmit the pathogen to a new plant. The bacteria do not systematically infect the body of the insect, instead being restricted to parts of the foregut, where the bacteria multiply. The vectors are persistently infectious until the time of their next moult. This means that, once an adult has acquired the bacterium, it remains infective for the remainder of its life. Eggs laid by infectious female vectors are free from *X. fastidiosa*: the only way an insect acquires the bacterium is through feeding on an infected plant.

9. What pathways provide opportunities for the pest to enter and transfer to a suitable host and what is the likelihood of entering the UK/PRA area?

Plants for planting

Infected plants for planting have been detected moving in trade, both from plants originating outside the EU (e.g. the UK interception on *Coffea* plants from Costa Rica) and in plants moving in trade within Europe, e.g. the findings in Switzerland (EPPO GD, 2019) or *Olea europaea* in Belgium (Belgian NPPO, unpublished data 2018). Furthermore, sequence types of *X. fastidiosa* isolates obtained from EU outbreaks have matched those found on coffee and oleander plants in Central America. There is molecular evidence for multiple introductions into Corsica, mainland France (Dénance *et al.*, 2017) and the Balearic Islands (Olmo *et al.*, 2017). While the pathway for these introductions is not known, plants for planting are an obvious suspect.

There are several factors which make detection of *X. fastidiosa* on traded plants difficult.

- Asymptomatic infections, especially as asymptomatic hosts can still act as a source of infection to other plants via vector transmission (EFSA, 2019a).
- Non-uniform distribution of infections in plants or long latent periods (particularly in woody hosts) mean that testing different parts of the same plant leads to different chances of detecting the infection (EFSA, 2019a).
- The very wide range of potential hosts means that targeting specific host species is difficult (EFSA, 2019a).
- When visual symptoms are present, they are rather generalised and similar to many other causes, including physiological stresses.

- Infections can be localised in a small part of a plant and even a symptomatic plant may test negative for *X. fastidiosa* if an uninfected plant part is tested.

There are extensive measures in the legislation to reduce the risk of *X. fastidiosa* moving in trade (see section 4 of this PRA for details of the legislation which applies). Defra has a contingency plan (Eyre & Parkinson, 2019), and section 4 of this contingency plan summarises all the various measures mitigating against *X. fastidiosa* which apply to imports of planting material to the UK.

Six host categories have been identified in the EU emergency measures as high-risk due to the fact they are all highly susceptible to *X. fastidiosa*, have been infected in Europe by more than one subspecies, and have been found to be infected in more than one location in Europe. These hosts are subject to additional measures, including testing, before they can be moved in trade. It should be noted that there are another eight hosts which meet roughly the same criteria (i.e. they have been found to be susceptible to more than one subspecies of *X. fastidiosa* in Europe). While some of these other species are unlikely to be commonly moving in trade, the list does include the common herb *Rosmarinus officinalis* (rosemary).

There is evidence that *X. fastidiosa* has moved in trade in plants for planting, and has succeeded in transferring to hosts growing in the wider environment in southern Europe. Though the UK has also imported plants for planting over many years from the Americas, *X. fastidiosa* has not been identified in this country (other than a single interception).

Due to the very wide host range, asymptomatic infections and non-specific symptoms, plants for planting other than seeds are considered to be the main pathway for entry to the UK. *Xylella fastidiosa* is present in parts of Europe, has a very wide host range, infected plants can have long latent periods (or be asymptomatic), and any symptoms are rather non-specific. Against this, there are extensive legislative measures in place designed to reduce the risk of entry, and these are kept under review and have been amended several times in the past to increase their efficacy. However, the legislation does only cover most host species from locations which are known to have *X. fastidiosa* and so there remains a possibility that plants may be moved from a newly infected site before the pathogen is detected. Measures on the six species of higher-risk hosts (*Coffea* spp., *Lavandula dentata*, *Nerium oleander*, *Olea europaea*, *Polygala myrtifolia* and *Prunus dulcis*) apply to plants from all origins, regardless of whether *X. fastidiosa* has been recorded from that location or not. There have been subsequent developments in relation to the risk situation for these species since the measures were introduced, including details from EFSA on asymptomatic periods and further interceptions/outbreaks of *X. fastidiosa* within Europe.

Overall, entry into the UK of *X. fastidiosa* on **plants for planting** is assessed as **moderately likely**, based on the legislation in force at the time of writing this PRA. There are many examples of the pest moving in trade, including some since the introduction of regulation to reduce the likelihood of this happening. The UK has traded with countries where *X. fastidiosa* is present for many years so it is possible (though highly uncertain) that transfer to other suitable hosts has been a limiting step in the UK. This judgement is made with **medium confidence** as it is unclear how effective the legislation is at reducing the chances of entry.

Infectious adult vectors moving in trade

Adult vectors might be associated with plants for planting, cut flowers or branches, fruits or vegetables as well as being hitchhikers on other commodities.

Adult insect vectors are winged and fly, and can also jump. Once an adult vector has acquired *X. fastidiosa*, it remains infective for the remainder of its lifespan (EFSA, 2013). Adults will jump and fly at the slightest disturbance, and it is likely that many will jump off plants being harvested or moved. The main risk will come from infectious vectors moving onto material already loaded and ready to be transported (i.e. the chances of further disturbance are relatively small). This includes (i) non-plant material, (ii) plant products (such as fruit or cut flowers), or (iii) growing plants.

(i) If infectious adults are associated with non-plant material, the insects may desiccate and die as they will not be able to feed, especially as humidity is likely to be low in many non-plant consignments. It is probable that viable insects will only be found in non-plant consignments which spend a comparatively short time in transit before the container is opened.
(ii) Infectious vectors associated with harvested plant products will not be able to feed, as they require growing plants, but the humidity in such consignments is likely to be reasonably high and they may survive for some time while the material is transported.
(iii) Infectious adult vectors associated with a consignment of uninfected growing plants are likely to feed on most plants, as vectors are often highly polyphagous. *Xylella fastidiosa* is likely to be introduced into the xylem of most hosts the infectious vector feeds on. Therefore, even during transport, an infectious vector may be able to transmit *X. fastidiosa*. The vector is also reasonably likely to survive transport as conditions are likely to be suitable.

Once a viable infectious adult vector has arrived in the UK it is very likely that it will be able to locate a suitable host upon arrival if it arrives in late spring or summer. These vector insects can fly, and most have a wide host range. Even weeds around cargo sheds are likely to be suitable hosts. As adults remain capable of transmitting *X. fastidiosa* throughout their lives, there is the potential for one infectious vector to infect a number of growing hosts after arrival in the UK. Once plants are infected in the UK, secondary spread to a range of plants in the vicinity would be possible by indigenous UK vector populations. However, vectors which arrive in autumn, winter or early spring will be less likely to be able to locate hosts. Insects are less mobile when temperatures are lower, freezing temperatures are likely to kill many species from warmer origins (especially as they will not have had a chance to acclimatise) and actively growing hosts will be harder to find.

Only one interception could be found in England of an adult cicadellid from any part of the Americas. This was a dead adult on *Passiflora* fruit from Colombia in 2016, and it was not identified past family. From other parts of the known range of *X. fastidiosa*, an interception of an adult cicadellid on *Ocimum* from Israel in 2012 again could not be identified past family (Fera, unpublished data). Cicadellidae is a very large family of insects, and it was not recorded if either of the intercepted specimens were phloem or xylem feeders. These interception records do not, however, tell the full story. Only non-European Cicadellidae which are known to be vectors of *X. fastidiosa* are listed pests. Other potential vector species are not included in the legislation therefore both findings and diagnoses of such insects are likely to be "for interest only". Data on vectors moving within the EU are even less accurate, especially as the key European vector species (*P. spumarius*) is native to the UK.

There are several limiting steps. The probability of the vectors being on pathway is dependent on a wide variety of factors and cannot be quantified accurately, but a major consideration is that all the vectors are very active, mobile insects which tend to jump away if disturbed. Trade volume data on planting material are available, but they are not broken down by host genus or even family. As discussed above, data on the frequency of vector movement is not collected in any systematic way, so it isn't possible to assess how commonly vectors may travel in trade. Seasonal timing is likely to limit the numbers, as only 4-6 months out of the year are likely to provide good conditions for a vector to move into the wider environment successfully and find suitable hosts. Pest management and phytosanitary procedures applied in country of origin may also help to reduce the association of vectors with commodities such as growing plants, fruit and cut flowers, but cannot address the problem of hitchhiking vectors on non-host commodities.

Although the likelihood is high of a viable infectious vector being able to transmit *X. fastidiosa* to growing plants after it has successfully arrived in the UK in the late spring or summer months, due to the many limiting steps on this pathway, the numbers of viable infectious vectors arriving in the UK at a suitable time of year is considered to be very small. Overall, the movement of *X. fastidiosa* on infectious adult vectors is assessed as **unlikely**, but with **low confidence** as there are a number of assumptions around this judgement.

Infectious immature vectors moving in trade

Immature vectors might be associated with plants for planting and cut flowers or branches. Nymphs from the family Cicadellidae may also be associated with fruits or vegetables, or be hitchhikers on other commodities.

Transovarial transmission does not take place (EFSA, 2013) (i.e., an infectious female vector lays eggs which do not have *X. fastidiosa*). Therefore, egg masses do not constitute a pathway and only nymphs are considered in this section. Nymphs of all vector species only remain infective until they moult. This is because *X. fastidiosa* is associated with the lining of the insect foregut, which is shed along with the rest of the cuticle at moulting (EFSA, 2013). After moulting, a previously infectious individual will not be infective, and must feed on an infected plant to re-acquire *X. fastidiosa*. Nymphs are most likely to be associated with herbaceous plants rather than woody hosts (Cornara *et al.*, 2018, EFSA, 2018a). Herbaceous plants will usually be of a smaller size and thus easier to inspect and detect the presence of insects. Only nymphs which arrive in late spring or summer are likely to be able to transfer to a suitable host in the wider environment.

NYMPHS FROM THE FAMILIES APHROPHORIDAE, CERCOPIDAE AND CLASTOPTERIDAE

A widely used common name for the nymphs from all three families is "spittlebugs", due to the fact they are covered in a white froth they exude as they feed. This makes the nymphs quite conspicuous, and likely to be detected, especially on plant products such as fruit or cut flowers. Away from a host, nymphs are likely to desiccate quickly if they cannot feed, as their biology means they egest water very rapidly to cope with the large volumes of nutrient-poor xylem they must ingest (Cornara *et al.*, 2018), and are usually protected by the froth they egest. On growing plants, while nymphs can walk from one plant to another, they are relatively immobile, certainly compared to immature Cicadellidae. Therefore, the chance of these nymphs moving from an infected growing plant to a clean one is relatively low. If an infectious nymph remains associated with a single growing plant, the pathway assessed becomes that of the plant (assessed earlier). This is because the UK already has a native vector species which is widespread (see section 10 of this PRA) and the plant will already be infected from the nymph's earlier feeding activities. Viable nymphs are not likely to be associated with commodities such as cut flowers or fruit and are very unlikely to hitchhike on non-plant commodities. If they can survive transport while not being associated with growing plants, it is likely that they will have some difficulty transferring to a new growing host after arrival.

No species in any of these families are listed in the legislation, and therefore the interception data below has not been gathered in any systematic way and does not present an accurate picture of insects which may be moving in trade. There have been recorded interceptions in England of nymphs of the main European vector species, *Philaenus spumarius*, though it is only recently that such insects have been sent for laboratory confirmation as it is native to the UK. A nymph on *Lavandula angustifolia* plants from Italy in 2018 was identified using molecular methods, and tested negative for *X. fastidiosa* using Taqman real-time PCR (Fera, unpublished data). A nymph on *Dichondra* in 2019 (origin unclear) was also identified as *P. spumarius*. No other diagnoses from the family Aphrophoridae were found. There have been interceptions from the family Cercopidae, but none on consignments originating from the known range of *X. fastidiosa*. No interceptions from the Clastopteridae have been recorded (Fera, unpublished data).

NYMPHS FROM THE FAMILY CICADELLIDAE

A widely used common name in North America (though it is also used in Europe) is "sharpshooters", especially for the xylem-feeding species. Currently, there are no proven vectors from this family in Europe, but there are a number in the Americas and two from Taiwan. Cicadellid nymphs are far more active than spittlebugs nymphs and are able to jump long distances. Physical disturbance caused by moving plants, and especially harvesting or cutting plant products, is likely to disturb the nymphs. It is probable that they will not remain associated with plant material, instead jumping off at the first movement.

Only non-European Cicadellidae which are known to be vectors of *X. fastidiosa* are listed pests. Other Cicadellidae are not included in the legislation and therefore interception data are not collected in any systematic manner. Data on vectors moving within the EU are even less accurate. Immature cicadellids have been intercepted by Fera on imports most years in the recent past (Fera unpublished data), but can seldom be identified beyond family as most are early instars which have hatched in transit (C. Malumphy, pers. comm., Oct 2019). Cicadellidae is a very large family, and there are comparatively few reference sequences meaning molecular diagnosis of intercepted immatures is seldom possible. Recorded interceptions from the Americas are of a nymph on *Dracaena* from Costa Rica in 2019; a dead nymph on *Mangifera* fruit from the Dominican Republic in 2017; eggs on *Gaultheria* from the USA in 2019 and a nymph in a mixed bunch of flowers from the USA in 2006 (Fera, unpublished data).

Only a proportion of cicadellids are xylem-feeding, and only xylem-feeders are considered to be vectors of *X. fastidiosa*. As immatures cannot be readily identified, the proportion of intercepted immature Cicadellidae which are xylem-feeding is not known. The cicadellid nymphs which do remain associated with plant material (or hitchhike on non-plant products) could infect growing plants in the consignment during transport as they move freely by jumping and walking. Cicadellid nymphs may also be more likely to survive transport as hitchhikers, because they do not live under a protective film of bubbles and they may be less prone to desiccation. Finally, being able to actively jump means cicadellid nymphs may have less difficulty in locating a new growing host after arrival than spittlebug nymphs. Overall, the risk from nymphs from this subfamily is considered to be slightly higher than spittlebug nymphs due to the cicadellids' higher capacity for movement.

SUMMARY

While the biology of spittlebug and sharpshooter nymphs is different, in neither case are they considered to pose a high risk of introducing *X. fastidiosa* to the UK. This is due to the relatively limited time they are infective, and either their conspicuous surrounding froth meaning detection is relatively likely, or their jumping ability and likelihood of leaving the plant after any disturbance. Overall, entry of *X. fastidiosa* on **immature vectors moving in trade** is assessed as **very unlikely** but with **low confidence** as this is based on a lot of assumptions.

Plants for planting (excluding seeds)	Very unlikely ☐	Unlikely ☐	Moderately likely ☑	Likely ☐	Very likely ☐
Confidence	High Confidence ☐	Medium Confidence ☑	Low Confidence ☐		

Infectious adult vectors moving in trade	Very unlikely ☐	Unlikely ☑	Moderately likely ☐	Likely ☐	Very likely ☐

Confidence	High Confidence ☐	Medium Confidence ☐	Low Confidence ☑		
Infectious immature vectors moving in trade	Very unlikely ☑	Unlikely ☐	Moderately likely ☐	Likely ☐	Very likely ☐
Confidence	High Confidence ☐	Medium Confidence ☐	Low Confidence ☑		

Pathways not rated

Several additional pathways were considered but ratings are not given here as, on the basis of current evidence, they either cannot be rated due to the lack of information, extremely high uncertainty, are considered very unlikely, or some combination of the three.

Seeds as a pathway have a very high uncertainty and could not be rated. Experiments on seed transmission have only been done on one host (*Citrus sinensis*), and the evidence is contradictory (EFSA 2015).

Fruit would be a pathway either due to seed transmission, or movement of infectious vectors associated with the commodity. Seeds could not be rated as a pathway, and movement of infectious vectors has been discussed earlier in this section.

Cut flowers and branches are largely assessed as part of infectious vector insects as the infection will need to transfer to a rooted host in the UK. While the native insect *Philaenus spumarius* is a proven vector, there is little evidence that it would select cut foliage to feed on. Once a stem has been cut, vector insects are not likely to remain associated with the foliage as they will be unable to feed properly, as most cut plant parts will not be transported in water, instead being chilled to preserve them. While there will be some residual risk from this commodity due to infectious vectors moving off the cut plants and finding new hosts, this is covered under movement of infectious vectors considered earlier.

Natural spread of infectious vectors. Little research has been done into the long-distance dispersal capability of the *P. spumarius*, the main European vector species of *X. fastidiosa* (EFSA, 2018a). What evidence is available, such as mark-recapture studies, suggests that the majority of adults move 100 m or less, though there is an older study which suggests that long-distance dispersal may be possible (EFSA, 2018a). Reynolds *et al.* (2017) trapped a male specimen of a potential vector species, *Neophilaenus lineatus*, at around 200 m above the ground in southern England, though no *P. spumarius* were caught during the study. Reynolds *et al.* (2017) also include data from trapping done over northern England in the mid-1930s, when a specimen of *P. spumarius* was trapped between 54 and 84 m above the ground, along with 14 *N. lineatus*. This does raise the possibility that at least occasional vectors may be found at heights where long-distance wind dispersal could take place. However, there is no conclusive evidence at this stage for long-distance movements of *P. spumarius* which would be sufficient for an insect to move naturally from the south of France, Spain or Italy (where the nearest known outbreaks of *X. fastidiosa* are) to the UK.

10. If the pest needs a vector, is it present in the UK/PRA area?

Details about the biology and interactions of *X. fastidiosa* with its vectors in general can be found in section 8. An overview of the biology of the main European vector species is at the end of this section.

Any xylem-feeding Hemiptera from the suborder Auchenorrhyncha, infraorder Cicadomorpha is considered to have the potential to be a vector (EFSA, 2018a). As mentioned in section 8 (pest biology), this is an over-simplification and insects are only vectors if *X. fastidiosa* is able to multiply in their foregut and form a microfilm, and it isn't possible to accurately predict in which of the xylem-feeding species of Hemiptera this takes place (EFSA, 2019b). The number of species which have been proven to be vectors is comparatively small (i.e. experiments in which an insect from the species in question has acquired *X. fastidiosa* from an infected plant and subsequently transmitted the bacterium to a clean plant which later tested positive for *X. fastidiosa*). Detecting *X. fastidiosa* from an insect only proves that it can acquire *X. fastidiosa*, and not that the insect is then capable of transmitting the bacterium to a new plant. This doesn't exclude other insects from consideration as potential vectors, but the discussion which follows is based on confirmed vector species, with the exception of Table 3.

Unsurprisingly, the majority of confirmed vectors are only known from the native range of *X. fastidiosa*, i.e., North, Central and South America (Table 2). Within Europe, only three species are confirmed as vectors, and of these three, only *Philaenus spumarius* has been shown to be a vector under both field and laboratory conditions (EFSA, 2018a). Only two confirmed vector species are present in the UK (Table 2). However, the list of potential vectors (i.e. xylem-feeding Auchenorrhyncha: Cicadomorpha) which are known to be present in the UK is longer, and can be found in Table 3. It must also be noted that there are additional potential vector species in the rest of Europe, and elsewhere, which are not present in the UK. These non-UK additional xylem-feeding species which are as yet not proven to be vectors of *X. fastidiosa* are not included in either Table 2 or Table 3.

Different vector-host species combinations have varying transmission efficiencies (Almeida, 2016). Some of this variation may be due to different host species having different bacterial population concentrations, and the different vector species having differing host preferences (Almeida, 2016). More variation can be explained by the distribution of *X. fastidiosa* within the plant, and different vector species having different preferential feeding sites on the plant, thus ingesting differing numbers of bacterial cells (Almeida, 2016). There may also be plant-vector interactions which affect the transmission efficiency (Almeida, 2016).

The infra-order Cicadomorpha (especially the family Cicadellidae) contains a very large number of species, and it should be noted that only a subset (the xylem-feeders) are considered to be vectors or potential vectors of *X. fastidiosa*. Species which feed on phloem are not considered to be vectors (Almeida, 2016), though while probing for phloem, it is possible that an insect may pierce a xylem vessel. At least some phloem feeders do appear to be capable of acquiring *X. fastidiosa*. For example, Elbeaino *et al*. (2014) detected the pathogen in the cicadellid *Euscelis lineolatus*, but this does not demonstrate that these insects can then go on to infect a clean plant. Some insects will feed on both xylem and phloem (for example, the cicadellid *Scaphoideus titanus* (Chuche *et al.*, 2017)). Current data suggests that phloem-feeders or phloem-feeders which occasionally feed on the xylem are not vectors of *X. fastidiosa* (Almeida, 2016).

For all distribution records, especially at sub-country level, there is a level of uncertainty associated with how accurately they reflect the true distribution of the species. This group of insects is almost certainly under-recorded, as they are usually difficult to separate in the field, many need microscopic examination, and a relatively low number of specialists are able to identify some of the more cryptic species. Distribution records may indicate where people who can identify the various species have sampled specimens more accurately than they depict the genuine species distributions.

Philaenus spumarius, the main vector in Europe and a species which is widespread in the UK, has one generation per year in Europe (more than one generation has been reported in the Middle East), with the overwintering stage being eggs (Cornara *et al.*, 2018). Adults are extremely variable in colour and markings. This website (http://www.britishbugs.org.uk) gives examples of some of the different forms. Nymphs hatch in spring and are one of the species which produce “cuckoo spit”, a white froth which covers the immatures. Adults are seen from late spring until autumn (Cornara *et al.*, 2018), though occasional adults have been seen in the UK in winter (pers. comm. C. Malumphy to R. Baker, September 2017). While nymphs feed on a wide range herbaceous plants, adults have an even broader host range and will also feed on numerous woody tree species (Cornara *et al.*, 2018). *Philaenus spumarius* nymphs (identified using molecular methods) were found developing on oak foliage in Northern England on three occasions in 2019, but the frequency of this is unknown (C. Malumphy, pers. comm. October 2019).

Table 2. Summary of proven vector species of *Xylella fastidiosa*. Continental distribution is given (or – for absence). Source: Redak *et al.* (2004) unless otherwise stated.

		Distribution		
Family[13]	**Vector species**	**UK**[14]	**Mainland Europe**[15]	**Americas [Global]**
Aprophoridae	*Aphrophora angulata*	–	–	North, Central
Aprophoridae	*Aphrophora permutata*	–	–	North
Aprophoridae	*Lepyronia quadrangularis* (EFSA, 2019b)	–	–	North
Aprophoridae	*Poophilus costalis* (EFSA, 2019b)	–	–	[Africa, Asia]
Aprophoridae	***Neophilaenus campestris*** (EFSA, 2018a)	**Southern**	**Widespread**	–
Aprophoridae	*Philaenus italosignus* (EFSA, 2018a)	–	**Limited (Italy)**	–
Aprophoridae	*Philaenus leucophtalmus*	–	–	North
Aprophoridae	***Philaenus spumarius***	**Widespread**	**Widespread**	North
Cicadellidae	*Acrogonia citrina*	–	–	South
Cicadellidae	*Acrogonia virescens*	–	–	South
Cicadellidae	*Amphigonalia severini*	–	–	North
Cicadellidae	*Bothrogonia ferruginea* (Tuan *et al.*, 2016)	–	–	[Asia]
Cicadellidae	*Bucephalogonia xanthophis*	–	–	South
Cicadellidae	*Cuerna costalis*	–	–	North
Cicadellidae	*Cuerna occidentalis*	–	–	North
Cicadellidae	*Cuerna yuccae*	–	–	North
Cicadellidae	*Dechacona missionum* (EFSA, 2019b)	–	–	South
Cicadellidae	*Dilobopterus costalimai*	–	–	South
Cicadellidae	*Draeculacephala californica*	–	–	Unknown Americas
Cicadellidae	*Draeculacephala crassicornis*	–	–	North
Cicadellidae	*Draeculacephala minerva*	–	–	North, Central
Cicadellidae	*Draeculacephala noveboracensis*	–	–	North
Cicadellidae	*Ferrariana trivittata*	–	–	Central, South
Cicadellidae	*Fingeriana dubia* (EFSA, 2019b)	–	–	South
Cicadellidae	*Friscanus friscanus*	–	–	North
Cicadellidae	*Graphocephala atropunctata*	–	–	North, Central
Cicadellidae	*Graphocephala confluens*	–	–	North
Cicadellidae	*Graphocephala cythura*	–	–	North
Cicadellidae	*Graphocephala hieroglyphica*	–	–	North
Cicadellidae	*Graphocephala versuta*	–	–	North, Central
Cicadellidae	*Helochara delta*	–	–	North
Cicadellidae	*Homalodisca ignorata*	–	–	South
Cicadellidae	*Homalodisca insolita*	–	–	North, Central
Cicadellidae	*Homalodisca liturata*	–	–	North
Cicadellidae	*Homalodisca vitripennis* (= *H. coagulata*)	–	–	North
Cicadellidae	*Kolla paulula* (Tuan *et al.*, 2016)	–	–	[Asia]
Cicadellidae	*Macugonalia clavifrons* (EFSA, 2019b)	–	–	South
Cicadellidae	*Macugonalia leucomelas*	–	–	South
Cicadellidae	*Molomea consolida* (EFSA, 2019b)	–	–	South
Cicadellidae	*Neokolla hyeroglyphica* (EFSA, 2019b)	–	–	North

(Table continues on next page)

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[13] Following the taxonomy in https://bugguide.net/node/view/12745/tree, accessed 25 July 2019
[14] UK checklist, 2011, available at http://www.ledra.co.uk/species.html, accessed 16 July 2019.
[15] Fauna Europeana (https://fauna-eu.org/, accessed 17 July 2019).

Table 2. (continued). Taxonomy and distribution sources as on previous page.

		Distribution		
Family	**Vector species**	**UK**	**Mainland Europe**	**Americas [Global]**
Cicadellidae	*Neokolla severini* (EFSA, 2019b)	–	–	North
Cicadellidae	*Oncometopia facialis*	–	–	South
Cicadellidae	*Oncometopia nigricans*	–	–	North
Cicadellidae	*Oncometopia orbona*	–	–	North
Cicadellidae	*Oragua discoidula* (EFSA, 2019b)	–	–	South
Cicadellidae	*Paragonia confusa*	–	–	North
Cicadellidae	*Paragonia furcata*	–	–	North
Cicadellidae	*Paragonia tredecimpunctata*	–	–	North
Cicadellidae	*Paragonia triundata*	–	–	North
Cicadellidae	*Parathona gratiosa*	–	–	South
Cicadellidae	*Plesiommata corniculata*	–	–	North, Central, South
Cicadellidae	*Plesiommata mollicella* (EFSA, 2019b)	–	–	North, Central, South
Cicadellidae	*Sibovia sagata* (EFSA, 2019b)	–	–	South
Cicadellidae	*Sonesimia grossa*	–	–	South
Cicadellidae	*Tapajosa rubromarginata* (EFSA, 2019b)	–	–	South
Cicadellidae	*Xyphon flaviceps*	–	–	North
Cicadellidae	*Xyphon fulgida* (= *Carneocephala fulgida*)	–	–	North
Cicadellidae	*Xyphon triguttana*	–	–	North
Clastopteridae	*Clastoptera achatina* (EFSA, 2019b)	–	–	North
Clastopteridae	*Clastoptera brunnea*	–	–	North
Membracidae	*Cyphonia clavigera* (EFSA, 2019b)	–	–	South

Table 3. Summary information on potential vector species of *Xylella fastidiosa* known to be in the UK. Broad details of distribution in the UK are given. Other potential vector species are present in mainland Europe, but not listed here. Source: Malumphy, Appendix 4 to Parkinson & Malumphy (2014).

Family	**Hemiptera species**	**UK distribution** (http://www.ledra.co.uk)
Aphrophoridae	*Aphrophora alni*	Widespread
Aphrophoridae	*Aphrophora major*	Relatively few, scattered, records
Aphrophoridae	*Aphrophora pectoralis*	Relatively few, scattered, records
Aphrophoridae	*Aphrophora salicina*	Scattered records in England & Wales
Aphrophoridae	*Neophilaenus exclamationis*	Widespread in Great Britain
Aphrophoridae	*Neophilaenus lineatus*	Widespread
Aphrophoridae	*Neophilaenus longiceps*	Records only from south-east England
Cercopidae	*Cercopis vulnerata*	Widespread in England & Wales
Cicadellidae	*Anoterostemma ivanoffi*	Recent introduction
Cicadellidae	*Cicadella lasiocarpae*	Very few, scattered, records
Cicadellidae	*Cicadella viridis*	Widespread
Cicadellidae	*Euscelis lineolatus* NB. This species is phloem feeding, but is listed as a potential vector of *X. fastidiosa* by Elbeaino *et al*. (2014)	Scattered records in England & Wales
Cicadellidae	*Evacanthus acuminatus*	Scattered records, but widespread
Cicadellidae	*Evacanthus interruptus*	Widespread
Cicadellidae	*Graphocephala fennahi*	England & Wales (introduced 1930s)

In summary, there are a large number of xylem-feeding Cicadomorpha species worldwide, and there is the possibility that these could vector *X. fastidiosa*. However, the number of confirmed vector species is lower. Unsurprisingly, most confirmed vector species are from the Americas (the native range of *X. fastidiosa*). There are three confirmed vector species in Europe, of which two are found in the UK. The most common proven vector of *X. fastidiosa* in Europe, *P. spumarius*, is also widespread in the UK and therefore vector availability is not considered to be a limiting factor for potential spread of *X. fastidiosa* in this country.

11. How likely is the pest to establish outdoors or under protection in the UK/PRA area?

Establishment outdoors

The factors which limit the distribution of *X. fastidiosa* (and each subspecies) are uncertain. In published work the main assumption is that climatic factors are limiting. Much of the published work on the potential of *X. fastidiosa* establishment has been done modelling the potential suitability based on various climatic factors. However, it is highly probable that other constraints, such as the distribution of suitable hosts for the subspecies and sequence type in question, could limit the area where each subspecies of *X. fastidiosa* could establish. Some evidence of host specificity by sequence type is available in the literature, e.g. Harris & Balci (2005), but the extent of such specificities is unknown. Additionally, vectors are likely to influence the potential distribution of *X. fastidiosa*. Different species of vector will differ in their distribution, have varying efficiencies of accumulation for *X. fastidiosa* and will have different preferences for different hosts. Different species of vector are also likely to interact with the environment differently, e.g. how readily an individual insect moves between plants, or what temperature it requires before it will move readily.

EXPERIMENTAL DATA ON THERMAL REQUIREMENTS

Feil & Purcell (2001) worked on identifying the thermal requirements of *X. fastidiosa* in the laboratory. Most experiments were done on *X. fastidiosa* subsp. *fastidiosa* (identified as strain STL at the time of the study). Bacteria were cultured in liquid media and kept at ten different constant temperatures, from 5°C to 35°C. Populations of *X. fastidiosa* subsp. *fastidiosa* declined at 5°C, showed no growth at 12°C, and grew fastest at 28°C (Feil & Purcell, 2001). Experiments were also done in growing *Vitis* plants, with inoculated plants kept at six different temperatures: 5, 12, 18, 22, 28 and 32°C. The minimum temperature for growth was determined as 17–25°C in *Vitis* plants. Compared to another bacterium *Erwinia amylovora* (fireblight) (which is present in the UK), *X. fastidiosa* has a slower growth rate, even at optimal temperatures, and requires warmer temperatures before any growth can start (Feil & Purcell, 2001).

Experiments were also done by Feil & Purcell (2001) comparing the growth rates of *X. fastidiosa* subsp. *fastidiosa* (as STL) with *X. fastidiosa* subspp. *multiplex* and *sandyi* (as almond leaf scorch strain Dixon and oleander leaf scorch strain Ann1 respectively).

Comparing the growth of different subspecies in liquid media at four different temperatures (12, 28, 32 and 35°C) demonstrated that none grew at 12°C. At 28 and 32°C, all subspecies reached the same maximum population levels at around day 9, though there were small differences in the rate different subspecies achieved this. At 28°C, *X. fastidiosa* subsp. *sandyi* showed slower growth after 2, 4 and 7 days, though by day 9 it had reached the same population levels as the others. At 32°C, *X. fastidiosa* subsp. *fastidiosa* showed faster growth than the other two subspecies at day 4 (during the exponential phase of growth), but by day 7 populations were approximately the same across all subspecies (Feil & Purcell, 2001).

CURRENT DISTRIBUTION – MARGINAL RECORDS

This section is largely based on Baker (2017) which was an update to part of the 2014 UK PRA (Parkinson & Malumphy), assessing the suitability of the UK climate. It must be noted that the records which follow are merely those which could be found in the literature. Records of pest species from outside the areas where they cause economic damage are usually scarce and do not form a complete picture. Often the distribution records in such marginal areas delineate the areas where surveys are done (for whatever reason), rather than mapping the true distribution of any given pest. From the available information, these caveats about marginal records would appear to apply to *X. fastidiosa* and so the information which follows must be treated with appropriate caution.

In **Canada**, there are reports of *X. fastidiosa* from the Niagara Peninsula in southern Ontario, where the host was *Ulmus americanum* (Goodwin & Zhang, 1997), though the subspecies was not determined. There are old reports of damage to *Acer* from British Columbia (Vancouver Island and the Gulf Islands) which were confirmed by ELISA tests (Turnquist & Clarke, 1992), but no subsequent findings from this area have been reported. Other Canadian records are not considered reliable. Saskatchewan reports of *X. fastidiosa* (Northover & Dokken-Bouchard, 2012) appear to have been based on visual examination only. An Alberta record on *Ulmus* (Holley, 1993) was likely again to have been based on visual examination, and in addition the name used in the report was illegitimate (or a major typing error, pers. comm. J-F Dubuc to R. Baker, June 2017). *Xylella fastidiosa* is a quarantine pest in Canada (EPPO GD, 2019).

Records from **northern USA** on the West Coast include Oregon (EPPO GD, 2019) and Washington State. The Washington reports are very recent: in 2017 *X. fastidiosa* was detected in the county of Grant and in 2018 in the counties of Chelan, Clark, Grant, Lincoln, Spokane and Whitman (CAPS pest tracker, 2019). The 2018 findings would have been identified using molecular methods (EU audit, 2018). On the East Coast, northern records of *X. fastidiosa* include New York State, Pennsylvania and New Jersey (EPPO GD, 2019). There are also continental records from Indiana, Missouri (EPPO GD, 2019), Illinois and south-east Michigan (Adams *et al.*, 2013). *Xylella fastidiosa* is found in all the southernmost mainland states of the USA (EPPO GD, 2019).

The northern half of **Argentina** provides the southernmost records of *X. fastidiosa*. There are records from *Olea* in the provinces of Córdoba, La Rioja and Catamarca (Haelterman *et al.*, 2013; Tolocka *et al.*, 2017). There are slightly more northerly records on *Citrus* from the provinces of Corrientes and Missiones, where Argentina borders southern Brazil and Paraguay (Coletta-Filho *et al.*, 2017).

While the findings near Porto in **Portugal** (EPPO GD, 2019) are relatively southern in latitude, Porto is on the Atlantic coast and has relatively cool, temperate summers compared to other locations where *X. fastidiosa* has been recorded.

COMPARING CLIMATE IN THE MARGINAL AREAS OF THE CURRENT DISTRIBUTION AND THE UK

This section is largely based on Baker (2017) which was an update to part of the 2014 UK PRA (Parkinson & Malumphy), assessing the suitability of the UK climate. Baker (2017) chose two locations in England for the climatic comparisons with known locations of *X. fastidiosa* in the northerly and southerly parts of the Americas (Fig. 4). Heathrow Airport to the west of London was selected as the summer temperatures here will be among the highest in the UK. St Marys in the Isles of Scilly was the second site, chosen as the winter temperatures are among the mildest in the UK. UK mean minimum and maximum monthly average temperatures were sourced from the UK Met Office (data obtained 2017), and use data for the period 1981–2010. The most northerly North American locations were in the Niagara Peninsula in Canada and also from the US: New Jersey and Michigan. Recent findings in Washington State were added to the analysis by the inclusion of Moses Lake in the centre of Grant County and Vancouver and Amboy from Clark County. The most southerly South American locations were in two locations in Argentina: Cordoba and La Rioja provinces. These data were transposed by six months so direct seasonal comparison with the northern hemisphere records was possible. Data for Porto, Portugal were also included as there is an outbreak near the city. Non-UK climate data were sourced from https://en.climate-data.org/ (accessed 2017 and 2019), and use data collected 1982–2012.

A comparison of **monthly mean winter temperatures** (Fig. 5) showed that the data from north easterly locations in North America all had substantially colder winters compared to the UK (Baker, 2017). However, two of the Washington locations did have warmer winters than the other North American sites, with the monthly mean minima and maxima from Vancouver (Washington) 1–2°C colder than Heathrow Airport in January and December. A confounding factor to bear in mind when comparing the North American and UK temperatures is that the North American locations are likely to have substantial snow cover for much of the winter. This will insulate plants close to the ground, leading to a microclimate with winter temperatures which are substantially warmer than the meteorological station-measured air temperatures. Data from Franklin Bluffs in the north of Alaska (USA) show that from October to March, the daily mean ground surface temperature underneath deep snow cover was usually between 5 and 20°C higher than the air temperature, apart from some short-duration periods where a warm air mass moved into the region, warming the air but not the ground underneath the snow (Zhang, 2005). It should be reiterated that these data are from northern Alaska. In the range of *X. fastidiosa*, winter temperatures under snow compared with air temperatures are unlikely to show such a large divergence in temperatures.

The Argentinian minimum winter temperatures are around the same as those in Heathrow, but the winter monthly mean maximum temperatures are much higher, i.e. the diurnal range in temperatures is much greater than at Heathrow (Baker, 2017). The monthly mean winter temperatures in Porto are warmer than Heathrow airport, but 1–2°C colder than St Mary's on the Isles of Scilly. However, the monthly mean maximum temperatures in Porto are higher than both UK locations.

Minimum winter temperatures have been used in the USA as a predictor of whether Pierce's disease of grapevine (caused by *X. fastidiosa* subsp. *fastidiosa*) is likely to survive. Temperature thresholds of either ≤ -12.2°C for 2–3 days, or ≤ -9.4°C for 4–5 days are considered to delimit areas where *X. fastidiosa* subsp. *fastidiosa* could establish (Engle & Margarey 2008). Baker (2017) used daily data from www.ecad.eu (Jan 1960–Aug 2017) for Heathrow Airport and found that such conditions are exceptional, and since 1990 an average of less than one day per winter has temperatures below either threshold (Baker, 2017).

Testing the shoots of American sycamore (or American plane) (*Platanus occidentalis*) suggested that temperatures of -5°C reduced the viable populations of *X. fastidiosa* in the shoots (Henneberger *et al.*, 2004). Cumulative hours below -5°C were more closely correlated with bacterial populations than the mean hours below such temperatures (Henneberger *et al.*, 2004). While air temperatures of -5°C are experienced in the UK, they typically only occur for a short time, and thus the accumulation of hours below this temperature in nearly all parts of the UK will be slow and therefore *X. fastidiosa* might remain at relatively high levels when protected in tree shoots over winter.

Figure 4. Location of sites where used for investigating temperature comparisons: marginal records of Xylella fastidiosa and two sites in the UK.

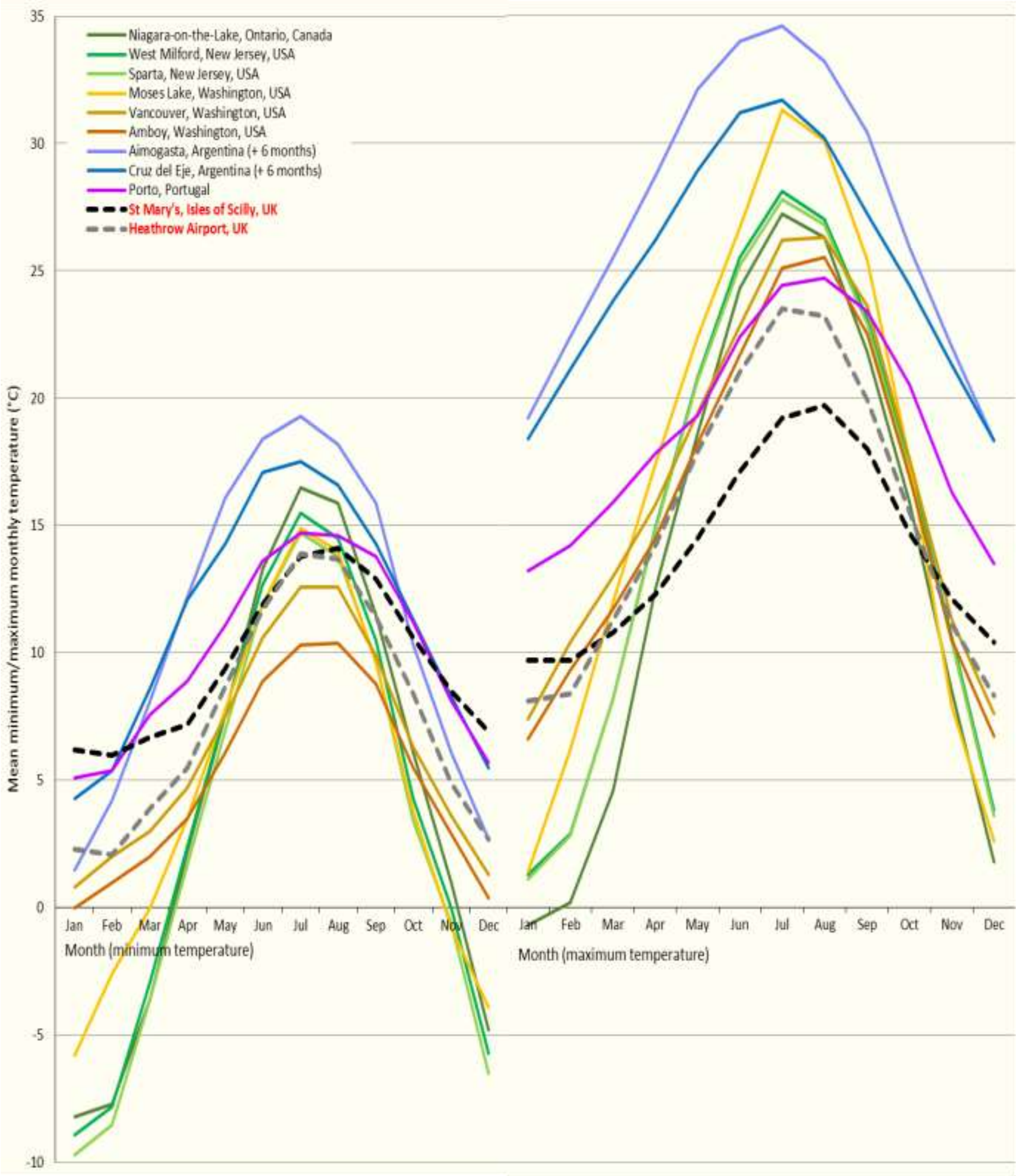

Figure 5. Mean monthly temperatures: minimum (left) and maximum (right). Data from selected weather stations near the records of *Xylella fastidiosa* from marginal locations in eastern North America (green), western North America (yellow-brown), South America (blue, data shifted by six months for direct comparison with the Northern hemisphere) and coastal Portugal (purple). These are compared with two warm sites in the UK (dashed black/grey). American data 1982-2012; UK data 1981-2010.

January isotherms were used by Purcell & Feil (2001) to predict the severity of impacts of Pierce's disease (caused by *X. fastidiosa* subsp. *fastidiosa* on *Vitis*). Using Met Office mean monthly January temperature and maps from the UK Met Office (data 1981–2010), only very small areas of Scotland, in the Highlands and Grampians, have mean January temperatures < -1°C, thus falling into the "rare" category for impacts according to Purcell & Feil (2001). The rest of the UK has mean January temperatures which suggest impacts would be more common. Therefore, January temperatures in the UK are not considered a barrier to the establishment of *X. fastidiosa* subsp. *fastidiosa* according to the models used to predict impacts in the USA.

Plant hardiness zones are based on the average extreme minimum temperature over the year. Adams *et al.* (2005) used 2006 plant hardiness zones to classify locations where *X. fastidiosa* had been detected. The area with the lowest extreme minimum temperature was in Wisconsin, classified as zone 5, which equates to extreme minimum temperatures of -23 to -29°C, but the infected sample only consisted of two trees. Other northerly records of *X. fastidiosa*, such as the southern part of Michigan were in zone 6 (-18 to -23°C) (Adams *et al*., 2005). USA-wide maps of plant hardiness are available for the time period 1976–2005[16]. The eastern counties in Washington where *X. fastidiosa* has been detected contain zones 6a, 6b and 7a (range of -23.3 to -15°C). Clark county in southern Washington has plant hardiness zones from 8a to 8b (range from -12.2 to -6.7°C). The other northerly locations in North America have hardiness zones of 8 or 9 (-12.2 to -1.1°C), while the southerly locations in South America are in plant hardiness zone 10 (-1.1 to +4.4°C). The UK has comparatively mild winters, with most of lowland UK in zones 8–9 and much of the rest of the country in zone 7, within the range of plant hardiness zones where *X. fastidiosa* is found in the Americas.

Summer temperatures are higher in most of the North and South American weather stations analysed when compared to the UK sites (Fig 5). The North American mean monthly maximum summer temperatures (including all three Washington locations) were higher than the UK mean monthly maxima (Fig. 5, right). The mean monthly minimum summer temperatures (Fig. 5, left) were more similar between the two continents. Two sites in the south of Washington State had lower mean minimum temperatures than Heathrow and St Mary's all year round, including the summer months. The South American summer was much hotter than either UK location, both for maximum and minimum mean monthly temperatures. Porto in Portugal, due to the Atlantic Ocean influence, had the lowest mean monthly maximum summer temperatures, but these were still around 1-2°C higher than the equivalent temperatures in Heathrow.

The warmer summer temperatures contribute to the fact that **growing degree days** (using a threshold temperature of 10°C) are considerably higher in the sites chosen in the Americas for comparison with the UK (Baker, 2017), even in the northern and southern sites chosen here as the limits of the known distribution of *X. fastidiosa*.

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[16] https://planthardiness.ars.usda.gov (accessed 6 August 2019)

MODELS – ASSUMPTIONS, LIMITATIONS AND SUMMARIES OF PUBLISHED WORK

Since *X. fastidiosa* was detected in Europe, there has been a great deal of interest in modelling its potential distribution, within a country, region or globally. The difficulty with all the models is the high level of uncertainty. Broadly, the models are based on the existing distribution records of *X. fastidiosa*, either in the invasive range, the native range, or both. The climate around the known distribution is analysed, and then regions in the target area which have similar climatic parameters are identified as potentially suitable. Three main sources of uncertainty have been identified which apply to most of the modelling reported on here, and which should be taken into account when considering the results of each summarised study:

1. Distribution in the native range, which may be under-recorded. This is exacerbated by the symptoms of *X. fastidiosa* not being especially distinctive, and in regions which are less suitable, there is a possibility of mild symptoms not being detected. Asymptomatic infections are also very unlikely to be detected without a systematic survey. In terms of modelling the potential distribution, the distribution records at the limits of the distribution (i.e. those least likely to be accurately recorded) have a large influence on the predicted suitable area. Many models require records of absence or pseudo-absence, which are always difficult to verify.
2. Distribution in the introduced range. Here, distribution records are of most use for climatic modelling if the pest has stopped spreading and has reached its maximum extent, constrained by climate. For *X. fastidiosa* in Europe, this is not the case.
3. Many models use older climate data, e.g. 30-year averages from 1970-2000, as more recent data climate data are much less available. These older data do not take account of recent climate change. However, if the same data are used worldwide, the influence of this factor is reduced. Many of the distribution points of *X. fastidiosa* used in the modelling will have been collected in the recent past, and so will be outside the period covered by the climate dataset.

Further limitations apply to the various modelling reports. The statements which follow may be obvious, but are still worth noting. The choice of model(s) and the constraints upon the model used (such as climatic variables included or excluded) have a very large impact on the predictions made. Much of the available work is to some extent contradictory, especially when fine details are compared. All models are an approximation of real life, and no model output will ever be wholly accurate in all respects (though some models will more closely approximate the actual world than others).

The text which follows is a summary of the inputs and predictions from various models attempting to predict the distribution of *X. fastidiosa*, and the work is presented in date order. The non-inclusion of any similar piece of work means either that it was not considered to add anything to the studies already presented, or, more simply, that the literature searches for this PRA did not locate it. More emphasis is given to papers which include the potential suitability of the UK, simply because this PRA is UK-based.

- Hoddle (2004) used CLIMEX to model the strain of *X. fastidiosa* which causes Pierce's disease of grapevine in California (which is likely to be the subspecies *fastidiosa*), both in the US and worldwide. Published data on *X. fastidiosa* temperature responses were used to set the appropriate CLIMEX parameters. The output was verified with the compare locations CLIMEX tool and a USA map of severity of Pierce's disease. The date range of the climate data was not explicitly specified, but CLIMEX has a default climatological dataset for the years 1961-1990. Extrapolating the model globally, the model suggests that the land around the Mediterranean would be suitable for the Pierce's disease-causing strain of *X. fastidiosa*, including parts of Italy and parts of Spain. No part of the UK was modelled as suitable, and all of France was also considered unsuitable by the model.

- Bosso *et al.* (2016a, 2016b) used the Maxent model to investigate potential distribution in Italy and around the Mediterranean. The distribution dataset used was only that of the Apulia region in Italy, and of that dataset, only records on olive trees from 2014-2015. The time period for climatic data collection was not explicitly stated in either paper. This modelling suggested that the farthest north *X. fastidiosa* would reach in Europe was northern Portugal and Galicia in north-western Spain. In Italy, the prediction was that the southern part of Italy, a thin strip along much of the western coast, Sicily and Sardinia would all be suitable.
- Hafi *et al.* (2017) used three models to examine the suitability of Australia for *X. fastidiosa*. Two complex models (CLIMEX and CLIMATCH) were run, but produced results which did not entirely agree. The Australian work was considering potential impacts on the grape and wine industry, and winter temperatures are considered to affect the severity of Pierce's disease of grapevines (caused by *X. fastidiosa* subsp. *fastidiosa*) in the USA. Therefore, a much simpler minimum winter temperature model was used for the modelling, using data collected between 1981 and 2010. This classified Australia into unsuitable (average minimum winter temperature below 1.7^{o}C), partially suitable (1.7–4.5^{o}C) or highly suitable (average minimum winter temperatures above 4.5^{o}C) when estimating the severity of impacts of *X. fastidiosa* affecting *Vitis*.
- Hernández & García (2018) used Maxent to predict the suitability of the Balearic Islands and the Iberian Peninsula. Distribution records were taken from the Balearic Islands. The date range for climate data was not explicitly stated. Bioclimatic variables were plotted in a dendrogram and only one variable per cluster (i.e., uncorrelated variables) were used for the model. Three models were produced: one calibrated with the Balearic Islands; the second calibrated using both the Balearics and the Iberian Peninsula and the third combining the outputs of the first two using a fuzzy sum function. The three models differ very markedly in their outputs, ranging from the majority of Spain and the southern half of Portugal being at least partially suitable, to only extreme southern coastal margins of mainland Spain and the Balearic Islands predicted to be suitable.
- Hernández & García (2019) used an ensemble of the ecological niche models Maxent and multivariate adaptive regression splines (MARS) to model the suitability of the world, with a focus on the Iberian Peninsula. Global distribution data were used. The climatic data did not have the date range used explicitly stated. The 19 Worldclim bioclimatic variables were transformed using Principal Component Analysis, and the first five principal components were selected for modelling. The results of the global predictions suggested that the south-east of the UK was moderately suitable using this model, while much of the rest of the UK was marginally suitable to unsuitable.

- EFSA (2019a) examined both the Köppen-Geiger climate classification and ensemble species distribution modelling (SDM) using ten different models (specified in the paper). While useful for a broad overview, Köppen-Geiger classifications are quite broad and take account of rainfall volumes and rainfall pattern across the year as well as temperature. At a level of north-western Europe, they do not provide sufficient discrimination between climatic regions for the analysis to be of much use in predicting whether any part of the UK might be susceptible to *X. fastidiosa*. Additionally, there is little evidence to suggest that rainfall volume and pattern are likely to be determinants of *X. fastidiosa* distribution, although the symptoms of *X. fastidiosa* may be more pronounced following drought. Therefore, only the EFSA SDM models will be discussed here. Global pathogen distribution data were used, and climate data was for the period 1979–2013. Highly correlated bioclimatic variables were removed from the analysis.
    - For ***X. fastidiosa*** as a whole, the modelling done by EFSA (2019a) showed only Cornwall as partially suitable, and the rest of the UK as essentially unsuitable. Highlighting Cornwall as a location with greater suitability for *X. fastidiosa* than the rest of the UK is likely to be a result of its milder winters. The overall importance of winter temperature in determining the potential distribution of *X. fastidiosa* in the UK is doubtful given that UK winters are much milder than those experienced in some of the North American locations from where *X. fastidiosa* has been reported.
    - For ***X. fastidiosa* subsp. *fastidiosa***, the area around the south coasts of England and Wales were partially suitable, while the rest of the UK was essentially unsuitable.
    - For ***X. fastidiosa* subsp. *multiplex***, the south-western tip of Cornwall was moderately suitable. Quite a few areas of the UK were modelled as partially suitable: the rest of the south coast of England, lowland areas of Wales and north-western England, East Anglia, Northern Ireland, coastal areas of Dumfries and Galloway, and, perhaps surprisingly, Caithness and eastern Aberdeenshire.
    - For ***X. fastidiosa* subsp. *pauca***, small areas around the English south coast, especially around Southampton, were partially suitable, while the rest of the UK was unsuitable.

  Modelling by sequence types (STs) (a further division of *X. fastidiosa* subspecies) was also carried out. While EFSA (2019a) do provide maps and analysis for each of the STs which are widespread in Europe, the number of samples are low, and the authors state there is considerable uncertainty as a result. These ST results are not summarised here, except to comment that the maps for each ST in the UK has substantial differences from the map calculated for its parent subspecies.
- Godefroid *et al.* (2019) used four different models (artificial neural network, Bioclim, generalised linear model and Maxent) in an ensemble approach to model the suitability of Europe. Occurrences of *X. fastidiosa* subspecies *fastidiosa, multiplex* and *pauca* in the native and invasive ranges were used and climate data was from the period 1970-2000. Each model was tested by fitting it to records in the native areas, and examining the predictions with the records in the invasive areas. Two to four climatic descriptors were used to prevent the models being over-fitted, in seven different datasets, each of which was tested against the four models. A small number of climate/model combinations were discarded for each subspecies, as they did not produce results over set thresholds of significance. The results from Godefroid *et al.* (2019) suggest that:

- For ***X. fastidiosa* subsp. *fastidiosa***, around half of the retained model combinations predict that much of England and Northern Ireland would be suitable for establishment, with much of Wales, most of Scotland and the north-west of England predicted as unsuitable by around 75% of the models.
- ***Xylella fastidiosa* subsp. *multiplex*** was modelled as having the greatest potential to establish in the UK. The London area was predicted to be suitable by almost all the retained models. The remainder of England, almost all of Wales, Northern Ireland and lowland and western Scotland were predicted as suitable by around 75% of the models. The Highlands of Scotland were shown to be suitable by around half of the models.
- For ***X. fastidiosa* subsp. *pauca***, only Cornwall and Devon were predicted to be even partially suitable, and that was by less than half of the retained models. The rest of the UK was not suitable for this subspecies according to all the models tested by Godefroid *et al.* (2019).

OTHER FACTORS OF RELEVANCE WHEN ASSESSING THE POTENTIAL FOR ESTABLISHMENT

Cold curing has been used as a means of eliminating *X. fastidiosa* from *Vitis vinifera* (grapevine) (Purcell, 1977), *Prunus dulcis* (almond) and *P. webbii* (a wild almond) (Ledbetter *et al.*, 2009). At least twelve weeks after inoculation, *V. vinifera* plants were subjected to cold treatments using combinations of different times and temperatures where the minimum was -12^{o}C, and exposure could be a single period or multiple (Purcell, 1977). Though a lot of plants were killed by the treatment, some did show recovery from the disease and thus, presumably, the infection. Experimenting on *Prunus* spp., Ledbetter *et al.* (2009) maintained plants in a temperature controlled glasshouse over the summer, then took them outside and exposed them to normal winter temperatures in the Californian San Joaquin Valley. Again, some tree death was seen, but of the survivors, after two winters, some plants were cured (tested by PCR) (Ledbetter *et al.*, 2009). While these studies show that low temperatures can eliminate *X. fastidiosa* (likely to be subspecies *fastidiosa*) from a plant, the presence of *X. fastidiosa* in northern parts of the USA and southern Canada where temperatures are below freezing for long periods each year indicates that cold treatment is only applicable to certain subspecies and/or pathogen-host interactions. Also, only a proportion of plants are cold-cured, and in terms of establishment, it would be possible for the infection to spread from plants where cold-curing had failed. Therefore, though cold-curing does exist, it remains unknown whether it would reduce the risk of establishment of *X. fastidiosa* in the UK.

Different vector lifecycles in North America and Europe are considered unlikely to affect the chances of establishment. In North America, adults of a major US vector, *Homalodisca vitripennis* (Cicadellidae), were trapped throughout the year in southern California, and eggs hatch within 1-2 weeks (Blua *et al.,* 1999). Again in California, *Graphocephala atropunctata* (Cicadellidae) overwinters as an adult, transmitting infection to vines in spring (Cornara *et al.* 2019). Most work with proven vector species and their overwintering lifecycle has been done with *Vitis* and *Citrus* hosts (Cornara *et al.*, 2019) which are grown commercially in more southerly locations of the USA. Further north, xylem-feeding insects have been identified from New Jersey *Quercus* trees and *X. fastidiosa* has been detected in many of them (Zhang *et al.*, 2011), though only three species are proven vectors (i.e.

infectious insects have transmitted the bacterium to a clean plant). At least one of these, *Graphocephala versuta* (Cicadellidae), is stated to overwinter as an adult[17], which is assumed to apply to the northern parts of its range as well as warmer southern states. Another proven vector identified by Zhang *et al.* (2011) is *P. spumarius*, which is also widely distributed in Europe and is the main vector of *X. fastidiosa* in this continent. *Philaenus spumarius* overwinters as an egg (Cornara *et al.*, 2018). As *X. fastidiosa* is not transmitted from adult insect to egg (EFSA, 2018a), this means the overwintering life stage of *P. spumarius* will not have *X. fastidiosa*. There are, however, some reports of *P. spumarius* adults in winter, though it is unclear how significant these are: occasionally adults are found during the winter in the UK (pers. comm. C. Malumphy to R. Baker, September 2017). Climate will also affect vector multiplication rates, their mobility, and other factors leading to different potential infection pressures.

CONCLUSIONS ON POTENTIAL FOR ESTABLISHMENT OUTDOORS IN THE UK

All conclusions at the current time on the potential distribution of *X. fastidiosa* are subject to very high levels of uncertainty, despite the abundance of data presented in this section of the PRA.

Based on comparing temperatures between the UK and locations where *X. fastidiosa* has been recorded, the UK has a mild temperate oceanic climate with relatively warm winters and cool summers. This precise combination is not found in any part of the current known range of *X. fastidiosa*. Winter temperatures in the UK are unlikely to prevent establishment as winters, at least in the marginal areas of the native range, can be much colder. Even if snow cover provides some insulation in North America, the bacterium will still experience temperatures below freezing for extended periods of time. The cooler UK summer temperatures may be more limiting for establishment and vector multiplication, or could reduce the severity of the damage by *X. fastidiosa*. Based on air temperatures in some of the current marginal locations, it seems probable that *X. fastidiosa* is capable of being found in at least warmer parts of the UK. It is unclear if it will be able to establish (persisting for the foreseeable future) or if any populations would be more transient. However, this is entirely unknown and a major source of uncertainty.

Based on published models (which assume that climate is limiting), the UK appears to be on the margins of the area considered suitable for *X. fastidiosa*. Different models can vary quite a lot in their predictions, probably because a small change in initial parameter(s) may have a large impact on predictions for such marginal areas. Some of the information gathered in this section suggests that *X. fastidiosa* subsp. *multiplex* would appear to be most likely to establish in the UK, and/or have the greatest potential distribution. *Xylella fastidiosa* subsp. *pauca* is modelled as being least likely to establish and/or being most restricted in the areas of the UK which would be suitable. This PRA considers the situation over a 5-10 year period assuming no significant and persistent change to climatic conditions in the UK during that period. The assessment of establishment would clearly change in the event of a warming climate.

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[17] https://bugguide.net/node/view/10022 (accessed 8 August 2019)

Overall, the risk of *X. fastidiosa* establishing outdoors in the UK is **likely** but with **low confidence** due to the very many uncertainties remaining including the precise global distribution, how closely the published models approximate reality, and which model best represents the risk to the UK of establishment of *X. fastidiosa* and whether temperatures are, in fact the major limiting factor on the distribution. Establishment may also be related to the host it enters the country with (assuming it arrives on planting material). The intended use of different hosts will affect where and how the plants are kept, and this could influence the exposure of the hosts (and hence *X. fastidiosa*) to suitable vectors, appropriate temperatures, etc.

Outdoors: Xylella fastidiosa	Very unlikely ☐	Unlikely ☐	Moderately likely ☐	Likely ☑	Very likely ☐
Confidence	High Confidence ☐	Medium Confidence ☐	Low Confidence ☑		

Establishment under protection

Very few reports of *X. fastidiosa* in protected cultivation could be found from its native range, other than where it was deliberately maintained in glasshouse plants for experimental purposes. In the Americas, it is unclear if it occurs in glasshouses, etc. but causes relatively few problems compared to woody hosts grown outdoors, or if it is seldom detected in glasshouses. It is possible that the lack of reports in protected cultivation are more to do with the exclusion or control of vector species rather than the suitability (or otherwise) of such sites for the bacterium. Alternatively, the lack of reports may be due to *X. fastidiosa* symptoms being expressed when the plants are stressed, e.g. by drought, and such conditions are less likely to occur in protected cultivation.

There have been isolated reports of *X. fastidiosa* infections on plants under protection in Europe. In Germany, a single host (*Nerium oleander*) was brought under cover to overwinter but it had previously been outside (EPPO GD, 2019). In Almeria, Spain, *X. fastidiosa* was detected on *Polygala myrtifolia* plants in a glasshouse which had physical protection against vector insects. Only three of the plants tested in the lot were positive, and the symptoms observed were general chlorosis (EUROPHYT outbreaks database November 2018, unpublished data). In Italy, there has been a recent report on *Vinca major* (greater periwinkle) in physically closed glasshouse near Rome, Italy. The plants showed no symptoms, but a small number tested positive for *X. fastidiosa* prior to being sold (EUROPHYT outbreaks database November 2019, unpublished data). However, these reports do not help in assessing whether *X. fastidiosa* is able to persist in protected environments, or if infections are transient due to the lack of vectors or other reasons.

It is likely that the temperatures in protected cultivation will be suitable for *X. fastidiosa*, particularly higher summer temperatures compared to outdoor environments in the UK. On the other hand, the vector population may be lower (or completely absent) compared to that which is seen in the field. This would be due to pest control strategies such as general pesticides routinely used against other insects also controlling the vectors. If a glasshouse or polytunnel was screened to exclude insects, this would help to control movement of vectors between the protected environment and outdoors, but such screens are expensive and aren’t necessarily used in normal crop production in the UK. It is also possible that symptoms in plants grown in such environments may be noticed more quickly than those in the wider environment, as the plants grown under protection are often of relatively high value and their condition will be monitored closely. A counter argument is that plants grown under protection will usually be grown in good conditions unlikely to cause stress, and thriving plants are likely to show fewer symptoms.

Theoretically, an outbreak in protected cultivation has more chance of successful eradication. This would apply only if there was early detection (which is only likely for particularly vulnerable hosts which express symptoms rapidly) and if vectors have been prevented from moving freely between the protected environment and outdoors.

Overall, **establishment under protection** is considered **likely**. This assessment is made with **medium confidence**, as temperatures will be higher compared to outdoor locations, and there is evidence of findings in such environments in other parts of Europe. The confidence level is not high, as there are uncertainties over whether *X. fastidiosa* would be able to persist in the longer term.

Under protection (all subspecies)	Very unlikely ☐	Unlikely ☐	Moderately likely ☐	Likely ☑	Very likely ☐
Confidence	High Confidence ☐	Medium Confidence ☑	Low Confidence ☐		

12. How quickly could the pest spread in the UK/PRA area?

Natural spread

The rate of natural spread of *X. fastidiosa* is dependent on the rate of spread of infectious vectors. In Europe, the main vector identified to date is *P. spumarius*, the meadow spittlebug, and this insect is widely distributed in the UK and highly polyphagous. However, vector efficiency (both uptake and transmission) is likely to depend on specific host/vector species interactions which are probably highly variable. The rate of spread may be slower in the UK compared to Europe as, while the vector *P. spumarius* is widespread in the UK, unpublished data suggest that it is less abundant in the UK compared to locations in southern Europe. If vectors are less abundant, spread is likely to be slower.

Nymphs of *P. spumarius* are able to move short distances, e.g. from one plant to another (Cornara *et al.*, 2018), but this is unlikely to contribute substantially to even local spread as the distance is very small. Adults are very mobile, walking, jumping and flying, of which the last is the mechanism which is most likely to lead to significant local dispersal distances. Published data suggest that a single natural flight of *P. spumarius* can be as much as 30 m (cited in Cornara *et al.*, 2018). Plazio *et al.* (2017) used mark-release-recapture methods to estimate spread in Italian olive orchards. Adult *P. spumarius* were released at a point location, and subsequent sweep-netting took place along 8 transects radiating from the release point, up to 200 m away. In Piedmont in north-western Italy, marked adults were detected a maximum of 60 m away from the release point up to 15 days post-release. In south-eastern Apulia, the maximum distance from the release point a marked individual was caught was 100 m up to 30 days post-release (Plazio *et al.*, 2017). Again using capture-mark-recapture studies in Italy, Simonetto *et al.* (2019) used experimental data to inform modelling of dispersal and estimated the daily median dispersal distance as between 19 and 51 m. Flight mill data suggest that a single flight of *P. spumarius* could cover almost 2 km in 1 hour 40 minutes (Lago e*t al.*, 2019). However, data from flight mill experiments are known to over-estimate distances insects travel naturally, as in a flight mill an insect must keep on flying while in nature it is very likely to land and is unlikely to fly for the same length of time.

It is possible that individuals in the UK might move shorter distances than these data suggest, as temperatures will be cooler and the insects less active, but this is uncertain. As summers are cooler and damper in the UK, there is also a wide variety of herbaceous hosts available all year round, and so less reason for the vectors to move long distances to locate new hosts. This contrasts with Apulia in Italy, where the herbaceous plants mostly desiccate in summer and the insects typically move up into trees to feed. Data or estimates of the potential total distances an insect may disperse over its whole adult lifespan do not seem to be available.

While most flights of *P. spumarius* take place close to the ground, Reynolds *et al.* (2017) report data from trapping done over northern England in the mid-1930s, when a specimen of *P. spumarius* was trapped between 54 and 84 m above the ground. If even a small number of individuals of *P. spumarius* are regularly to be found at this height, then it is possible that longer-distance flight with the aid of wind currents may enable dispersal over much longer distances than those reported by other studies.

Overall the natural rate of spread is assessed as **slowly**, but with **low confidence** due to the uncertainty around adult vector lifetime dispersal distances in the UK and/or the possibility of flights by the vector aided by the wind at height.

Natural Spread	Very slowly ☐	Slowly ☑	Moderate pace ☐	Quickly ☐	Very quickly ☐
Confidence	High Confidence ☐	Medium Confidence ☐	Low Confidence ☑		

Spread with trade

Spread with trade is likely to be much faster. As a proven vector is already present and widespread in the UK, only the bacterium needs to be moved in trade. There are several factors which make detection difficult, including:

- A number of hosts can have asymptomatic infections.

- Infections (particularly of woody hosts) can have long latent periods (EFSA, 2019a).
- Visual symptoms (if present at all), are rather generalised and similar to many other causes, including physiological stresses.
- Infections can be localised in a small part of a plant, therefore even a symptomatic plant may test negative for *X. fastidiosa* if an uninfected plant part is tested.
- Even in symptomatic hosts, there is a delay between infection and detection of symptoms. This allows the infected plant to have been moved and/or for the infection to have spread undetected to its neighbours which are then moved.

All of these factors mean that it is possible to move infected plants in trade, despite precautions. There have been several findings of *X. fastidiosa* in plants moved in trade, both within Europe (e.g. Switzerland) and in plants traded from the native range of the pathogen (e.g. UK and other European countries on imported *Coffea* plants from Central America, or Belgium on *Olea* trees). Several of these findings on traded material have occurred since regulations were introduced to reduce this likelihood. Epidemiological models by Soubeyrand *et al.* (2018) suggest that *X. fastidiosa* may have been present in Corsica for 15-20 years or more before it was detected. Even if the delay before detection was shorter in the UK, there is still the potential for infected plants to be dispersed widely in trade. There is a latent period in symptomatic hosts, which can be many months for regularly traded hosts such as *Olea europaea* (olive) (EFSA, 2019a), and many hosts are asymptomatic. This means that by the time *X. fastidiosa* is detected, the infected plant(s) may already have been moved. This factor is especially relevant given that symptom expression in the UK is likely to be slow due to the cooler summer temperatures reducing bacterial population build up.

Spread could also occur via the movement of infectious vectors hitchhiking on vehicles, non-host commodities or uninfected plants. Expert elicitation in the spread section of the EFSA Opinion (2019) considered that hitchhiking of vectors had a low efficiency. It is difficult to apply the EFSA spread modelling in general to the potential situation in the UK, as EFSA recognise they were basing their data on the situation in southern Italy.

In mitigation against the spread of *X. fastidiosa*, Defra has a contingency plan (Eyre & Parkinson, 2019) which contains measures that England would take in the event of an outbreak to limit the spread. (The other three countries in the UK have agreed to use Defra's contingency plan as a basis for any action in response to findings on their territories.) Many of the measures in the Defra contingency plan are enshrined in legislation. *Xylella fastidiosa* is a priority pest in the legislation and thus there are requirements for annual surveys to detect if it is present or not. There is also a great deal of awareness of *X. fastidiosa* in the UK horticultural trade.

The rate of spread in trade is assessed as **very quickly** with **high confidence** due to the many difficulties of early detection of infections in traded plant material.

With trade	Very slowly ☐	Slowly ☐	Moderate pace ☐	Quickly ☐	Very quickly ☑

Confidence High Confidence ☑ Medium Confidence ☐ Low Confidence ☐

13. What is the pest's economic, environmental and social impact within its existing distribution?

Many hosts affected are subtropical species, and the impacts on these is well documented to be high. Due to the vast number of hosts which have been recorded and lower importance of some of these hosts to the UK the details that follow have focused on hosts on which the comparison with the UK is useful to this risk assessment.

For details of impacts on hosts grown in warmer countries, EFSA (2018a) or EFSA (2015) give short summaries of damage on *Citrus* in Brazil, *Olea* (olive) in southern Italy, and *Nerium oleander* in California. Impacts on *Coffea* in Brazil are covered by de Lima *et al.* (1998).

Many hosts grown for fruit or nut production in warmer countries are grown as ornamentals in the UK, e.g. *Citrus, Olea* or *Prunus dulcis* (almond). While yield loss in such hosts will be of less importance in this country, dieback of branches or even leaves will reduce the value of these ornamentals. Understandably, the impact data on these hosts from the current range of *X. fastidiosa* focuses on yield loss and data could not be found on the aesthetic impact of infections in the current range of *X. fastidiosa*.

Hosts of greater importance to the UK include plum, though the data found were on *Prunus salicina* (Japanese plum), which is less commonly grown in the UK. Kleina *et al.* (2018) investigated the effect of *X. fastidiosa* on *P. salicina* fruit yield in Brazil. Fruit from symptomatic plants generally weighed less, were smaller and less firm, and were more susceptible to brown rot (Kleina *et al.*, 2018).

Vaccinium (blueberry) is an increasingly important host in the UK, and while data could not be found for impact on the species commonly grown commercially in this country (*V. corymbosum*), data are available for impacts on *V. virgatum*. From Louisiana in the southern USA, mean yields of naturally infected plants were 55 and 62% lower than plants which tested negative for *X. fastidiosa* (Ferguson *et al.*, 2017). After three years, 4/9 positive plants appeared to be dead, with no leaves present, though it was noted that they had, by this time, undergone extensive sampling which may have contributed to their lack of foliage. Other symptoms in *V. virgatum* which were suspected to be associated with *X. fastidiosa* infection were: shoot dieback, leaf reddening and marginal necrosis, and defoliation combined with yellow stems (Ferguson *et al.*, 2017). However, the infection did not appear to spread rapidly within the crop.

Pierce's disease caused by *X. fastidiosa* can have high impacts on *Vitis* (grapevine). Pierce's disease was historically considered to be a chronic problem in locations such as California, USA, with some years worse for the disease than others and grapevines usually dying 1–5 years after infection (Tumber *et al.*, 2014). However, Pierce's disease has increased in importance in California following the introduction of a highly efficient vector, *Homalodisca vitripennis* (glassy-winged sharpshooter) in the late 1980s (Jetter *et al.*, 2014). Accordingly, much of the recent impact data for *X. fastidiosa* on *Vitis* comes from California. The Temecula valley in southern California had very high impacts in the late 1990s, with around 80 ha (approximately 10% of the total vineyard area) estimated to have been lost to Pierce's disease (Jetter *et al.*, 2014). In 2007, the incidence of Pierce's disease in the Temecula valley was estimated to be 2–3% (Jetter *et al.*, 2014). In northern California, only "minor instances" of Pierce's disease have been recorded, and the winters are considered too cold for *H. vitripennis* to establish (Tumber *et al.*, 2014). Estimates were made of the average annual losses in all *Vitis* (wine, raisin and table grapes) in different parts of California by Tumber *et al.* (2014), and selected parts of these data are summarised in Table 4.

Table 4. Estimated average annual losses in Californian *Vitis* from *Xylella fastidiosa* for selected regions in the state for 2010 (data source: Tumber *et al.*, 2014*).

Region	Average annual cost of *Vitis* lost due to Pierce's disease ($ million)	Total area of *Vitis* (ha)	Approximate cost per hectare
Northern California	0.2	5,380	$37
Southern California	3.0	3,680	$815
Total California	56.1	300,000	$188

*Data extracted from Tumber *et al.* (2014) [their Table 3] for districts 9, 10 (northern) and 16 (southern). Areas converted from acres to ha and rounded. It should be noted that these figures are from the most likely estimates and the range of potential losses is very large.

The initial symptoms of *X. fastidiosa* infections in many tree species are leaf scorches. In trees in the north eastern USA, the growing season is shortened as the affected leaf area is reduced by necrosis in late summer and decline and dieback of trees can occur in infections in later years (Henneberger *et al.*, 2004). Tree species can vary in their susceptibility to *X. fastidiosa*, but prolonged infection over a period of time can lead to tree death (Gould & Lashomb, 2005). Infected trees of many species are often more susceptible to other pests, and, as the infection progresses, trees may require removal on safety grounds due to the risk posed by dead branches (Gould & Lashomb, 2005). Not all leaf scorch symptoms in North America are due to *X. fastidiosa*, however. In southern Ontario (Canada), 114 samples of leaves showing scorch were taken, but only three (all *Ulmus americana*, American elm) were positive for *X. fastidiosa* (Goodwin & Zhang, 1997). In the District of Columbia, 96 out of 169 samples of symptomatic foliage from symptomatic trees were positive in 2011, and 130/186 in 2012 (Harris *et al.*, 2014). Positive samples came from eleven different tree species in 2011 and ten in 2012 with the most commonly infected being *Platanus occidentalis* (American sycamore), *Quercus palustris* (pin oak), *Q. rubra* (red oak) and *Ulmus americana* (Harris *et al.*, 2014). In addition to trees showing scorch symptoms, *X. fastidiosa* was also detected in asymptomatic trees and trees showing other symptoms including stunted or chlorotic foliage (Harris *et al.*, 2014). Gould & Lashomb (2005) estimate that in specific areas of Washington D.C., 30% of *U. americana* were "affected" by *X. fastidiosa*, though it is not known what level of that damage that implies. Similarly, 80% of *P. occidentalis* trees “were affected by the disease” in Washington D.C., while in some parts of New Jersey, up to 35% of *Quercus* street trees were affected (Gould & Lashomb, 2005). *Xylella fastidiosa* infections in trees in the “North Central and Plains States” of the USA appear to cause symptoms which are apparently not severe (Adams *et al.,* 2013).

Data on impacts on trees in the northern part of the range in North America are comparatively scarce. Many reports of damage are from street trees which are often stressed, and therefore impacts by *X. fastidiosa* may be increased as the trees are more susceptible to any pathogen or pest. The findings in Washington State in north-western USA were as part of a survey for nursery certification, but no further details (e.g. if the hosts were symptomatic) were found (Buckley & Laus, 2018). The Portuguese detection near Porto was part of an official survey. The affected *Lavandula dentata* plants were around 6 years old and asymptomatic (EPPO RS, 2019). Though it is not known when the plants became infected, *L. dentata* is one of the hosts considered to be highly susceptible to *X. fastidiosa* according to the EU Emergency measures 2015/789.

Impacts on **hosts highly susceptible to the bacterium in areas with hot summers** (e.g. Brazil, California or southern Europe) are assessed as **very large** with **high confidence** as there is a great deal of evidence on the devastating impacts *X. fastidiosa* can have on highly susceptible hosts in warmer parts of the world, e.g. on the olive groves around Lecce in southern Italy.

Impacts on **tree hosts in temperate areas** such as north-eastern USA are assessed as **medium**. This judgement is made with **low confidence** as quantified data on impacts from these areas tends to be comparatively scarce. The data which are available often focus on the number of trees found to be infected, rather than trees with evidence of impacts. Data on non-tree hosts from more temperate areas could not be found in the time available.

The overall impact of *X. fastidiosa* in its current range is assessed as large with medium confidence. The medium confidence reflects the wide range in variation in impacts across the range (both host and geographic) of *X. fastidiosa*.

Impacts on vulnerable hosts in warm areas	Very small ☐	Small ☐	Medium ☐	Large ☐	Very large ☑
Confidence	High Confidence ☑	Medium Confidence ☐	Low Confidence ☐		

Impacts on tree hosts in temperate areas	Very small ☐	Small ☐	Medium ☑	Large ☐	Very large ☐
Confidence	High Confidence ☐	Medium Confidence ☐	Low Confidence ☑		

Overall impact in current range	**Very small** ☐	**Small** ☐	**Medium** ☐	**Large** ☑	**Very large** ☐
Confidence	**High Confidence** ☐	**Medium Confidence** ☑	**Low Confidence** ☐		

14. What is the pest’s potential to cause economic, environmental and social impacts in the UK/PRA area?

There are significant uncertainties about the potential impacts of *X. fastidiosa* in the UK. The evidence suggests that at least some subspecies of *X. fastidiosa* would be likely to be able to establish in the UK, but there is high uncertainty over potential impacts. It is unclear what conditions the pest requires in order to cause damage to hosts, and how susceptible different hosts in the UK might be to infection.

Winters in the UK are unlikely to be limiting for establishment, but the UK may not have warm enough summers for high impacts to occur. To briefly recap some data presented in the establishment section:
Experimentally, the optimum growth rate in liquid media for *X. fastidiosa* was 28^{o}C for all three subspecies tested (*X. fastidiosa* subspp. *fastidiosa, multiplex* and *sandyi*), and no growth was seen at or below 12^{o}C (Feil & Purcell, 2001).
Mean monthly maximum summer temperature data comparisons (Fig. 5) between one of the warmest sites in the UK (Heathrow) and locations in North America:

- The mean monthly maximum summer temperature for July is 23.5^{o}C, at one of the warmest locations in the UK, Heathrow Airport.
- The marginal North American sites (where impacts have not been recorded but *X. fastidiosa* has) have mean monthly maximum temperatures between 25.5^{o}C (Clark County, Washington) and 31.3^{o}C (Grant County, Washington).
- In large parts of the USA, mean maximum temperatures for June, July and August combined are usually between 25 and 35^{o}C in states where *X. fastidiosa* has been recorded, often with impacts (data analysed but not presented in this PRA).

This PRA considers the situation over a 5-10 year period assuming no significant and persistent change to climatic conditions in the UK during that period. Clearly, the potential impacts could be different in the event of a warmer climate in the UK.

Economic impacts

ECONOMIC IMPACTS ON HOSTS

It is unclear what the direct effect of *X. fastidiosa* infection on UK plants might be. As demonstrated in Figs. 4 and 5, even in the warmest south-eastern part of the country, UK summers are cooler than parts of the world where *X. fastidiosa* is known to be present and causing impacts. Details of any impacts are lacking from the findings associated with records from locations such as Clark Country, Washington State, USA where the summer temperatures are relatively low and more comparable to those in warmer parts of the UK. The infected *Lavandula dentata* plants detected near Porto, Portugal (another location with relatively low summer temperatures) were asymptomatic (EPPO GD, 2019). Many of the hosts on which *X. fastidiosa* has caused damage in its current range are, with the exception of some niche growers, only grown as ornamentals in the UK, e.g. olives and citrus. Data on aesthetic impacts on olive, citrus and almond trees in the current range could not be found: understandably, the data available focus on fruit/nut yield losses which are not relevant for the UK uses of these species.

Olive (*Olea*) and **almond** (*Prunus dulcis*) trees are commonly grown as ornamental species in the UK. EFSA (2019a) used expert elicitation to model the impact of *X. fastidiosa* in Europe. The data on *Olea*, *Prunus dulcis* and *Citrus* spp. were not considered to be relevant to the UK as the assessment of impacts was for yield losses in the fruit crops. While trees of at least *P. dulcis* and *Olea* are imported (Table 5), only a small number of *P. dulcis* are notified, though the number of *Olea* trees is much higher. Equivalent data are not available for *Citrus*. All are primarily imported for ornamental purposes with little or no commercial fruit production. While olive fruit and almond nut crops may become more important to the UK in the distant future (e.g. as part of agroforestry), this PRA is based on the situation in the next 5–10 years. Protecting potential UK crops further into the future may need to be considered in other ways.

Table 5. Imports of *Prunus dulcis* and *Olea* spp. to England and Wales between January 2016 and December 2019. Data from the tree pre-notification scheme, which may be incomplete. Numbers in brackets indicate data are only for part of the year.

Host		**2016**	**2017**	**2018**	**2019**
Prunus dulcis (almond)	Number of notified consignments	24	17	23	22
	Number of plants	256	325	326	372
Olea spp. (olive)	Number of notified consignments	Scheme introduced November 2018		*(42)*	1380
	Number of plants			*(2,979)*	100,127

The main risk to *Olea* ornamental trees is that they could suffer disfiguring leaf symptoms, dieback, or be killed, but these impacts are uncertain. No data on impacts could be found from parts of the existing range with summers which are relatively cool and comparable to the UK, on *Olea* or any other host. The main risk to the UK is from *Olea* as a source of infection. *Olea* is recognised as a highly susceptible host for *X. fastidiosa* in the emergency measures. This host also has the potential for a long latent period of infection. For these reasons, *Olea* is included in the pre-notification scheme for import of selected trees in the UK.

Grapevine was the only host EFSA (2019a) considered which has fruit harvests of high commercial significance to the UK. In the UK, there were over 500 registered vineyards in 2017 (Food Standards Agency (FSA) Vineyard Register), with a total area of well over 2,000 ha in 2018 (englishwine.com). Vineyards are a rapidly growing industry in the UK, especially in the south-east of England where there is a high concentration of wine-growers. EFSA provided two assessments for grapevine in the EU, one for the south, and one for central areas (where freezing temperatures are expected in winter and some recovery from infection was considered to occur). The central European model is considered here, as most parts of the UK have at least some frost in winter. According to EFSA's model, the impact on wine grapes is assessed as less than 2% at the 99th percentile (i.e. 99% of the time, modelled impacts will be < 2%); impacts at the 90th percentile are 1.1% while impacts at the 50th percentile (i.e. those which would be expected in around half of infections) are 0.5% (EFSA, 2019a). It is worth re-stating that UK summers will be cooler than those in central Europe, and it is unclear what level of impacts might actually be seen in UK vineyards. That said, many UK vineyards are small businesses (with a significant number of hobby vineyards), and any finding of *X. fastidiosa* on a production site could affect a very large proportion of that businesses' plants.

Stone fruit (*Prunus* spp.) are an important fruit crop in the UK. However, most of the literature on impacts of *X. fastidiosa* on *Prunus* involve hosts such as peach and almond, which are not grown commercially as fruit crops in the UK, though both are reasonably common garden ornamentals.

There have been some fruit impacts recorded on *P. salicina* (Japanese plum) fruit (Kleina *et al.*, 2018), a species not widely grown in the UK. Impacts on the plum species commonly grown in the UK, *P. domestica*, could be similar but no data could be found on impacts of *X. fastidiosa* on this host and, again, it is uncertain how suitable the relatively cool UK summer temperatures would be for the development of damaging populations of the pest.

Cherries are another rapidly expanding crop in the UK, often grown under semi-protected cultivation. This entails growing dwarfed rootstock under polytunnel covers, open at the sides. Such sites may be more likely to have impacts, as summer temperatures will be higher which is likely to promote bacterial growth and hence increase the chances of impacts. Additionally, there is no barrier to vectors moving on and off the trees from the wider environment so *X. fastidiosa* would be able to spread within and between each polytunnel.

OTHER ECONOMIC IMPACTS

The major source of economic impacts to the UK are not thought to be the direct impact of the bacterium itself on plants. Instead, the majority of the expected UK impacts are considered likely to arise from the indirect impacts associated with measures to maintain freedom from the pathogen.

If the UK were to have an outbreak of *X. fastidiosa*, it is likely that the export of plants to many other countries, currently free of the pathogen, will be seriously affected. *Xylella fastidiosa* is a high profile and/or quarantine pest in many parts of the world, and a large number of countries are likely to impose significant restrictions on UK material entering their territories after a positive finding of *X. fastidiosa* in this country. EPPO GD (2019) lists 15 countries where *X. fastidiosa* is a quarantine pest, though EPPO stress that this information is incomplete and it may perhaps be best regarded as a minimum. Horticultural

Statistics (2019) data suggest that the value of UK exports in the ornamental horticulture sector (excluding bulbs, cut flowers, foliage and mycelium) was £33.08 million in 2017, with a provisional figure of £29.39 million in 2018. An anecdotal report suggested some destinations outside Europe already regard the UK as infested due to the known outbreaks in the EU, but this could not be verified in the time available.

Xylella fastidiosa is a high profile pest in much of Europe and other countries beyond, e.g. Australia. If the UK were to have an outbreak, there is likely to be a loss of confidence in the UK plant industry, and even biosecurity (at least as it applies to plants). There is also the risk of reputational damage as, despite all the legislation and measures in place, the UK did not succeed in keeping *X. fastidiosa* out of its territory.

Another source of indirect impacts would be the measures taken to prevent *X. fastidiosa* establishing or containing the outbreak. There is a legal obligation to take action on any finding of *X. fastidiosa* in the UK (and the wider EU), and, as mentioned previously, the need to take action to prevent potentially worse future impacts which could occur if *X. fastidiosa* were to spread or become established. The actions which would be taken are outlined in detail in the Defra contingency plan (Eyre & Parkinson, 2019). A very brief summary of the action which must be taken in response to a finding of *X. fastidiosa* (of any subspecies) in the wider environment as of December 2019 is included here.

Establishment of a **demarcated area** which consists of:

- Infested zone, 100 m radius. All infected plants, symptomatic plants and host plants within a 100 m radius of the finding would be removed and destroyed. Since the host range is so wide (especially for some subspecies), this could represent a significant economic loss depending on the subspecies identified.
- Minimum buffer zone, 5 km radius. Surveys based on 100 m squares between 100 m and 1 km; surveys by 1 km squares from 1–5 km.
    - (If no evidence of spread, buffer zone may be reduced to 1 km radius).
- Demarcated area may only be lifted 5 years after the last detection of *X. fastidiosa*
    - (If no evidence of spread and a 1 km buffer, demarcated area can be removed after 12 months, but intensive sampling must continue).
- Nurseries within the demarcated area cannot move stock unless very stringent requirements are met. This restriction applies for the length of time the demarcated area exists.

Depending on the region of the country where an outbreak occurs, the 5 km demarcated area could include a relatively large number of nurseries or garden centres, especially when outlets such as supermarkets or discount stores which sell growing plants are included. Recent data are not available, but in 2004 a total of 9,464 ha of Hardy Ornamental Nursery Stock (HONS) were grown outdoors in the UK and 273.7 ha of container grown nursery stock (Horticultural Statistics, 2019). It is likely that much of this stock will be sold in UK outlets, with additional material imported. If there was a delay in detection of *X. fastidiosa* (which is very likely to be the case if asymptomatic hosts or hosts with a long latent period were involved), or a delay in reporting the outbreak, and *X. fastidiosa* has spread, the demarcated area would be larger and thus the resultant impacts would also increase. It should be noted that the emergency measures are currently under review, and it is possible that in future the required measures may affect smaller zones, and thus have less impact. Taking account of existing knowledge and the current scenario, it is more cost effective to continue to exclude *X. fastidiosa* from the UK in the short term than it would be to eradicate it or mitigate its impacts in the longer term.

SUMMARY OF ECONOMIC IMPACTS

Overall, the expected economic impacts of *X. fastidiosa* as a plant pathogen in even the warmer parts of the UK are assessed as small, but with low confidence, as there are very many uncertainties over whether the pest could establish, and what the potential impacts might be. Vineyards might be most at risk of economic impacts, but EFSA modelling suggests that even here, losses are expected to be 1-2% at worst. While other hosts such as *Olea* or *Citrus* are commonly grown in the UK as ornamentals, and there will be some economic impacts from any loss or damage of such trees, the majority of impacts on these hosts in the UK are considered to be social and as such are assessed there.

However, the **economic impact overall**, including possible export restrictions on UK plants, the reputational damage associated with the UK failing to prevent *X. fastidiosa* entering the UK and the legally required responses to any outbreak, is assessed as **medium** with **low confidence** due to the potential for changes in the legislation.

Environmental impacts

It is unclear what the environmental impacts will be. From the evidence from the northern parts of the USA, the hosts most at risk in the UK are likely to be street or amenity trees. Infections of trees may take a long time to have serious impacts, especially given the UK's relatively cool summers meaning that *X. fastidiosa* may not find optimal conditions for its development, but this is uncertain, especially given the warming climate. If vectors are capable of travelling long distances at relatively high altitudes then the impact could increase as the disease could be spread over a relatively wide area, and potentially to a number of hosts. Combined with an assumed long latent period of infection in the cooler summers of the UK, a comparatively large number of hosts could be affected before the outbreak was detected, which would lead to control measures being applied over a wider area.

If an infection was found in the wider environment, then the mandatory destruction of all hosts within a 100 m radius of every infected plant will have severe impacts, but only in a very localised area. Overall, potential **environmental impacts** in the UK are assessed as **small**, but with **low confidence** due to the many uncertainties and lack of data.

Social impacts

Direct social impacts due to *X. fastidiosa* would arise from the visible damage to street or amenity trees. Leaf scorch symptoms are highly visible, and are likely to cause local concern. As is the case in North America, as branches die back, it is likely that costs will be incurred from pruning or even felling the affected trees for safety reasons, as well as replacing affected trees with new plantings.

Indirect social impacts are also likely. As detailed under economic impacts, there are legal requirements for action following a finding of *X. fastidiosa*, including clearing all hosts within a 100 m radius and long-lasting and stringent restrictions on the movement of host plants within a 5 km radius. The clearance of plants is likely to be highly visible and cause local concern, particularly if private gardens or amenity areas such as parks are within the area for host clearance. This would be dependent on the subspecies of *X. fastidiosa* detected, as some subspecies have longer lists of hosts which must be removed than others. Plant nurseries within the demarcated 5 km zone will be severely affected, and it is possible that jobs will be lost and/or some local businesses could suffer significant financial losses and potentially be forced to close due to the restrictions on plant movements. Though these impacts would be very severe, they would be reasonably localised as long as *X. fastidiosa* remained limited to a small area.

Other indirect social impacts would arise from the fact that *X. fastidiosa* is already a very high-profile pest in the UK. There have been numerous publicity campaigns by a variety of organisations in the UK including the Animal and Plant Health Agency, Defra, the Horticultural Trades Association, the Royal Horticultural Society, the Scottish Government and others, all with the intention of educating the public not to bring back plant material from abroad because of the risk it poses. If *X. fastidiosa* were to be detected in the UK, there is likely to be a significant public backlash at the failure to keep the UK free of this pest, especially as *X. fastidiosa* has a very high profile within the UK plant and tree sector compared to other plant pests. Many people nationwide are likely to be highly concerned about the finding (especially those connected with horticulture, arboriculture, or who are keen gardeners or environmentalists), and it is possible that it could be picked up by the mainstream media, such as happened with Chalara ash dieback. It is also possible that national concern may be caused by inaccurate or sensationalist media reporting. The overall **social impacts** to the UK are considered to be **large**, though social impacts in the immediate area around a finding of *X. fastidiosa* could be higher. This judgement is made with **medium** confidence.

Economic Impacts	Very small ☐	Small ☐	Medium ☑	Large ☐	Very large ☐
Confidence	High Confidence ☐	Medium Confidence ☐	Low Confidence ☑		
Environmental Impacts	Very small ☐	Small ☑	Medium ☐	Large ☐	Very large ☐
Confidence	High Confidence ☐	Medium Confidence ☐	Low Confidence ☑		
Social Impacts	Very small ☐	Small ☐	Medium ☐	Large ☑	Very large ☐
Confidence	High Confidence ☐	Medium Confidence ☑	Low Confidence ☐		

15. What is the pest's potential as a vector of plant pathogens?

Not applicable. *Xylella fastidiosa* is a plant pathogen and does not vector other organisms.

16. What is the area endangered by the pest?

For an area to be considered "endangered", the pest must be able to establish and be capable of causing economically important loss (ISPM 05, ISPM 11).There are so many uncertainties remaining about the potential for establishment and impacts in the UK that it is has not been possible to identify particular areas of the UK which might suffer important economic losses. Therefore, identifying specific areas in the UK which are considered endangered has not been possible due to this uncertainty. This does not mean that the UK is not at risk of impacts from *X. fastidiosa*, rather it is a reflection of the high levels of uncertainty surrounding key aspects of the PRA. The whole of the UK could be considered at risk from the impacts of reputational damage, export restrictions and public concern.

Assuming warmer summer temperatures are required for higher impact, then plants and trees in the urban heat island around London and the south coast of England might be most at risk of developing symptoms. Vineyards, especially those in the south of England, may be at risk of *X. fastidiosa* subsp. *fastidiosa* (Pierce's disease). However, the levels of damage which might be expected are uncertain, in these warmer areas or any other part of the UK. It is possible that none of the UK would be endangered by *X. fastidiosa* subsp. *pauca*, while *X. fastidiosa* subsp. *multiplex* appears most likely to have the largest endangered area of the three subspecies. These statements are based on published models, but it is worth restating that there is uncertainty over whether different subspecies have different impacts, and if so, whether the difference is due to differing temperature requirements between the subspecies or differing host ranges.

In summary, the uncertainties mean that definitively identifying if a particular endangered area exists in the UK and if so, what extent it might have, has not been possible.

Stage 3: Pest Risk Management

17. What are the risk management options for the UK/PRA area?

Defra has published a detailed contingency plan on *X. fastidiosa* for England, and the plant health Devolved Authorities in the other countries in the UK have agreed that the English plan would be used as a basis for actions in Wales, Scotland and Northern Ireland. Therefore, the information in the contingency plan is applicable to the whole UK. The most recent version (Eyre & Parkinson, 2019) is available via links on the UK Plant Health Portal: https://planthealthportal.defra.gov.uk/pests-and-diseases/contingency-planning/

and this document (or any succeeding versions thereof) should be consulted for details of actual (exclusion) and proposed (eradication/containment) responses to *X. fastidiosa*.

Exclusion

Current UK actions and legislation against *X. fastidiosa* are aimed at continued exclusion of this pest from the UK, which remains the preferred option. The legislation is continually under review in light of new information, and additional measures have previously been added to the legislation as deemed necessary to further mitigate the risk of introducing *X. fastidiosa* to the UK with imported planting material. There have been further developments since such legislation (including new EFSA information and further interceptions and outbreaks of *Xylella fastidiosa* in Europe) and it is expected that this process of reviewing the existing legislation in response to any new evidence will continue in the future.

The Defra contingency plan outlines current actions to exclude *X. fastidiosa* in **section 4** (pages 5-8) (Eyre & Parkinson, 2019).

Eradication and/or containment

If *X. fastidiosa* were to be detected in the UK, measures would be taken to eradicate the outbreak. Proposed responses to findings of *X. fastidiosa* are covered in section 5 (pages 8-21) of the Defra contingency plan by Eyre & Parkinson (2019). As a priority pest in the legislation, annual surveys are required to monitor for the presence of *X. fastidiosa* in the UK. A further factor influencing the potential success of eradication is the latent period in symptomatic hosts and the existence of asymptomatic hosts. This means that by the time *X. fastidiosa* is found in the wider environment, it may have already spread a significant distance beyond the original infected plant(s), complicating eradication efforts. On the other hand, the finding on imported trees in Belgium in a nursery wholesaler does not appear to have spread, emphasising the importance of early detection and prompt action. If the outbreak was in protected cultivation, there is a better chance it will be more localised. Experiences elsewhere in Europe support this: the findings in protected cultivation in Italy and Spain do not seem to have spread. Speed of detection is especially relevant given that symptom expression in the UK is likely to be slow due to the cooler summer temperatures reducing bacterial population build up.

Non-statutory controls

As *X. fastidiosa* is a quarantine plant pest listed in Plant Health legislation, non-statutory controls are not appropriate. All findings or suspected findings must be reported to the appropriate UK Plant Health Authority. Good practice by individual nurseries and other businesses in sourcing stock will help to complement the statutory requirements. Similarly, good biosecurity practice by individual businesses will help to contain any outbreak, and would complement the statutory requirements by reducing the potential for the pest to spread.

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