Department
for Environment
Food & Rural Affairs

Rapid Pest Risk Analysis (PRA) for:

Crisicoccus pini

April 2019

Summary and conclusions of the rapid PRA

This rapid PRA shows:

Crisicoccus pini is a scale insect native to eastern Asia that was recorded in Europe for the first time in 2016. The introduction to Italy saw extensive damage in a localised area around the town of Milano Marittima, causing significant concern at the local level. *Crisicoccus pini* infects *Pinus* species, and in heavy infestations causes host mortality and significant tree decline. *Pinus* species are very important to the UK economy and environment, and because of the damage seen during a recent outbreak in Italy a Rapid Pest Risk Analysis for *Crisicoccus pini* was deemed appropriate.

Risk of entry

Crisicoccus pini is most likely to enter the PRA area through plants for planting. This includes both the import of *Pinus* species from Italy, from which there is a moderate trade, and the import of dwarfed-*Pinus* under derogation from Japan and Korea, within the pest's native range. The risk of entry into the UK through plants for planting has been assessed as moderately likely with medium confidence.

Plant products, cut branches and pine cones in this case are a potential, but unlikely route of entry for this pest. We cannot rule out association with bark, wood with bark or woodchip as potential pathways for entry with the limited life cycle information about this pest, and these routes have been rated unlikely, with low confidence. There is no reason to believe this pest could enter the UK through seed, squared wood or natural spread at present.

Risk of establishment

Its distribution worldwide suggests establishment in the UK may be possible, but it's uncertain if the UKs climate would limit the population build-up of the pest. There is a moderate degree of climatic similarity with northern Italy, and the hosts are very common across the UK. A lack of data on the pest's life cycle leads to a degree of uncertainty about this pest's ability to establish in the UK. Risk of establishment has been rated as medium, with medium confidence.

Economic, environmental and social impact

Pinus species are very important for the UK economy and environment and an outbreak would see significant disruption at the local level. Because of the very low rate of spread of these pests, impacts are expected to be highly localised for the first few years, limiting the damage an introduction could cause. A high degree of uncertainty around *C. pini's* ability to build up to damaging levels in the UK limits the certainty surrounding impacts. Economic, environmental and social impacts have all been assessed as low, with low confidence.

Endangered area

All *Pinus* species within the UK are considered at risk.

Risk management options

Exclusion is unlikely to be effective in controlling this pest, it has already established within the EU and dwarfed-*Pinus* could be imported from Japan and Korea under derogation. Containment and eradication of the pest, and application of effective phytosanitary measures would be possible. An outbreak in the UK would likely have a restricted geographic distribution, if symptoms were identified quickly. Control measures applied in the Italian outbreak, including trunk injections with insecticides and the release of biocontrol agents have been effective in limiting impacts there. Insecticides are available for use against mealybugs in the UK, and in the event of an outbreak are likely to be effective in limiting damage.

Key uncertainties and topics that would benefit from further investigation

There is very little information about the lifecycle and development thresholds of *Crisicoccus pini*, and the uncertainties have direct bearing on the risk assessment, routes of entry and risk management options available. We do not know the possible association with bark, or the temperatures this pest needs in order to establish.

Images of the pest

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<td>Adult Crisicoccus pini showing white waxy secretions. Image courtesy of Vai – SFR Bologna</td>
<td>Dieback of Pinus infested with Crisicoccus pini. Image courtesy of Vai – SFR Bologna</td>
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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.

This PRA identifies many uncertainties surrounding this pest. However, the lack of available information about it would limit the value of a longer PRA at this time. If more information arises for this pest, or new outbreaks across Europe or within the UK are seen, then there might be a need to update this PRA.

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?

Statutory action is appropriate to prevent both the entry of this pest in the UK and in response to any introduction that might occur. Significant uncertainties exist about the impact this pest could cause, and how widespread the damage would be. *Pinus* species are essential UK hosts however, and given the likely effectiveness of mitigations in preventing this pest's entry and spread, statutory action would be appropriate and justified.

Yes Statutory action	✓	No Statutory action	

Stage 1: Initiation

1. What is the name of the pest?

Crisicoccus pini, the Kuwana pine mealybug, or Japanese pine mealybug.

It was first described as *Dactylopius pini* by Kuwana (1902) and subsequently assigned to the genus *Pseudococcus* by Fernald (1903) and *Crisicoccus* by Ferris (1950). *Crisicoccus pini* is in the order Hemiptera and the family Pseudococcidae (mealybugs). Currently, the genus *Crisicoccus* comprises 37 species, mainly identified from Asia and the Australasian region (Danzig & Gavrilov-Zimin, 2010; García Morales *et al*., 2016). It is a single taxonomic entry and distinguishable from related species. There is no single comprehensive key for the identification of *Crisicoccus* but the species present in the Palearctic (including *C. pini*) can be identified using Danzig & Gavrilov-Zimin (2015).

2. What initiated this rapid PRA?

Crisicoccus pini has been identified in Europe twice. The first finding was in Monaco in 2006 within a Japanese garden (EPPO, 2019), but there is no further information available on this and the current status of this finding is unclear. In 2015 it was found in the town of Milano Marittama, Northern Italy, where it had spread over 51.2 ha. The wide distribution and late stages of damage observed suggested it had been present for several years and only detected when the infected trees (*Pinus pinaster* and *P. pinea*) started to show decline.

In January 2019 *C. pini* was added to the EPPO alert list citing the severity of the damage seen in Italy, and the potential for spread across European pine. Because of two findings in mainland Europe, its addition to the EPPO alert list, and the threat to a significant UK host, a PRA was requested to better assess the risk to the UK.

3. What is the PRA area?

The PRA area is the United Kingdom.

Stage 2: Risk Assessment

4. What is the pest's status in the EC Plant Health Directive (Council Directive 2000/29/EC[1]) and in the lists of EPPO[2]?

Crisicoccus pini is not listed in the EC Plant Health Directive and is not recommended for regulation as a quarantine pest by EPPO. The pest was added to the EPPO alert list in January 2019.

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

Crisicoccus pini is a mealybug native to Japan, first described in 1902 (Kuwana, 1902). From there it has spread to China, South Korea, Taiwan and far eastern Russia (Boselli, 2016). Detailed data about the pests distribution in these regions is lacking, but in Japan *C. pini* has only been reported from the southern islands of Honshu and Kyushu, not Hokkaido (Kuwana, 1902). In China it is reported from Shandong and Xihang provinces in the far East and far West of the country, respectively.

Crisicoccus pini was first introduced to America through a Californian nursery in 1918 (McKenzie, 1967). In 1967, it was present in coastal regions of California between San Diego and San Francisco, but was considered very rare (Danzig *et al*., 2010; McKenzie, 1967). By the 1990s it was reported as becoming a pest of ornamental pines in California (Kosztarab, 1996). It has also been reported in Washington D. C., but the extent of the population there remains unclear (Kosztarab, 1996). No significant reports of impacts by *C. pini* have been reported from the US.

In 2006 a finding of *C. pini* occurred in a Japanese garden in Monaco. No further information is available about the extent of the Monaco outbreak, the impacts it had, or what has happened at the outbreak site since. A list of scale insects in France from 2018 includes *C. pini,* but it is unclear if the journal included Monaco within its analysis or if the pest was found in France itself (Foldi, 2018).

In 2015, an outbreak was observed near the town of Milano Marittima in northern Italy, and is expected to have been present for several years prior (Boselli, 2016). The outbreak here was extensive, with significant host mortality and phytosanitary measures applied (Boselli, 2016; Boselli, 2018).

[1] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CONSLEG:2000L0029:20100113:EN:PDF

[2] https://www.eppo.int/ACTIVITIES/quarantine_activities (accessed 1 August 2018)

Table : Distribution of *Crisicoccus pini*	
North America:	USA: California (Ben-Dov, 1994), District of Columbia[1] (Kosztarab, 1996)
Central America:	No records.
South America:	No records.
Europe:	France[2] (Foldi *et al.,* 2018), Italy (Boselli, 2016), Monaco (Germain, 2006), Russia[3] (Danzig *et al*., 2010)
Africa:	No records.
Asia:	China (Shandong, Xizhang) (Danzig *et al*., 2010), Japan (Honshu, Kyushu) (Kuwana, 1902), North Korea (EPPO, 2019), South Korea (Danzig *et al*., 2010), Taiwan (Ben-Dov, 1994)
Oceania:	No records.

[1] The reference to a finding of *C. pini* in Washington D.C is based on a distribution survey in Kosztarab, 1996. It is unknown how extensive an outbreak this was, if there is a breeding population, or if it was a one time finding. There has been no update since 1996.

[2] The finding in France is listed in a list of scale insects in the region (Foldi *et al.,* 2018). It is unclear at present if the region assessed includes Monaco. The EPPO Global database includes France in its distribution list (EPPO, 2019b).

[3] Danzig *et al*., 2010 indicate this was found in Primorsk territory of Russia. There are no reports of *C. pini* further west within the region.

This scattered distribution suggests *C. pini* is present in more countries but has not been recorded as causing damage. It is very likely that more countries in East Asia have *C. pini* present.

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

The pest has never been recorded in the UK, and has not been intercepted. There are no records on EUROPHYT (accessed 07/02/2019) of interceptions of *Crisicoccus pini*, or any *Crisicoccus* species from other European countries.

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?

Crisicoccus pini is only known to infect *Pinus* species. Below is the table of confirmed hosts of *C. pini*. It not clear if all species of *Pinus* are susceptible to the mealybug, or if there is varying resistance amongst different *Pinus* species. The most common pine in the UK is *Pinus sylvestris* and there is no data on the susceptibility of this species to *C. pini*.

There is a single reference in the literature to *Abies* being a host (ScaleNet, 2019)). There is no other source confirming this. *Abies* as a potential host of *C. pini* remains a source of uncertainty.

Table : Hosts of *Crisicoccus pini*

Family	Species	Source	Reference
Pinaceae	*Pinus coulteri*	Natural	EPPO, 2019
Pinaceae	*Pinus densiflora*	Natural	Ben-Dov, 1994
Pinaceae	*Pinus funebris*	Natural	Danzig *et al*., 2010
Pinaceae	*Pinus halepensis*	Natural	EPPO, 2019
Pinaceae	*Pinus koraiensis*	Natural	Ben-Dov, 1994
Pinaceae	*Pinus massoniana*	Natural	García Morales, 2016
Pinaceae	*Pinus nigra*	Natural	García Morales, 2016
Pinaceae	*Pinus parviflora*	Natural	García Morales, 2016
Pinaceae	*Pinus pinaster*	Natural	Boselli, 2006
Pinaceae	*Pinus pinea*	Natural	Boselli, 2016
Pinaceae	*Pinus pentaphylla*	Natural	Boselli, 2016

Pinaceae	*Pinus radiata*	Natural	Ben-Dov, 1994
Pinaceae	*Pinus tabuliformis*	Natural	EPPO, 2019
Pinaceae	*Pinus thunbergiana*	Natural	Ben-Dov, 1994
Pinaceae	*Pinus thunbergii*	Natural	Ben-Dov, 1994

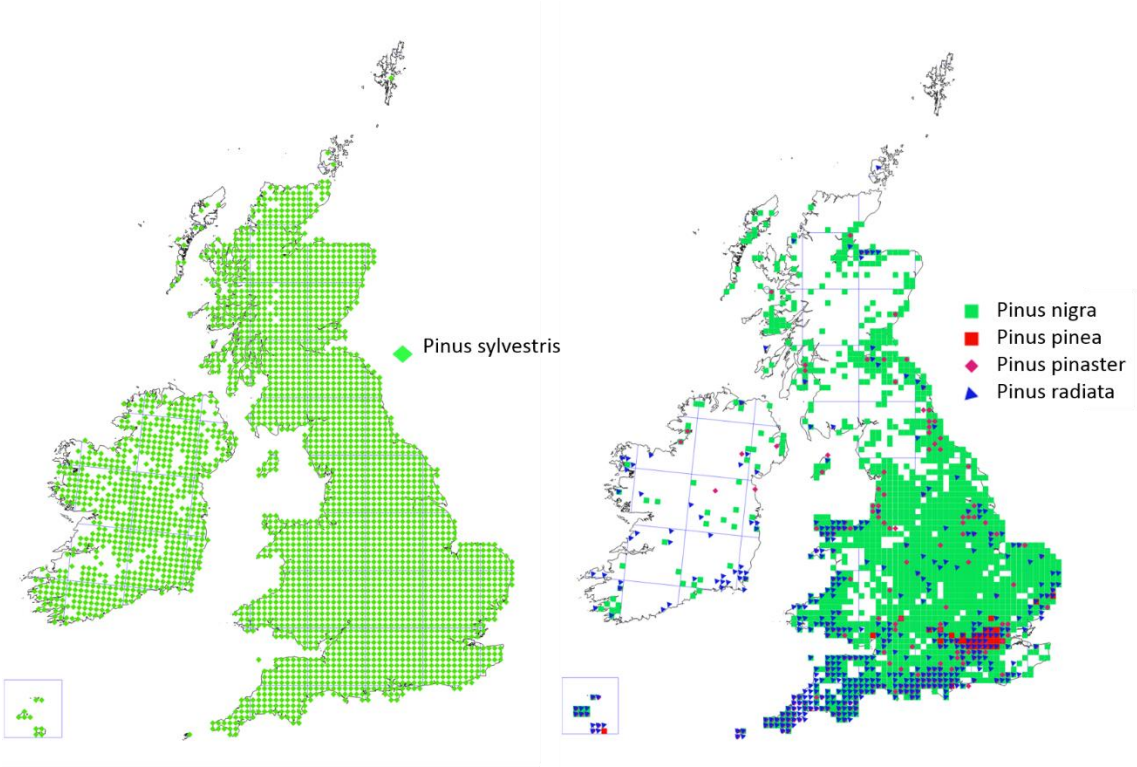

Figure 1 Distribution of *Pinus* species in the UK. Distribution of *P. sylvestris* (left), and the four most abundant confirmed hosts of *Crisicoccus pini* (right). Image created using BSBI Botanical distribution mapping tool, http://bsbi.org/maps.

Pinus species are very common in the UK, covering an area of approximately 407,882 ha in the UK (Forestry Commission, 2003). *Pinus sylvestris*, which has not yet been confirmed as a host of *C. pini*, is abundant across the UK (Fig 1). *Pinus* species are of particular importance to Scotland, with very large Caledonian pine forests covering 180 square Km in the highlands. Confirmed *Pinus* hosts of *C. pini* are rarer, with *P. pinea*, *P. pinaster* and *P. radiata* showing a scattered distribution in southern England and parts of Wales (Fig 1). *Pinus nigra* is more common across most of England, with a scattered distribution in Scotland and Northern Ireland (Fig 1). Other confirmed *Pinus* hosts from the table above have a very limited distribution in the UK, mostly found as ornamentals.

8. Summary of pest biology and/or lifecycle

There is very limited specific data available about the life cycle of *Crisicoccus pini*. The pest feeds on developing pine needles, resulting in yellowing and partial necrosis (Boselli, 2016). Like other mealybugs, the egestion of honeydew onto plant tissues results in the development of dark sooty moulds that limit photosynthesis and gas exchange of green tissues (EPPO, 2019). When numbers of *C. pini* are high, the canopy can show extensive necrosis, and host mortality has been observed in Italy (EPPO, 2019). White waxy secretions appear on the adult mealybugs which aids defence and might reduce the penetration of chemical sprays (Boselli, 2016).

Without specific information about the life cycle of *C. pini*, a generic description of mealybugs (focussed on the family Pseudococcidae where possible) is below. There is some variation between mealybugs in respect to many elements of the life cycle, including how they overwinter, so care must be taken about using the life cycle of other mealybugs in the absence of specific information about *C. pini.*

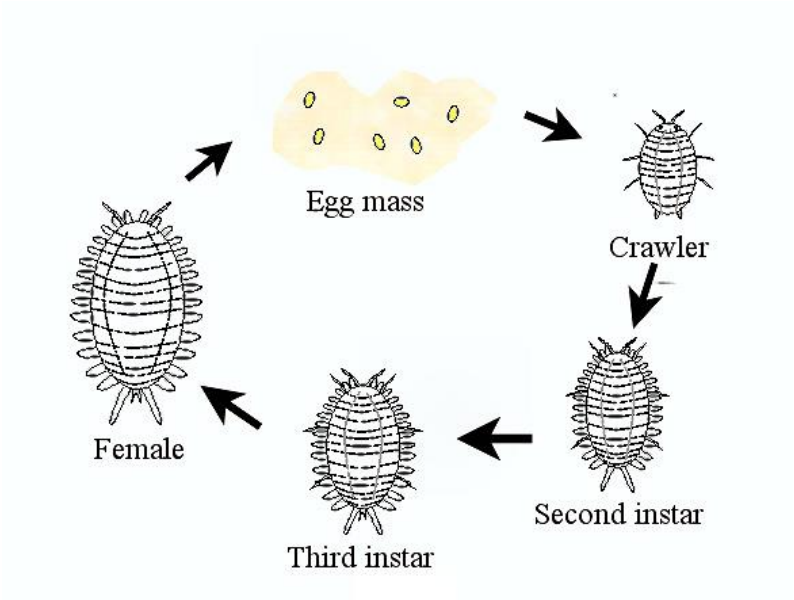

Figure 2 Lifecycle of *Crissicoccu*s species. Image courtesy of Broughton, 2015.

The mealybug lifecycle consists of three stages, the egg, the immature nymphal stage and the adult stage (Broughton, 2015). Eggs are laid within a cotton like pouch and hatch in 5 to 10 days, immature crawlers mature to adults between 6 to 9 weeks (Pundt, 2003). Some species of longtailed mealybugs lay eggs which immediately hatch into live young (Pundt, 2003). Mature females die after laying eggs. Some species of mealybug can lay between 300 and 600 eggs, resulting in very rapid population growth on a susceptible host (Pundt, 2003). There can be multiple generations of mealybugs within a year. Adult females can survive between 10 and 19 days in the absence of a host plant. It is unclear which stage of *C. pini* is the overwintering stage, and where within the host it overwinters. Most native European species overwinter as early instar nymphs in bark crevices or when on pines, at the base of the needles.

Immature stages of the mealybug, the nymphal stages can move between hosts over short distances, with limited capacity for long distance dispersal outside of the movement of infected hosts. Natural spread of *C. pini* is expected to be very slow. Adult females tend to remain stationary on a host plant. Adult males are winged, and significantly more mobile, but do not develop mouth parts, therefore cannot feed after pupation and only live for up to three days to mate with females (Pundt, 2003).

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?

Introductions into North America are likely to have been through plants for planting of ornamental *Pinus* species from Asia, as it was first reported in California at a nursery (McKenzie, 1967). How it spread to Washington D.C. is unclear, as is the extent of the finding there and the current status of the pest in the rest of the USA.

As the finding in Monaco was in a Japanese ornamental garden, it's highly likely that plants for planting from Asia were the pathway of introduction there. Dwarf *Pinus* can be imported under derogation (Commission Decision 2002/887/EC for dwarfed *Pinus* from Japan, Commission Decision 2002/499/EC from South Korea), but without further details about the finding in Monaco, it's difficult to confirm the import of bonsai as the source of the outbreak there.

The source of the outbreak in Italy is unclear, but again plants for planting seems a very likely pathway. Italy is particularly vulnerable to invasive insects, being a centre of trade within the Mediterranean. At least 49 species of invasive scale insects have been reported in Italy since 1945, around 50% of which have become established there (Mazzeo *et a*l., 2014).

Plants for planting

The import of *Pinus* plants for planting into the UK is a likely route of entry. *Crisicoccus pini* lives in close association with developing pine needles, so plants for planting are the most likely route that provides medium term survival for the pest. Most plants for planting will be imported at a very young age, and early infestations of *C. pini* are going to be difficult to detect. The crawler stage is relatively cryptic, and small numbers of crawlers could be imported without visible symptoms. Later stages of infection, with large numbers of larvae/adults would be conspicuous, with the white waxy build ups and egg sacs easily identifiable.

Prohibitions exist for the import of *Pinus* species from any country outside of Europe (Plant Health, (England) Order 2015, Schedule 3). This limits the likelihood of import of infected hosts from the USA, and most of Asia. It does not limit the import of plants for planting from Italy however.

The import of *Pinus* from European countries is subject to plant passporting requirements and are notifiable. Because of this the PHSI have detailed statistics on which species of *Pinus* were imported and from which country. For the reporting year April 2015-March 2016, a detailed analysis of the import of *Pinus* was conducted, the outputs of which can be found in Appendix 1. It's important to note that not all *Pinus* imported from Italy will be from regions where *C. pini* is present, so it's likely that only a very small number of plants, if any, are sourced from this region. As establishment in a new region in Italy, or another EU member state, would be difficult to detect for many years as populations build up, it's possible that this pest has established beyond the region surrounding Milano Marittima and plants for planting from other regions could be a source of *C. pini*.

A total of 409,470 individual *Pinus* trees were imported into the UK from other European countries in 2015/16 (Fig. 3). The majority of this (293,081 trees) were imported from the Republic of Ireland (Fig. 3). From Italy, the UK imported 451 *Pinus* trees in 2015/16 (Fig. 3). It is very likely that plants for planting from Italy will first move through other EU countries, predominantly the Netherlands, so it's possible the number of pines being imported that originated in Italy is higher than what is reported.

34 different *Pinus* species were imported into the UK in 2015/16. *Pinus strobus* (eastern white pine / Weymouth pine) made up the majority of the imported trees (316,980), followed by *P. peuce, P. pinea, P. silverstris* and *P. nigra* (Fig. 4). From Italy alone, we imported *P. strobus, P. monticola, P. parviflora, P. nigra, P. wallichiana, P. silvestris, P. mugo* and *P. pinea,* in numbers ranging from 2 to 151 plants (Fig. 5). Of these, *P. pinea, P. nigra* and *P. parviflora* are confirmed hosts of *C. pini.*

The majority of *Pinus* species are imported into the UK in the winter, between November and April (Fig. 6). This is also true when only considering imports from Italy, which sees most *Pinus* imported in December, February and March (Fig.6). The UK nurseries that first receive *Pinus* plants for planting, where the risk of establishment is highest, are plotted in Figure 7. For English importers of *Pinus*, there is a uniform distribution of first import locations across England, with only a few centres seen in Scotland and Wales and no importers in Northern Ireland in 2016

There is also the import of dwarfed *Pinus* coming from Japan and South Korea. Dwarfed plants imported under the derogations have specific conditions attached to them. The plants will have been grown for two years prior to dispatch in a nursery subject to at least 6 inspections a year. *Crisicoccus pini* is not listed on the harmful organisms stated in the annex to either derogation, and now it has established within the community there is no requirement to exclude it. Any finding would be subject to an action recommendation however. Only *Pinus pentaphylla* (or *P. pentaphylla* on rootstock of another species) can be imported from Japan and South Korea.

As all dwarfed *Pinus* is notifiable under derogation, we have specific numbers for this. In 2014, 334 *P. pentaphylla* were declared, 251 in 2015, 397 in 2016, 207 in 2017, and 126 in 2018 (Defra Internal statistics). This is an average of 263 declared *P. pentaphylla* imports coming directly into the UK a year. EU wide data for 2017 and 2018 is also available. Notifications of EU imports of *Pinus pentaphylla* came from Belgium, Czech

Republic, Germany, Spain, Italy and the Netherlands in both years, with 4710 total imports from Japan in 2016, and 4294 in 2017.The largest importers are Italy and the Netherlands. Bonsai imported into other member states would be subject to quarantine there, before moving unrestricted in the community.

Plants for plantingare the most likely route of entry for this pest. There is significant trade in plants for planting with Italy where the outbreak in Europe has occurred. The majority of these imports will not be from within the outbreak site, but if *C. pini* has spread small numbers of insects could be imported from other regions. The import of dwarfed *Pinus* carrying the scale from Japan is also possible, and seems to be the most likely pathway for the recorded finding in Monaco. Measures under the derogation may help limit the pathway risk, however *C. pini* is not a specifically listed pest, and may be cryptic at certain lifestages. Because of the open pathways for infected plants to enter the UK, the pathway has been assessed as moderately likely, with medium confidence. Medium confidence has been selected because of the lack of clarity surrounding the introductions to Italy and Monaco, doubts about the effectiveness of phytosanitary measures applied to Bonsai imported under derogation and uncertainty about how widespread the pest could be in Italy.

Plants for planting	Very unlikely	☐	Unlikely	☐	Moderately likely	☑	Likely	☐	Very likely ☐
Confidence	High Confidence	☐	Medium Confidence	☑	Low Confidence	☐			

Bark, Non-squared wood and Woodchip

It is unlikely that *C. pini* could be found in association with the bark of hosts in the absence of living needles. Because of this there is the possibility that bark, non-squared wood and woodchip could hold the pest. Pre-export treatments, including drying, are likely to be very effective in removing the pest, but will not be applied to all imports. Due to limited mobility of the pest, even if living mealybugs could enter the UK through these pathways, they would have difficulty transferring to a suitable host unless the wood chip were used as part of a mulch around planted trees. The import of coniferous woodchip from outside the EU is prohibited, and the area of establishment in the EU is very small. The risk of *C. pini* being imported alongside unsquared wood, bark and woodchip has been assessed as unlikely with low confidence.

Unsquared wood, Bark, Woodchip	Very unlikely	☐	Unlikely	☑	Moderately likely	☐	Likely	☐	Very likely ☐
Confidence	High Confidence	☐	Medium Confidence	☐	Low Confidence	☑			

Squared wood, WPM

There is no indication that squared wood or wood packaging material are viable pathways for this pest. The mealybug is not associated with the heartwood and does not penetrate the cambium. Wood and squared wood have been rated very unlikely with medium confidence.

Squared wood, WPM	Very unlikely	☑	Unlikely	☐	Moderately likely	☐	Likely	☐	Very likely ☐
Confidence	High Confidence	☐	Medium Confidence	☑	Low Confidence	☐			

Seed (excluding pine cones)

There is no indication this pest can spread on seeds. The pest feeds exclusively on pine needles. This pathway has been assessed as very unlikely with medium confidence (due to the lack of information about the pest).

Seed	Very unlikely	☑	Unlikely	☐	Moderately likely	☐	Likely	☐	Very likely ☐
Confidence	High Confidence	☐	Medium Confidence	☑	Low Confidence	☐			

Natural spread

Mealybugs typically spread very slowly. We do not have specific spread rates for this pest, and it is difficult to determine the rate of spread seen in Italy as we do not know the date of first introduction. The rate of spread in the years since it was observed has been low however, and it has not spread beyond the initial infection zone within the last two years (Boselli, 2018). It does not appear to be widespread in other regions it has been introduced, and there is no indication of extensive spread in the US. Even if the pest spreads from Italy to Northern Europe, the scale would be incapable of crossing the English Channel. Natural spread to the PRA area has been rated as very unlikely with medium confidence. The confidence is set at medium due to lack of detailed biology about this pest.

Natural spread	Very unlikely	☑	Unlikely	☐	Moderately likely	☐	Likely	☐	Very likely ☐
Confidence	High Confidence	☐	Medium Confidence	☑	Low Confidence	☐			

Plant products

Pine branches and pine cones are commonly used in floristry and in the production of Christmas decorations (like wreathes). It is unclear if *C. pini* could be associated with the import of pine cones, but cut branches from infected hosts are likely to carry the mealybug. A high degree of infestation on a branch will be noticed in production, due to the presence of woolly sacs, but low numbers of mealybugs could be associated with cut branches.

Even if mealybugs are imported on plant products, there is only a low chance of movement from the imported product to living *Pinus*, due to the limited mobility of the pest The import of cut branches from outside of Europe is also prohibited. Plant products as a pathway for *C. pini* has been assessed as unlikely, with low confidence. Confidence is limited due to the absence of information about how the pest overwinters, and its association with pine cones.

Plant products	Very unlikely	☐	Unlikely	☑	Moderately likely	☐	Likely	☐	Very likely ☐
Confidence	High Confidence	☐	Medium Confidence	☐	Low Confidence	☑			

Hitchhiking (including passenger baggage)

There is not enough specific information about this pest to provide an accurate assessment of the likelihood of hitchhiking as a pathway of entry. As a mealybug with limited mobility, survival away from a living host is likely very limited. Passenger baggage as a route of entry might apply for dwarfed *Pinus* that could be brought from Italy to the UK, and the movement of very young non-dwarfed *Pinus* is possible but expected to be very low. This pathway has been rated as very unlikely with medium confidence.

Hitchhiking	Very unlikely	☑	Unlikely	☐	Moderately likely	☐	Likely	☐	Very likely ☐
Confidence	High Confidence	☐	Medium Confidence	☑	Low Confidence	☐			

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

No vector is required, this is a free-living insect.

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

Pinus species are spread throughout the UK, and the vast majority are found outdoors. Ornamental bonsai species can be grown indoors, and a few pines are grown in protected cultivation whilst very young.

There is a lack of detailed data about *C. pini's* temperature development requirements. As such a detailed analysis of the pest's ability to establish outdoors in the UK is difficult. Climatic comparison of the UK with regions the pest is present is possible however.

The pest is present in the Japanese islands of Honshu and Kyushu but is not reported from Hokkaido in Kuwana (1902), and in no other source since. Hokkaido has a similar

climate to the UK, and is often a marker for if an Asian pest could establish here. *Crisicoccus pini* was originally isolated in Nishigahara, Tokyo (Kuwana, 1902). This region is warmer than the UK for most of the year (Fig 8.b), with much higher rainfall annually (Fig 9.b). The lack of reports of *C. pini* in Hokkaido might suggest that the UK climate could limit the establishment and spread of the pest. The number of degree days above 10ºC is significantly higher in Tokyo than London, but without clear thermal requirements of this pest we are unable to predict with more certainty the likelihood of *C. pini* completing its life cycle in the UK.

The climate of Washington D.C. is similar to the UK, with warmer summers and colder winters, but significantly higher monthly rainfall (Figs 8.a, 9.a). The number of degree days above 10ºC is also higher in Washington D.C. (Fig 10.a). As we do not have details of the extent of *C. pini's* presence in Washington D.C. it is difficult to know if the climate there is supportive of growth of this pest. The climate of southern California is significantly warmer and drier than the UK, and is not a good measure of climatic suitability with the UK.

Milano Marittima, the site of the *C. pini* outbreak in Italy and the only recorded location with significant damage observed from the pest, has a moderate degree of climatic similarity to some parts of the UK. There is overlap in the average high and low temperatures of London and Cervia (the town closest to Milano Marittama), but daily high temperatures for Cervia can be up to 6ºC warmer than London, which is already warmer than most of the UK (Fig 8.c). There is almost no overlap between the daily temperatures of Cervia and Aviemore, in the central Scottish Highlands. Average rainfall between London and Cervia are fairly similar, with Cervia seeing higher rainfall in the spring and autumn, and less in December and January (Fig 9.c). There are far more accumulated degree days above 10ºC in Cervia than London (Fig 10.c).

Pine forests are distributed throughout the UK, with significant pine forests in the Scottish highlands. Aviemore, in the central highlands, is significantly colder than London and Cervia, sees more rainfall for most of the year, and has far fewer degree days above 10ºC (Fig 8.c, Fig 9.c, Fig 10.c). If *C. pini* could establish in southern parts of the UK it is not clear if it would be able to spread to all *Pinus* in the UK, or if it would be restricted to warmer regions.

Without detailed thermal requirements of this pest, it's uncertain how suitable the UK is likely to be. It's likely that southern parts of the UK will be more suitable for this pest. There is a moderate degree of climatic similarity between Cervia and London, but the lower average temperatures in the UK might be a significant factor in limiting *C. pini's* establishment. Establishment outdoors has been rated moderately likely, with low confidence. The low confidence is a result of the lack of detailed information about the pest's development thresholds, and lack of data about spread and establishment in locations it has been reported from (particularly Washington D.C.).

Outdoors	Very unlikely	☐	Unlikely	☐	Moderately likely	☑	Likely	☐	Very likely	☐

Confidence	High Confidence	☐	Medium Confidence	☐	Low Confidence	☑		

Pinus species are rarely grown under protected cultivation in the UK, and if they are its likely to only be for a short period while the tree is very young before replanting outdoors. The only *Pinus* grown routinely in protected cultivation is bonsai, as nurseries have a requirement to keep it in protected/semi-protected cultivation before moving on. Many dwarfed ornamental *Pinus* species are common indoors, and the climatic suitability of these is likely to be high. Should it establish on an indoor bonsai, there is only limited capacity to spread to natural hosts due to the limited mobility of the pest. Under protected cultivation, establishment has been rated as moderately likely, with medium confidence.

Under Protection	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?

Mealybugs typically spread very slowly. Immature nymphs are capable of crawling between hosts, but have restricted range and a limited ability to survive away from a host. Adult males can fly, but only have a limited lifespan dedicated to finding a mate. *Crisicoccus pini* is only likely to spread very slowly naturally. This is supported by evidence from the Italian outbreak. In Milano Maritama, the pest had spread over an unknown number of years to cover over 50 ha. In 2016 sampling identified *C. pini* in 5 new areas surrounding Milano Marittama and the coastal area of Pinarella (Boselli, 2018). Sampling in the wider environment in 2017 did not detect any new pests outside of the quarantined area (Boselli, 2018). The outbreak appears to be restricted by the rate of spread of the pest, not the presence of the host. Milano Maritama is a garden city with tourist accommodation built within a pine wood of around 260 ha (Boselli, 2018). The mealybug has not spread throughout this region despite the presence of suitable hosts

Without specific data about the rate of spread of the pest, and basing the rate of spread of the pest on the Italian outbreak, natural spread has been determined to be slowly, with medium confidence.

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

With trade movement over longer distances is possible. It's clear that *C. pini* can move in trade, after introductions to California, Monaco and Italy. Movement of pines within the UK could lead to the establishment in new areas. Rate of spread with trade is set at moderate pace, with medium confidence. Confidence is limited by the lack of clear examples of its movement through trade within a country.

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?

There are no records of a significant impact caused by *C. pini* in its native range. This might be a result of control by local predators, a high degree of host resistance in these regions, or the lack of current scientific enquiry into the pest. Where it has been introduced in California, there are no reports of economic, social or environmental impacts. Its first discovery was in 1918, with no records found between then and 1967 (Danzig *et al*., 2010; McKenzie, 1967). The possibility of a stable population in Washington D.C. remains unconfirmed, and there are no reports of impacts.

No further details have been found about its introduction to a Japanese garden in Monaco in 2006. There is no indication it has spread beyond the initial finding, and no updates about what happened to the infected hosts. No further details have been found to confirm the source of the pest, but as the garden is likely to contain imported bonsai species this seems a likely means of introduction.

The introduction to Italy in 2015 has caused significant disruption at the local level. When damage was first observed the pest had already spread across ornamental *Pinus* planted along streets and in private gardens, covering an area of approximately 513,000 m^2 (Boselli *et al.*, 2016). Severe decay of *Pinus pinaster* (maritime pine) and *Pinus pinea* (stone pine) was reported. Because of the high numbers of *C. pini* observed, the spread over a large area and the extent of the damage observed on the host it is assumed the pest was introduced several years prior to being identified (Boselli *et al*., 2016).

Upon finding the pest and observing extensive damage to trees throughout the town of Milano Marittima phytosanitary measures were undertaken. These including a national decree for 'emergency measures to avoid the spread of *Crisicoccus pini* in Italy' in March 2016. Severely infected pine trees were destroyed, abamectin containing insecticide was applied through trunk inoculations and authorities released the natural predator *Cryptolaemus montrouzieri* (the mealybug ladybird, or mealybug destroyer, a native Australian ladybird also present in parts of southern Europe) between 2015 and 2018

(Boselli, 2018). This was a significant effort with high cost implications for control, and a large social disruption at the local level.

It is unclear why impacts in the town of Milano Maritama were much higher than reports from this pest's native range or in other areas the pest was introduced to. It might be that the slightly cooler climate with less annual rainfall was more suitable for *C. pini*. The lack of natural predators might also be a factor in the higher impacts seen here.

By 2018, the control measures in place since 2015 had significantly reduced the population of *C. pini* in Milano Marittima. Scale numbers had fallen from an average of 5.72 per shoot, to 0.09 (Boselli, 2018). Chemically treated trees have started to show recovery.

Economic impacts have been rated as medium, with medium confidence. The damage done by the pest is significant, but the low rate of spread, and effectiveness of control measures (though expensive and disruptive) limits the impact this pest is having. In addition, the pest has caused significant social disruption at the local level. Medium confidence is suggested because of the lack of further details about the impacts in Monaco, the US and its native range.

Impacts	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?

Impacts are not likely to be very high for this pest. Assuming *C. pini* can complete its life cycle in the UK, and were a stable population were to establish here, impacts are likely to be significant but restricted to local areas. Any impact seen would be reduced by the very slow rate of spread, with significant impacts only seen at a local level for a long time. It would be many years before an outbreak stretched to cover a significant area, and the experience from the Italian outbreak suggests that mitigations could be put in place to help prevent this outcome. The same chemical controls used in Milano Maritama could not be used in the UK without first applying for an extension of use however.

Impact on individual trees is very high. There is a high degree of host mortality in later stages of infestation, and the decline of even moderately infested trees is rapid. It's unclear if the UK climate would limit the impacts seen here. If the pest were to establish, cooler temperatures might limit the rate of population build up and lower the impact that would be seen. Without detailed information about *C. pini*'s development requirements however, there is a high degree of uncertainty surrounding the suitability of the UK climate and establishment in the UK could present a risk to a very common host.

The outbreak in Milano Maritama was within an urban development. *C. pini* might cause more impacts in urban areas as urban heat islands provide a slightly warmer climate, urban trees can be more susceptible due to stress, and there are lower levels of predation by natural predators. Pine is commonly grown in urban areas, including a minimum of 5550 trees in greater London.The density of the *Pinus* in urban areas however is low, limiting the potential for scale to spread significantly.

It is unclear how much natural predation *C. pini* would face in the UK. *Cryptolaemus montrouzieri* was found already on the infested pines in Milano Maritama during the outbreak, before it was used as a biological control agent (Boselli, 2016). This ladybird is established outdoors in London, but it's unknown how established it is in other areas, or if its population is high enough to provide any mitigation.

Pinus is a very important genus in the UK. A substantial amount of the total value of forestry species is contributed by *Pinus,* with *Pinus sylvestris* estimated to be worth £14,556 million. It's a vital species for the UK timber industries, contributes significantly to the tourism industry and is a common ornamental within urban landscapes.

Economic impacts have been calculated as small with low confidence. The industry at risk is very substantial, but the very low rate of spread of the pest and doubts about both the climatic suitability of the UK and the susceptibility of *P. sylvestris* limit the impact this pest might have. The lack of significant data about this pest's biology has led to the low confidence score.

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

Environmental impacts have been assessed as small with low confidence. *Pinus* species are essential to UK woodlands. Caledonian pine forests in Scotland are of particular importance. Again, the low rate of spread of the pest limits the impacts this pest could cause, and provides opportunities for pest management to act on local outbreaks. Significant uncertainties about the life cycle, suitability of the climate and susceptibility of *P. sylvestris* lead to a low confidence score.

Environ - mental Impacts	Very small	☐	Small	☑	Medium	☐	Large	☐	Very large	☐
Confidence	High Confidence	☐	Medium Confidence	☐	Low Confidence	☑				

Social impacts have been assessed as medium with low confidence. If a similar outbreak to Milano Marittima was seen within an urban environment in the UK there would be significant alarm at a local level. Ornamental *Pinus* is commonly grown in gardens and parks, and bonsai are popular in both gardens and indoors. As a major species in the UK, the introduction of a new pest is likely to cause alarm.

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?

There is no data about *C. pini* vectoring plant pathogens. *Crisicoccus pini* is likely to aid in the establishment of several rot pathogens, and the egested honeydew does lead to the development of sooty mould. Some species of mealybug are known to vector plant viruses, with several grapevine leafroll-associated viruses known to be transmitted by the mealybugs *Planococcus ficus* and *Pseudococcus longispinus* for example (Tsai *et al*., 2010). *Crisicoccus pini* might have potential in vectoring plant viruses, but further research is required to establish this.

16. What is the area endangered by the pest?

The trees most likely to be at risk based on the evidence that is available to date are those in warmer parts of the UK, and in urban heat islands. However, *Pinus* species are found across the UK, and without any specific data to suggest that parts of the UK climate would limit the pests spread in the UK, it should be considered that all *Pinus* in the UK is at risk.

Pinus sylvestris is the most common *Pinus* species in the UK, and it still remains unknown if this can act as a suitable host. On introduction to Italy, *C. pini* was found to have infected *Pinus pinea*, common to Italy and not found within *C. pini's* native range, and not considered a host in North America. This does suggest the pest is capable of infecting a broader range of *Pinus* species outside of those it has been recorded on so far.

Stage 3: Pest Risk Management

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

Exclusion

Only a very low level of trade in plants for planting from the region where *C. pini* has established is likely however. Continued exclusion of imports of the host from the US is likely to be highly effective in preventing what population is present there from entering the UK. Bonsai imported under derogation from Japan and Korea are already subject to high phytosanitary requirements, however, it is strongly suspected that these may have been the original source of at least one outbreak (Monaco), and so exclusion based on the current requirements cannot be guaranteed.

Eradication or containment

As this pest would most likely be found in the wider environment, eradication or containment could be difficult. Like with the outbreak in Italy, it is likely that several years would pass before any infestation is noticed, only becoming visible in later stages of symptom development. In this time some local spread would be anticipated, but the pest is unlikely to spread across a large area quickly. Containment and eradication of the pest, and application of effective phytosanitary measures would be possible. Control measures applied in Italy, including the application of abamectin containing insecticide and the release of the natural predator *Cryptolaemus montrouzieri* (which is already established in parts of London) have been effective in lowering the damage seen on infected hosts and limiting the spread through the region (Boselli, 2018).

If the pest was found on quarantined imports of bonsai, eradication and containment would be relatively easy, with some degree of containment already provided by the conditions stipulated in the bonsai derogations. There is likely to be very big differences in the degree of protection used by different bonsai importers however.

Non-statutory controls

Insecticides are available for use against other mealybugs in the UK, and like with the outbreak in Italy are likely to prove effective in limiting the damage of *C. pini*. Trunk inoculations with abamectin did result in infected trees showing recovery (Bosseli, 2018). Abamectin is not authorised for use on trees in the UK however. Approved insecticides that might be useful are Alphacypermethrin (for the control of chewing and sucking insects), Diiflubenzuron (for leaf eating insects) and Cypermethrin (approved for broad spectrum pests). It is unclear how effective they would be at controlling this mealybug.

Biological controls are also likely to be effective. *Cryptolaemus montrouzieri,* used in the Milano Marritama outbreak, does not require a licence for release in the UK. Other availiable biological controls that can be used without a licence against mealybugs include *Leptomastix epona* and *L. dactylopii*.

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Name of Pest Risk Analysts(s)

Dr Simon Lloyd

Appendix 1: Trade Statistics for *Pinus* Plants for Planting

Data for notifications of *Pinus* imports was kindly provided by Guy Nettleton, PHSI.

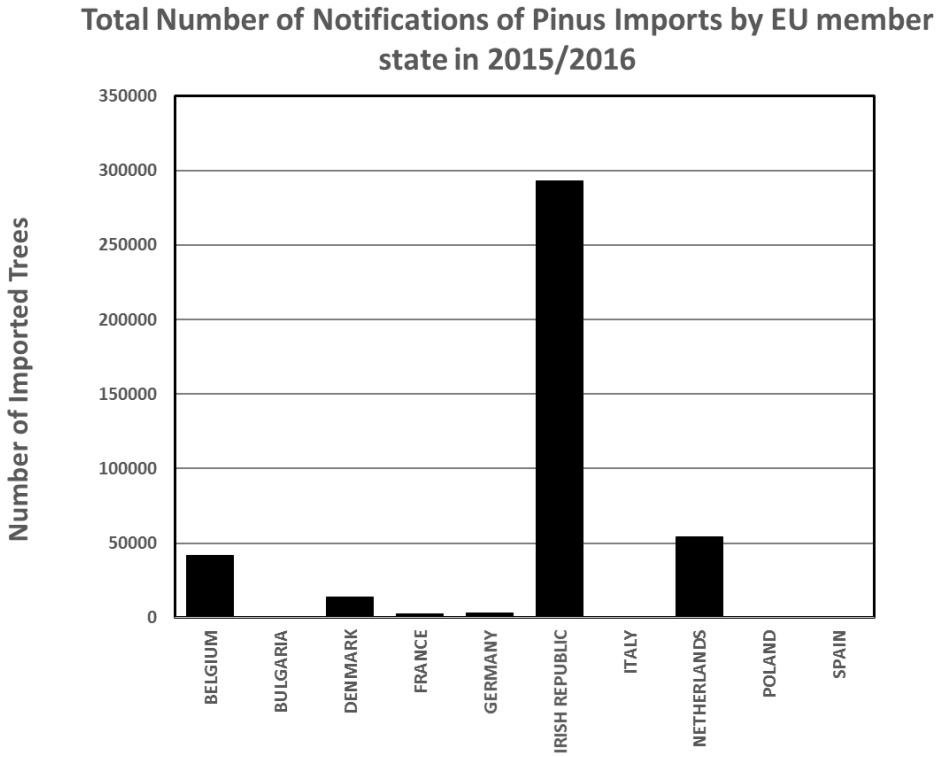

Figure 3 Total Number of Notifications of *Pinus* imports by EU member state in 2015/2016.

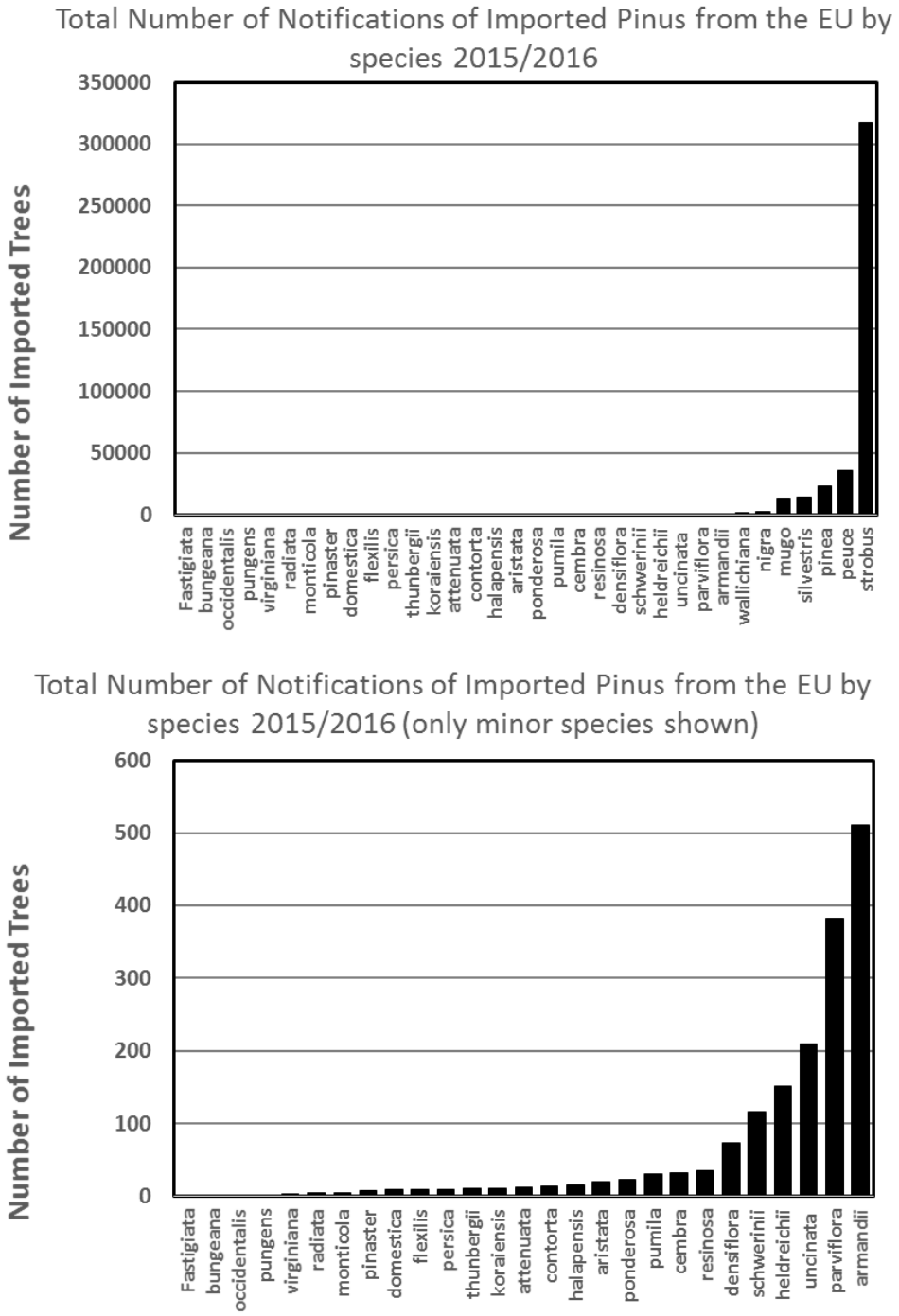

Figure 4 Notified species of *Pinus* being imported into the UK from the EU. Full host range (top) and closer look at minor species (bottom).

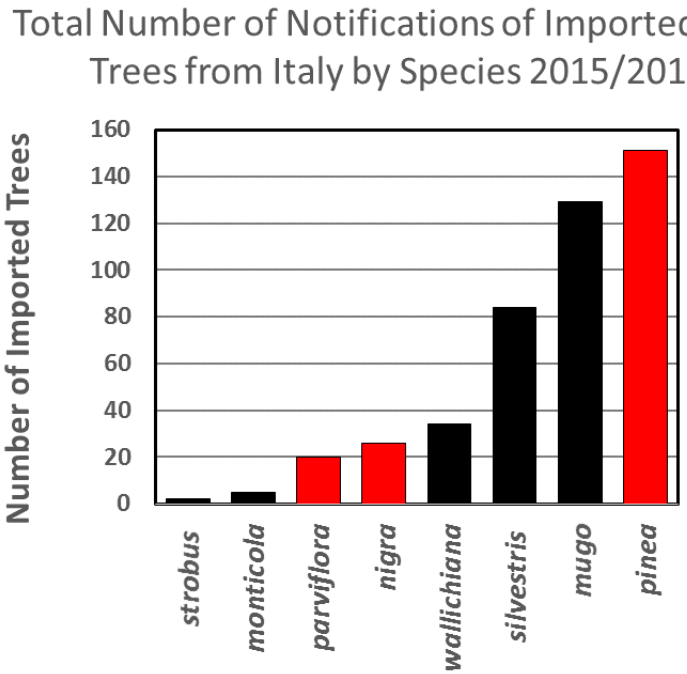

Figure 5 Notified imports of *Pinus* plants for planting from Italy in 2015/16. Red bars indicate confirmed hosts of *C. pini.*

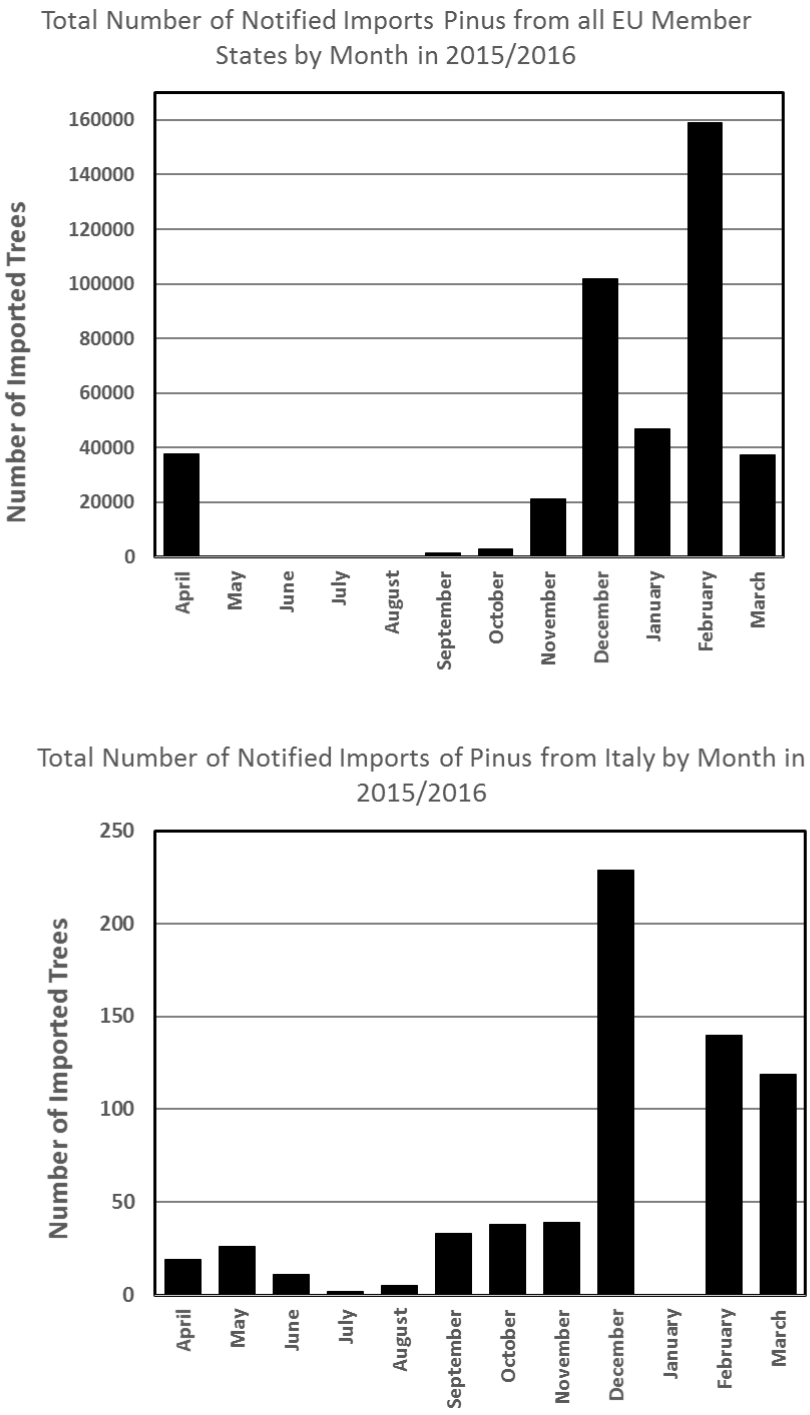

Figure 6 Date of import of notifications for *Pinus* coming from the EU (top) and Italy alone (bottom).

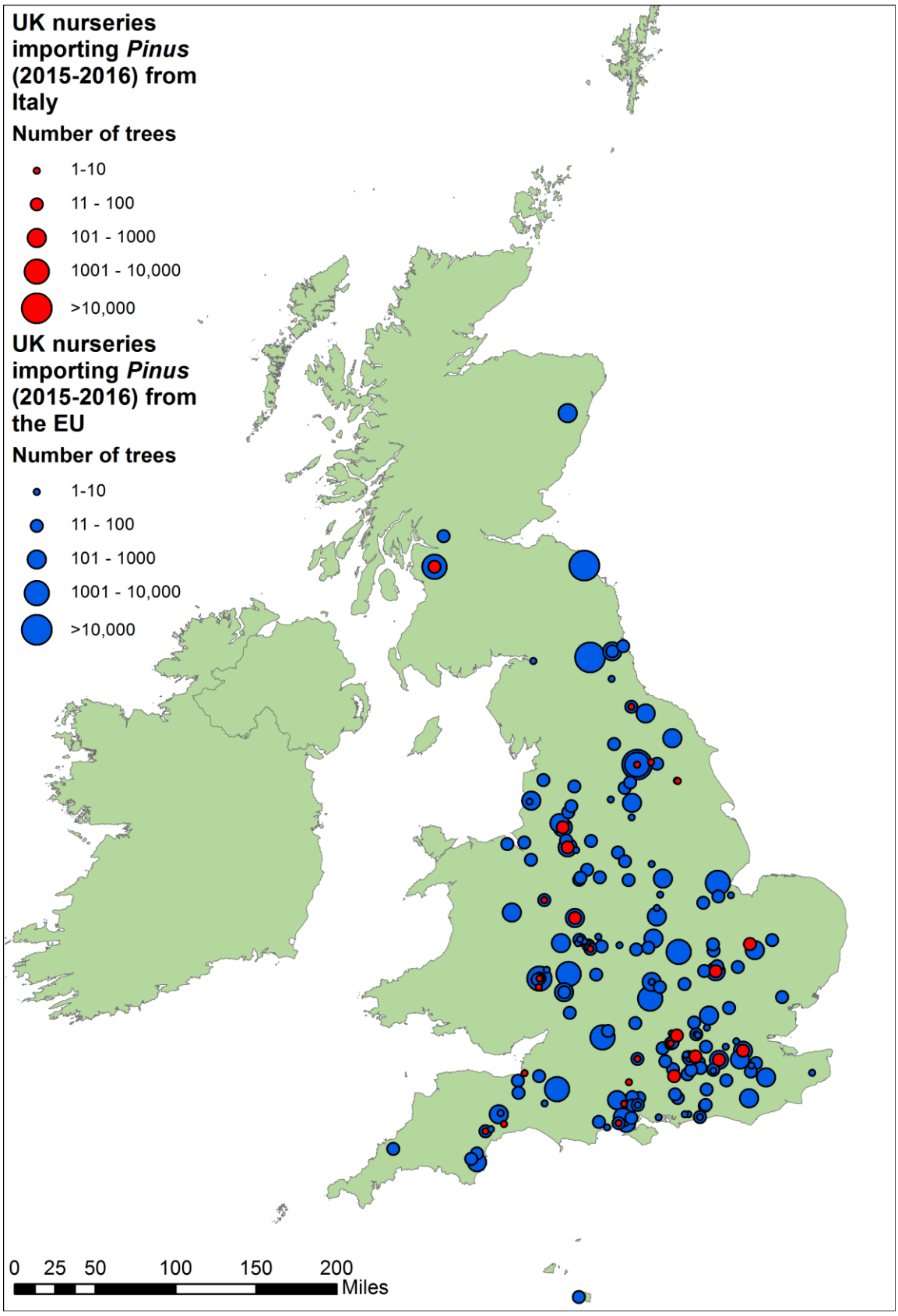

Figure 7: Location of Importers of *Pinus* from the EU in 2015/16. Dot sizes correspond to numbers of *Pinus* being imported. Red circles indicate where *Pinus* was imported from Italy.

Appendix 2: Climatic Comparison of UK with locations within *Crissicoccus pini*'s Current Distribution

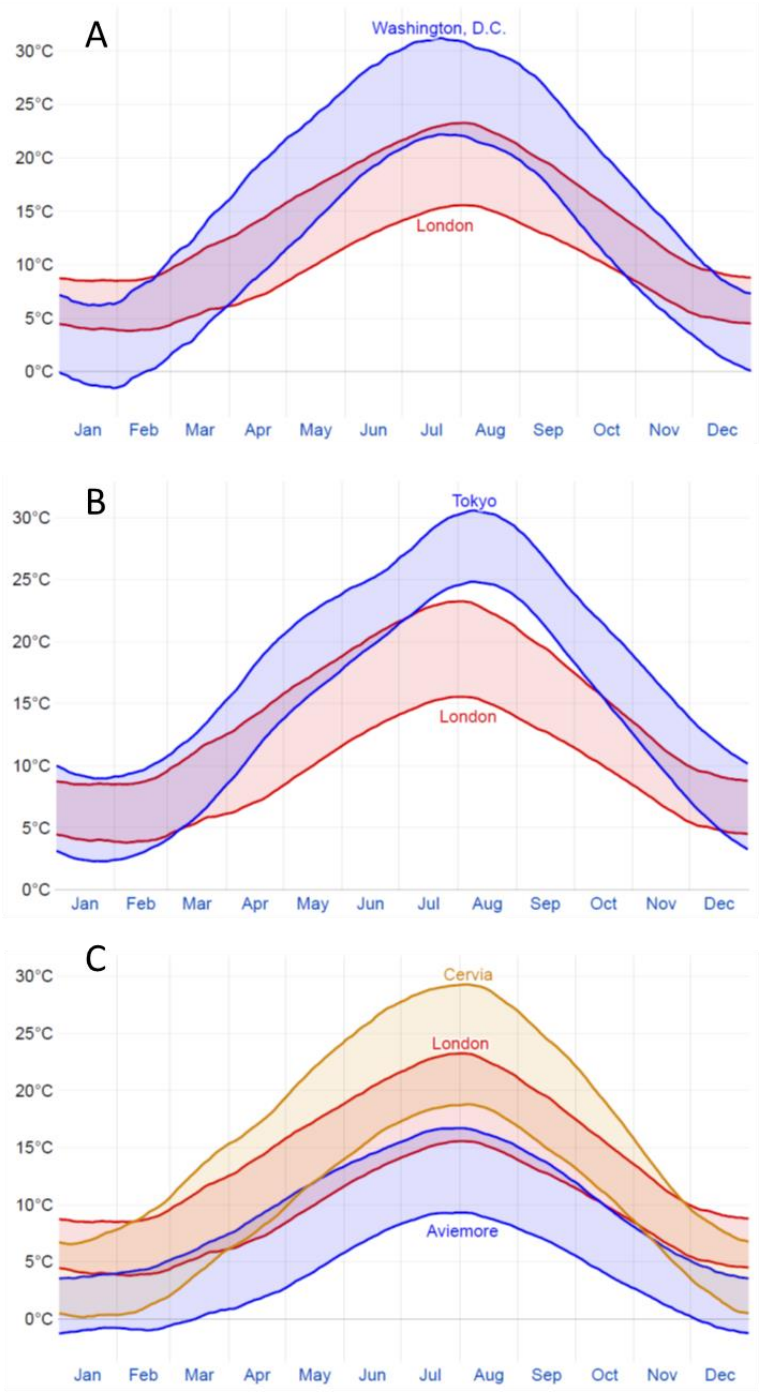

Figure 8 Average high and low temperatures by month for London and Washington D.C. (A), London and Tokyo (B), and London, Cervia (site of the Italian outbreak) and Aviemore (central Scottish Highlands) (C).

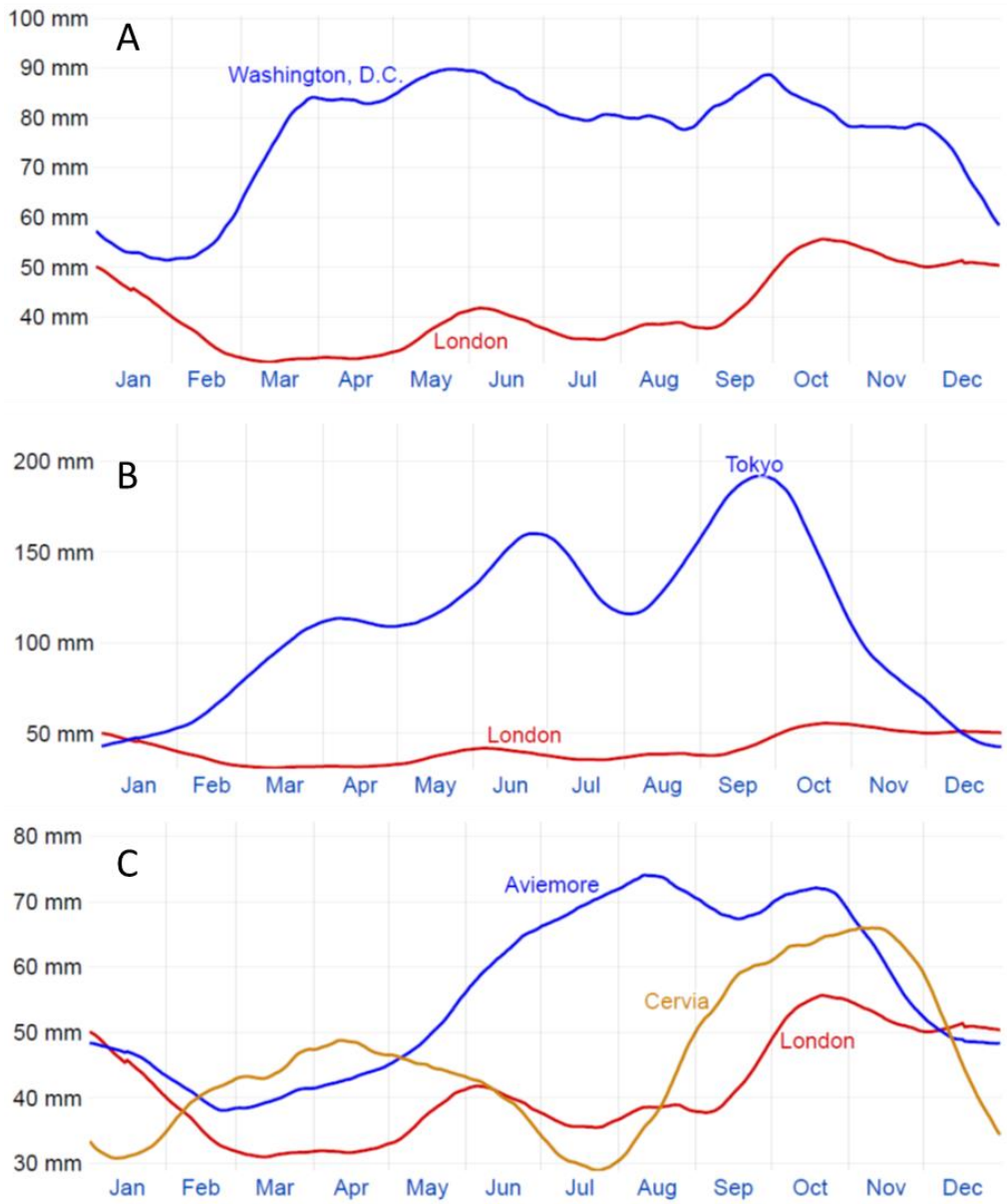

Figure 9 Average rainfall for London and Washington D.C. (A), London and Tokyo (B), and London, Cervia (site of the Italian outbreak) and Aviemore (central Scottish Highlands) (C).

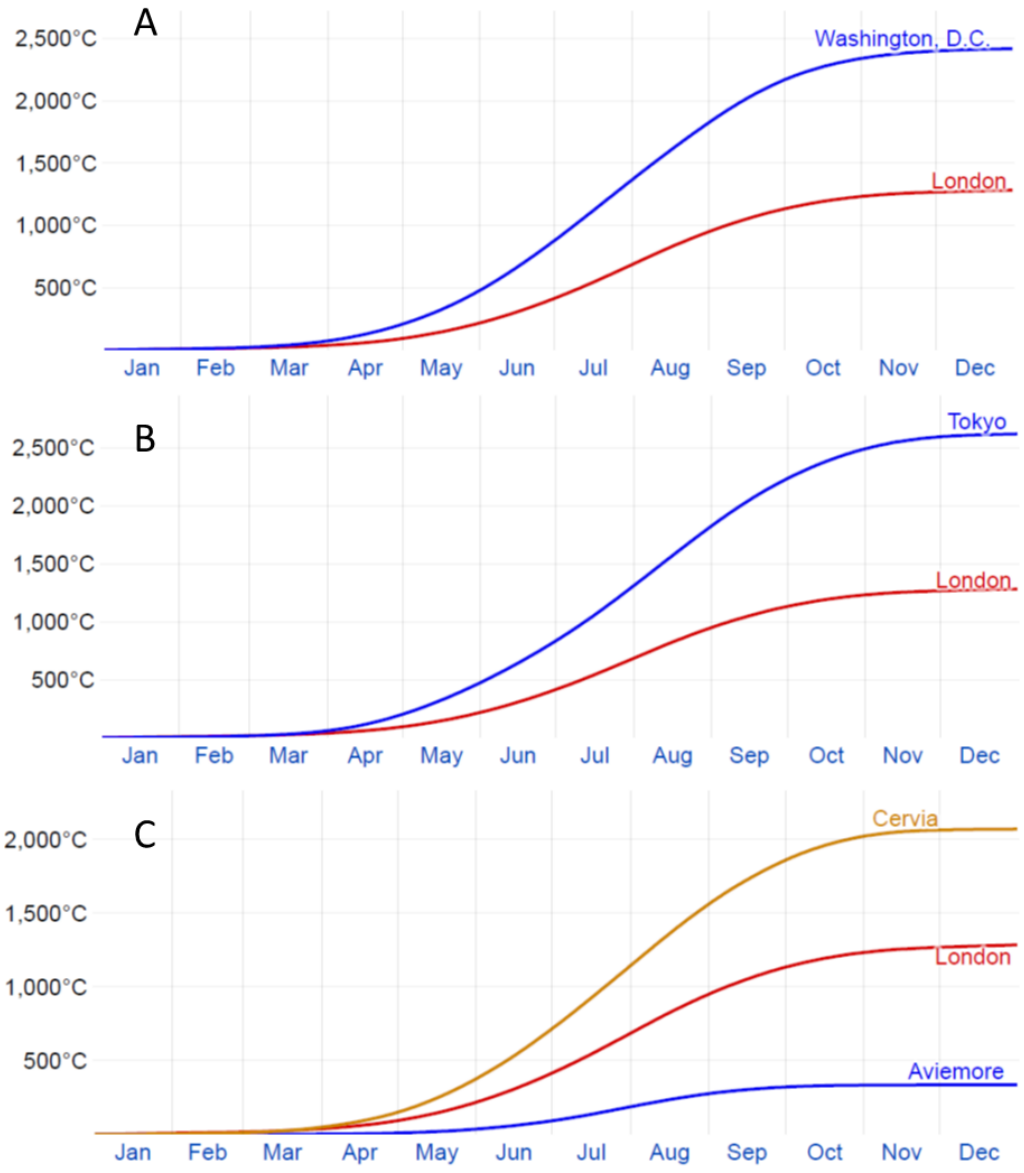

Figure 10 Degree days accumulated over the course of a year, where degree days are defined as the integral of warmth above a base of 10ºC, for London and Washington D.C. (A), London and Tokyo (B), and London, Cervia (site of the Italian outbreak) and Aviemore (central Scottish Highlands) (C).

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