Department
for Environment
Food & Rural Affairs

Rapid Pest Risk Analysis (PRA) for: *Lycorma delicatula*

Date in format: March 2023

Summary and conclusions of the rapid PRA

This rapid PRA was requested as *Lycorma delicatula* has been spreading rapidly in the northeast states of the United States of America (USA) having first been reported there in 2014. The pest, which is of Asian origin, has been added to Great Britain (GB) legislation as a Provisional Quarantine Pest, and this PRA has been developed to determine if it should become a Regulated Quarantine Pest. It is already regulated in Northern Ireland.

Risk of entry

The main pathways of entry are hitchhiking, plants for planting and wood products from countries with *L. delicatula* (USA and east Asia). Due to the nature of hitchhiking in the inconspicuous egg stage especially, the risk is rated **very likely** with **high confidence** as this has been the main mode of large-scale movement of *L. delicatula*. The second pathway on plants for planting, is **moderately likely** with **low confidence**. It could be a future pathway if countries that trade in large volumes of plants for planting with the United Kingdom (UK) become infested but this is uncertain and so it is rated with low confidence. The last pathway is wood products, and this risk is rated as **unlikely** with **low confidence** as some wood products that come into the UK have to undergo certain treatments that would kill most stages of *L. delicatula*. However, *L. delicatula* is not being specifically targeted and it would be mitigated against along with other pests where there is a specific regulation in place and only specific wood products would be treated. Whereas *L. delicatula* lays eggs indiscriminately on wood substrate.

Risk of establishment

The temperate climate of the UK, more specifically the cool summers, is thought to be a slight barrier to establishment. However, climate change will likely increase the number of hot days in summer months, which might increase population growth. *Ailanthus altissima*, commonly called tree of heaven, is the preferred host and is found throughout the south of the UK. Therefore, if *L. delicatula* enters into the south of the UK, then establishment outdoors has been judged **unlikely** with **low confidence** and under protection it is **very unlikely** with **medium confidence.**

Economic, environmental and social impact

Based on uncertainty about climatically suitable conditions for *L. delicatula* to reach maturity and lay eggs, as well as potential quarantine and management practices that industries may have to comply to, the potential economic impact is rated **small** with **low confidence**. The environmental impacts are **very small** with **low confidence** and social impacts are **medium** with **medium confidence**.

Endangered area

The UK is on the edge of climatic suitability, but there are suitable hosts for *L. delicatula* present throughout the southern more temperate areas of the UK.

Risk management options

There are many different options, including exclusion, eradication, containment, and management with chemicals and biocontrol.

Key uncertainties and topics that would benefit from further investigation

- The lower temperature threshold for reproduction and egg development
- Ability to reach high population levels in UK climate
- Is the number of *A. altissima* (tree of heaven) in south of England enough to support high population numbers
- Biocontrol options

Images of the pest

Adult Lycorma delicatula showing underwing colouring 	 *Sooty mould growing on the honeydew produced by adult Lycorma delicatula.*
© [Rebekah D. Wallace, University of Georgia, Bugwood.org]()	© [Richard Gardner, Bugwood.org]()
 *Adults and late instar nymphs of Lycorma delicatula on Ailanthus altissima*	 *Early instar nymphs of Lycorma delicatula on basil (for size)*
© [Richard Gardner, Bugwood.org]()	© [Lawrence Barringer, Pennsylvania Department of Agriculture, 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 EPPO) and the PRA scheme (UK or EPPO) to be used.

No	X

Yes		PRA area: UK or EPPO		PRA scheme: UK or EPPO	

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

There is a high likelihood of *L. delicatula* entering the UK as a hitchhiker into the United Kingdom.

However, there is considerable uncertainty in its ability to establish and build up high population numbers as currently seen in the USA and Korean peninsula due to the cooler summer climate in the UK. There is also uncertainty in how climate change will impact this. There are also issues with the ability for legislative measures to be effective due to *L. delicatula's* ability to hitchhike on any commodity. If *L. delicatula* invades EU member states, it will be very difficult to regulate effectively due to the high volume of trade between the UK and the EU.

Yes Statutory action	X	No Statutory action	

Stage 1: Initiation

1. What is the name of the pest?

Lycorma delicatula (White), is an insect in the order Hemiptera, family Fulgoridae also known by the common name, spotted lanternfly. This is sometimes written as SLF (**S**potted **L**antern**f**ly). Less frequently used names include spot clothing wax cicada, Chinese blistering cicada and flower cicada.

2. What initiated this rapid PRA?

Lycorma delicatula spread from Asia to USA, where it was first reported in 2014. An EPPO PRA was published in 2016, but this was prior to the largescale spread of *L. delicatula* in the north-eastern states. A UK PRA was therefore requested to provide an update on the situation and help assess whether statutory action against future interceptions and outbreaks is justified as the current climate of the UK could possibly support the life cycle of *L. delicatula.* Future climatic conditions may be even more hospitable.

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 the plant health legislation, and in the lists of EPPO[1]?

The legislation for Great Britain is The Plant Health (Phytosanitary Conditions) (Amendment) (EU Exit) Regulations 2020[2] (as amended) (GB PCR). The legislation which applies to Northern Ireland is the EU legislation: 2019/2072 (as amended).

Lycorma delicatula is currently a Union Quarantine pest in the European Union (added to Annex II part A of Commission Implementing Regulation (EU) 2019/2072[3] in April 2022) and was added to the GB regulations the Phytosanitary Conditions (Amendment) Regulations 2022 (2022 No. 114[4]) as a Provisional Quarantine pest as an amendment in February 2022 and came into force August 2022.

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

Lycorma delicatula is a pest native to Asia and is recorded from many Chinese provinces, also from Japan, Laos, Republic of Korea, Taiwan and Vietnam (Figure 1, Table 1). Based on its known distribution, it would be reasonable to assume that *L. delicatula* is also present in PDR of Korea.

Lycorma delicatula is spreading rapidly in north-eastern USA having been introduced from its native China. The first finding of *L. delicatula* was in Pennsylvania in September 2014, and the collector noted that "this unusual pest was found in large numbers on [tree of heaven] *Ailanthus altissima*". Over 100 adult individuals from the original site were collected and identified (Barringer *et al.* 2015). Table 1 lists the states in which *L. delicatula* has been recorded (up to December 2022). The states are listed alphabetically in Table 1 but it is worth noting the years *L. delicatula* was first found, as this shows the

[1] https://www.eppo.int/ACTIVITIES/quarantine_activities
[2] https://www.legislation.gov.uk/uksi/2020/1527/contents/made

[3] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:02019R2072-20220714&qid=1672301833748&from=EN

[4] https://www.legislation.gov.uk/uksi/2022/114/pdfs/uksi_20220114_en.pdf

rapid spread. Where it is listed as 'absent, intercepted only', this is often from hitchhiking on various commodities from infested states.

For current distribution outside of the USA check EPPO global database for the most recent distribution. For the most up to date distribution in the USA, check this [University of Cornell website] for recent findings (currently updated regularly).

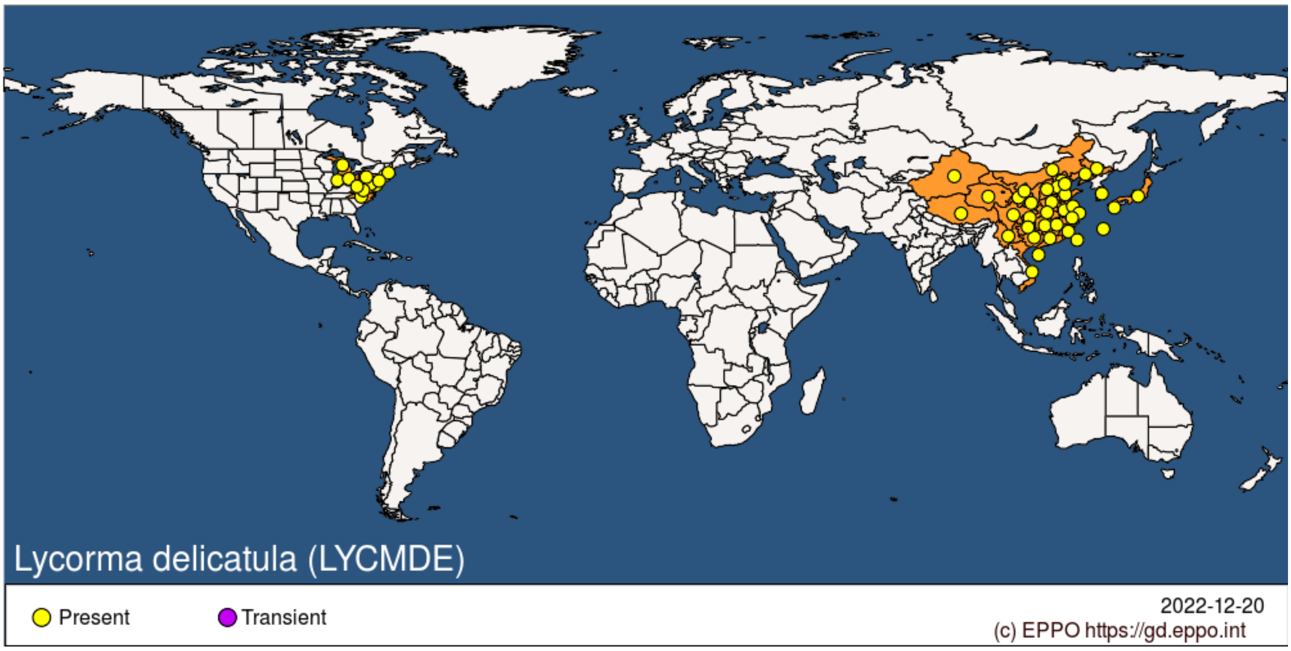

Figure 1 Global distribution of *Lycorma delicatula*

Table 1: Distribution of *Lycorma delicatula*	
North America:	USA Present, restricted distribution: Connecticut (EPPO Reporting Service: 2020/249), Delaware (EPPO Reporting Service: 2017/211), Indiana (EPPO Reporting Service:2021/166), Maryland (EPPO Reporting Service: 2019/223), Massachusetts (EPPO Reporting Service: 2020/249), Michigan (Michigan.gov 2022), New Jersey (EPPO Reporting Service: 2018/173), New York (EPPO Reporting Service: 2018/053), North Carolina EPPO Reporting Service:2022/143), Ohio (EPPO Reporting Service: 2020/249), Pennsylvania (Barringer *et al.* 2015), Virginia (EPPO Reporting Service: 2018/052), West Virginia (Agriculture 2022) Absent, intercepted only- Kansas (EPPO Reporting Service: 2021/190), Maine (EPPO Reporting Service: 2020/249), Oregon (EPPO Reporting Service: 2020/249), Rhode Island (EPPO Reporting Service: 2021/190),

	Absent eradicated- Vermont (EPPO Reporting Service: 2021/190)
Central America:	Absent
South America:	Absent
Europe:	Absent- interceptions of dead hitchhikers
Africa:	Absent
Asia:	Present: China (Xin *et al.* 2021), Japan (Kim *et al.* 2013), Laos, Republic of Korea (Han *et al.* 2008), Taiwan (Li *et al.* 1997), Vietnam (Pham 2009)
Oceania:	Absent

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

Lycorma delicatula is not known to be established or transient in the UK although there has been at least one unofficial interception in the UK of a dead specimen by a member of the public in some packing material. The packing material was provided by a UK seller but likely originated from China. There was also concern about a freight ship from the USA in October 2021 where there were observations by customs agents of a high number of *L. delicatula* aboard when it left its last port of call in the USA. They informed UK authorities, the ship was cleaned while at sea and inspected once docked in the UK. No specimens were found (S. Bishop, DEFRA,1st Oct 2021, pers. comm).

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?

The preferred host for *L. delicatula* is *A. altissima*, a tree native to China, and regarded as an invasive species outside its native range including Europe with the exception of the Nordic countries: Denmark, Finland, Iceland, Norway and Sweden (Sladonja *et al.* 2015). *Ailanthus altissima* is prevalent in southern parts of the UK, especially the London area as seen in Figure 2. Seeds were thought to have been first brought to the UK in 1751 under the assumption that they were of a lacquer or varnish tree from Nanking, China. After planting in the UK, they were then found to not be from the lacquer or varnish tree but instead from the *A. altissima*, distinguished by its suckers, smell and leaf shape (Swingle 1916). *A. altissima* is called tree of heaven for its quick growth upwards and also has common names that reference its unique smell, including stinking quassia and stinking sumac (EPPO 2022a). The smell is said to be a cross between gym socks and rancid peanut butter (Portland.gov 2021).

Lycorma delicatula has a clear preference for *A. altissima* and was once considered as a potential biological control agent for the rapid spread of *A. altissima* in the USA, but it was discarded due to the large host range of *L. delicatula* (Ding *et al. 2006).* The current full list of hosts as found on the EPPO Global Database is listed in Appendix 1. This list is correct at the time of writing but may change quickly, so it is advised that the EPPO Global Database is checked for an up-to-date list. *Lycorma delicatula* is least host selective during earlier instars and when egg laying, with fewer preferred host plants for feeding adults (Kim *et al.* 2011). *Lycorma delicatula* still has many hosts on which it may be found feeding on though, with 70 listed by Urban *et al.* (2021) and EPPO GD listing a much higher total of 159 (EPPO 2022). This discrepancy in host numbers shows that this list is likely not complete at present and that *L. delicatula* can feed and survive on many host plants.

There has been a small American research project that looked at whether the carbohydrate ratio of plant sap could be used to predict the tree feeding preference of *L. delicatula.* This study found that plants that attract more spotted lanternfly have higher sucrose and lower glucose and fructose concentrations, and this could be used to predict expansion into new host ranges (Horack 2021).

Studies show that both fecundity and number of *L. delicatula* that survive to adulthood is impacted if its preferred host of *A. altissima* is not available (Nixon *et al.* 2022, Uyi *et al.* 2021). *Lycorma delicatula* economically threatens many sectors, either by its feeding behaviour and resulting honeydew/sooty mould production or it's potential to easily hitchhike on material. This could have an impact on imports and exports through quarantine measures on movement of plant products. *Ailanthus altissima* is not considered under threat in the United Kingdom and is more often seen as a nuisance tree due to prolific spread. It is now listed as an invasive plant and should not be sold by retailers.

In the USA, the United States Department of Agriculture (USDA) has nominated grapes, apples, cherries, and several other fruit and timber tree species as at risk (USDA-APHIS 2018) from *L. delicatula*. The Canadian Food Inspection Agency has identified *L. delicatula* as a threat to Canadian industries of grape, tree fruit and timber (Canadian Food Inspection Agency 2021). It seems likely that the same industries will be under threat in the southern parts of the UK as well, whether from quarantine measures on movement of plant products or feeding damage which would depend on *L. delicatula* population levels.

8. Summary of pest biology and/or lifecycle

Lycorma delicatula is a generally univoltine (one life cycle per year), phloem feeding pest and overwinters in egg masses covered with a waxy camouflage/protective coating (Wakie *et al.* 2020). The egg masses can be particularly difficult to see as they can be laid on almost any object, including concrete, fence posts, walls and in bark crevices (Dara *et al.* 2015). In North America, the females lay eggs in the autumn (Kreitman *et al.* 2021) and then cover the eggs with a coating, initially described as foamy (Wakie *et al.* 2020) but turning into a brown-grey waxy substance after a couple of hours (Nakashita *et al.* 2022). The eggs hatch in the spring and there are four juvenile instars with different colourations, moving from predominantly black and white in the first three stages to predominantly red, black and white in the fourth (Kreitman *et al.* 2021). The adults are mainly found from late summer to autumn (Canadian Food Inspection Agency 2021, Cook *et al.* 2021, Dara *et al.* 2015).

The nymphs participate in a cyclical ascending-falling behaviour on host plants; they fall to the ground due to physical stimuli such as wind, and then climb back up. The ascending-falling cycle time duration becomes longer as nymphs develop due in part to the development of larger arolium which are adhesive pads on the pretarsus (Lee *et al.* 2019). *Lycorma delicatula* are attracted to tall buildings and objects and exhibit this climbing behaviour in cities where it can become a nuisance (Melisurgo 2022). This behaviour will be discussed further in the PRA when looking at management options.

The first three instars have black and white colouring and this changes to red, white and black in the last nymphal instar which may be due to the increase in quassinoids, as adults also show red colouring. There have been some studies that focused on the sequestration of defensive chemicals in adults from host plants ((Kim *et al.* 2011, Song *et al.* 2018) and this change in colouring could be attributed to the host preference change to *A. altissima* which is chemically defended by quassinoids. Later instars of *L. delicatula* had higher levels of quassinoids and were shown to be less palatable to birds (Song *et al.* 2018). The sequestration of defensive chemicals may affect the ability of natural predators to control *L. delicatula* in new environments. Nymphs develop earlier into adults if they feed on a mix of hosts that include tree of heaven rather than tree of heaven exclusively or feeding on a mix of trees with the absence of tree of heaven, though this early development does not lead to greater adult survivorship (Nixon *et al.* 2022). It is unknown if there are less quassinoids in adults that do not feed on *A. altissima* and simply benefit from mimicking the warning colouration of *A. altissima* fed nymphs and adults.

The number of egg masses deposited on trees varies between countries due to known differences. An average of 3.4 egg masses were laid on trees in South Korea over a four year study (Lee *et al.* 2014). This number is lower than in the USA where 197 egg masses were observed on one tree in Pennsylvania (Dara *et al.* 2015). Another study in Pennsylvania found an average of 20 egg masses on a small sample size (5) of each *A. altissima* and Black walnut (*Juglans nigra* L.) (Liu & Hartlieb 2020).

Lycorma delicatula adults are one of the first cases of permanent endothermy (ability to maintain elevated body temperature by generating heat) found in semisessile (mainly non-moving) animals and this endothermy ends a few weeks before egg laying for unknown reasons (Dinets 2022). This ability to generate their own heat could improve their ability to survive in cooler temperatures as well as contribute to their spread in areas assumed to be uninhabitable due to low temperatures. This highly unusual ability has only recently been discovered and the extent to which it will affect other aspects of *L. delicatula* behaviour has not yet been explored.

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?

Hitchhiking

Hitchhiking is the most likely pathway as that is thought to be how *L. delicatula* has spread from China originally, first to South Korea in 2004, Japan at an unknown time ((Hong *et al.* 2012) and then to the USA in 2014 (Barringer *et al.* 2015). The eggs can be laid on any material, and thus the egg stage can be present on any inert object being moved. The nymphs will only survive transport if they are able to feed on a suitable host during transit while adults are quite large and drop or fly when startled so they are likely to be discovered. Eggs therefore present the greatest risk for entry. The temperature during transportation is not necessarily a limiting factor. It has been shown that eggs suffer 100% mortality when they are exposed for three months at a mean daily temperature of -3.44°C, as well as at 30 days at -12.72°C (Lee *et al.* 2011) but the exact temperatures for survival have not been studied.

This pathway is difficult to mitigate for as any cargo coming from an area which has *L. delicatula* has the potential to carry eggs if at any part of the production cycle, pallets which carry the goods or the goods themselves are left outside during the autumn laying season.

Lycorma delicatula was likely first introduced into the USA as egg masses on a shipment of stone (Kingan *et al.* 2019) though there is no hard evidence for this conclusion. Hitchhiking routes are very difficult to mitigate and as the egg masses are very inconspicuous, it seems **very likely** (**high confidence**) that this route will be the route of entry into the UK. *Lycorma delicatula* is a provisional quarantine pest in Great Britain, and a European Union quarantine pest in EU legislation and thus action would be taken on this insect if found in any part of the UK.

Link to the legislation.

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

Plants for planting

The other pathway that may allow entry of *L. delicatula* to the UK is plants for planting. *Lycorma delicatula* has such a wide range of hosts (Appendix 1), that there are many host plants that it could possibly be associated with. The egg stage is the most likely life stage to travel on plants for planting as the eggs are laid indiscriminately. The nymphs and adults could come in on host plants but if inspected, are more likely to be detected. Plants for planting coming from Asian countries and North America generally have more restrictive legislation for large trees than for smaller ones. However, if *L. delicatula* establishes undetected populations in the EU, it is very likely that plants for planting will become a major pathway into the UK due to the high volumes of trade. Due to the nature of the commodities, accurate import data is difficult to obtain.

The pathway of plants for planting is **moderately likely** with **low confidence** as though it is possible, legislation prohibits many of the trees coming in from highly infested areas.

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

Wood

There is a trade of wood from the USA (5.6 billion kg in 2019, 5.8 billion kg in 2020, and 5.6 billion kg 2021-HMRC trade data), usually for fuel (98% of total wood imported from the USA in 2019, 2020, 2021- HMRC trade data) and this could be a pathway of entry. This data is not always trusted as reliable and so must be treated with caution. There are currently import requirements in place for wood of hosts from the USA in relation to other pests which are likely to partially mitigate the risk associated with these commodities. Similar measures apply to Northern Ireland.

There is also a large trade with China for wood products including ~500 million kg in 2019 and 2020 and ~600 million kg in 2021 (HMRC trade data) but these are mainly treated wood products such as plywood, veneer or furniture products (58% in 2019, 59% in 2020, and 59% in 2021 of total wood products -HMRC trade data). The amount of fuel wood imported was very small equating to 595,470 kg in 2019, 165,685 kg in 2020, and 343,507 kg in 2021. *Lycorma delicatula* may lay eggs on treated wood products, but it is less likely that these goods would be left outside for long periods of time for egg laying to occur.

There was a 2018 study that looked at the chipping size that is needed to prevent *L. delicatula* from surviving the chipping process and this study found that there was no emergence of nymphs from the products of high speed chipping, possibly due to the combination of physical chipping forces and ensuing heat of barrels due to wood decay (Cooperband *et al.* 2018). The dimension of chips followed quarantine safe mitigation methods for other pests, namely Asian longhorn beetle (*Anoplophora glabripennis*) (Motschulsky), and emerald ash borer (*Agrilus planipennis*) (Fairmaire) (Cooperband *et al.* 2018). Further studies to determine if egg masses, nymphs or adults could survive heat treatment required to enter the UK could be useful to determine if this pathway is completely closed. However, at this stage, it does not appear to be a pathway.

The specific issue, as detailed above, is that unless all wood products (treated, debarked, chipped or not, etc) are kept in a protected area, there is a high chance that eggs will be laid after treatment as the adults do not prefer certain hosts over others. Wood is often stored outdoors and frequently in areas with trees around in which *L. delicatula* could fly from. There is the greatest risk from eggs laid on wood products after production and treatment and hatching at the final destination. If the eggs hatched and nymphs emerged while in transit, it seems unlikely they would survive as they could not feed on cut or chipped wood. Wood packaging material or dunnage could also be a risk as these are often left outside the final destination for long periods of time. Eggs could easily be laid on them and not noticed by handlers as the egg masses are so well camouflaged.

The pathway for wood is thought to be **unlikely** with **low confidence** as it is possible and might become a problem in the future but *L. delicatula* is more likely to move by hitchhiking on wood products rather than on the wood itself.

Pathway Wood	Very unlikely	☐	Unlikely	x	Moderately likely	☐	Likely	☐	Very likely	☐
Confidence	High Confidence	☐	Medium Confidence	☐	Low Confidence	x				

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

No vector is needed to spread *L. delicatula.*

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

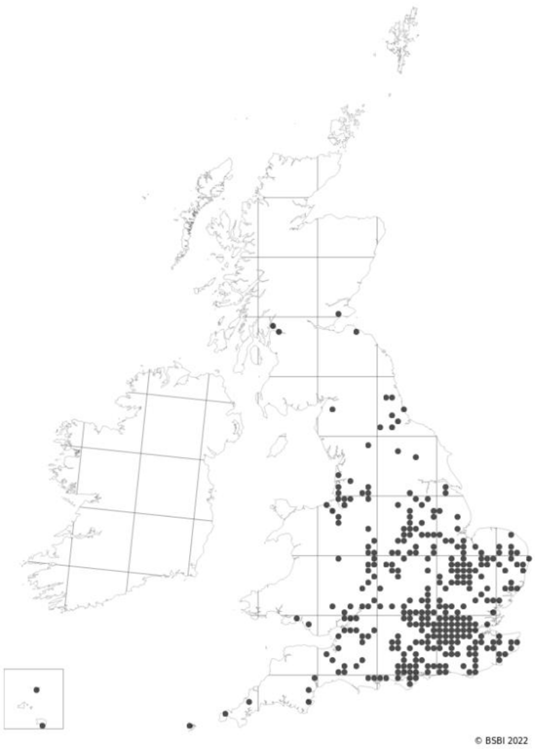

Figure 2. Presence of *Ailanthus altissima* in United Kingdom (BSBI 2022) This is likely under reported due to the rapid spread of the tree in other similar habitats. London and Cambridge can be seen to have high levels.

Outdoors

The limiting factors for *L. delicatula* distribution are so far uncertain. However, *L. delicatula* has a strong host preference throughout most stages of its life for *A. altissima*, especially during the adult stages. *Ailanthus altissima* is known to be present and prevalent in large parts of the UK but especially in and around London and this may be the most suitable environment. However, as Figure 2 shows, the distribution of *A. altissima* across the UK is scattered and thus the known distribution may more accurately reflect where recorders live as opposed to where the greatest number of *A. altissima* are.

Models- Assumptions, limitations, and summaries of published work

There is much debate on the suitability of the UK for *L. delicatula* development and reproduction. A few studies will be mentioned below and each one uses different parameters to create the forecasting model. MaxEnt and CLIMEX are models of approximations, working from the assumption that the pest distribution is limited by climatic factors. Where the pest is absent from an area adjacent to its current distribution, these models assume that climatic factors are preventing the expansion of the pest into those neighbouring areas. It is worth remembering that the populations of *L. delicatula* in new invasive ranges - particularly Japan, South Korea, and USA, may not have reached their maximum extent and thus all forecasting must be <u>especially</u> precautionary as the underlying assumptions of climate limiting the species range may not apply. The confidence scores reflect this.

There are a few points of uncertainty around modelling for *L. delicatula* to mention:

- Older climate data sets. Recent climate data is difficult to obtain, and so many models have used older climate data sets e.g. climate data from 1970-2000 which might not reflect current climatic conditions and may not lead to accurate models.

- Limiting temperatures for egg and nymph/adult development were markedly different. Egg mortality is much less sensitive to both cold and high temperatures and so nymph and adult mortality were used as the limiting factors. Various temperatures have been used in the models below. Optimal development in the Maino study was set at between 30-33°C with mortality increasing sharply after 30°C (Maino *et al.* 2022) - “live fast die young” seems an apt description. Post embryonically, cold limiting temperatures below 8°C (Jung *et al.* 2017) or 10°C (Maino *et al.* 2022) and heat limiting of 33°C (Jung *et al.* 2017) and 35°C (Maino *et al.* 2022) were used.
- Underreported distribution data from the *L. delicatula’s* native range. This is likely not an “interesting” insect in its native range in China as it is not invasive, and so there may be underreporting.
- Underreported data from marginal areas in the native range. Due to the way climate models typically work, records from the margins of suitable areas are some of the most crucial but also hardest to obtain. If an insect is very scarce and causing no damage, it is far less likely to be recorded.
- Distribution data in its new introduced area. As this pest is still spreading, any data points used in areas where it has not spread to its full extent (e.g. South Korean data points do not likely show the full extent of the spread in the country and do not include North Korea at all even though the pest is likely to be found there) which will likely skew models.
- It was recently shown that adult *L. delicatula* are endothermic for the early portion of their adult life and this may explain why they could be able to survive in so many climatic conditions (Dinets 2022, Liu *et al.* 2021). This has not been taken into account by any models mentioned in this paper as this is a relatively recent development.

The following models for *L. delicatula* distribution are looked at in greater detail.

- A study by Wakie et al. (2020) predicted that there were highly suitable areas in parts of Europe and areas with medium and low suitability in the UK when using the ecological niche model MaxEnt. The model predicted low and medium suitable areas in parts of Asia where *L. delicatula* has already been found and this could be due to *L. delicatula* endothermy. This study used a climate data set from 1970-2000, and this is likely out of date for current climatic conditions.
- Another study in 2017 using CLIMEX modelling proposed that low densities of *L. delicatula* could survive in the UK, France, Belgium, Switzerland, Spain and Italy. They also predicted that there may be high population densities under current climatic conditions found in south America, south eastern USA, central and eastern parts of Africa, and areas of east Asia if *L. delicatula* is introduced (Jung *et al.* 2017). This study used climate data from 1981-2010.
- A third forecasting study done by Maino *et al.* (2022) looked at 2000 instances of *L. delicatula* occurrences in its native and exotic range and used these to create a prediction model for *L. delicatula* life stages throughout the year. The model most closely followed environmental temperatures for most suitable environments. The

model predicted that in Europe, the reproduction potential of *L. delicatula* was only in countries with a Mediterranean climate such as Portugal, Spain and Italy. In countries such as the UK and Germany, development to the adult stage was frequently unable to be completed due to cooler temperatures (Maino *et al.* 2022).

- The map below is preliminary unpublished modelling work made using MaxEnt (Lisboa 2022) and shows the possible European areas suitable for establishment under current climate (Figure 3). The UK is suggested to be unsuitable for establishment, with a potential distribution around 0.2 which means it is unsuitable for establishment under current climatic conditions. However, the modelling of predicted suitability for Europe shows that nearby countries in Europe range from moderately suitable to very suitable. This raises the possibility there could be yearly movement of adults or egg masses from the continent into the UK. This model only used data from Asian occurrences to predict spread, and it should be remembered that Asian occurrences from some countries may not have spread to maximum extent.

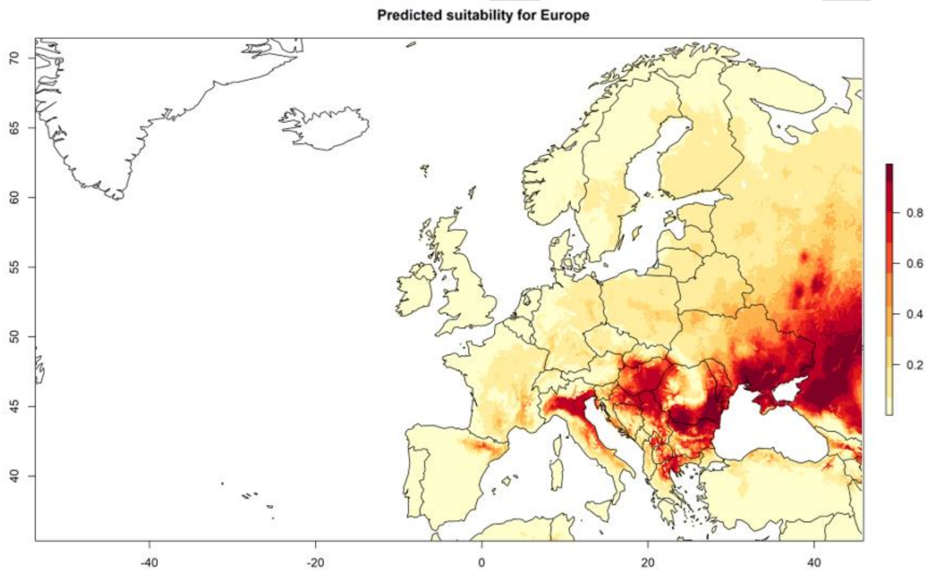

Figure 3 Unpublished data by Lisboa 2022 showing modelling using MaxEnt of European potential distribution of *L. delicatula* under current climatic conditions.

Establishment is not easy to predict even once *L. delicatula* is in the country. In Japan, Nakashita *et al.* (2022) found that *L. delicatula* had limited spread and damage, despite being first reported in the Hokuriku region in 2009. There are plenty of *A. altissima* trees found throughout Japan, so the authors suggest there should be further research to ascertain if biotic or abiotic factors are at play, for example predators, or native parasitoids. The authors' main theory is that this slow expansion in Japan could be due to heavy precipitation in the area where *L. delicatula* was first found, which might decrease egg viability by washing away the protective waxy egg mass coating.

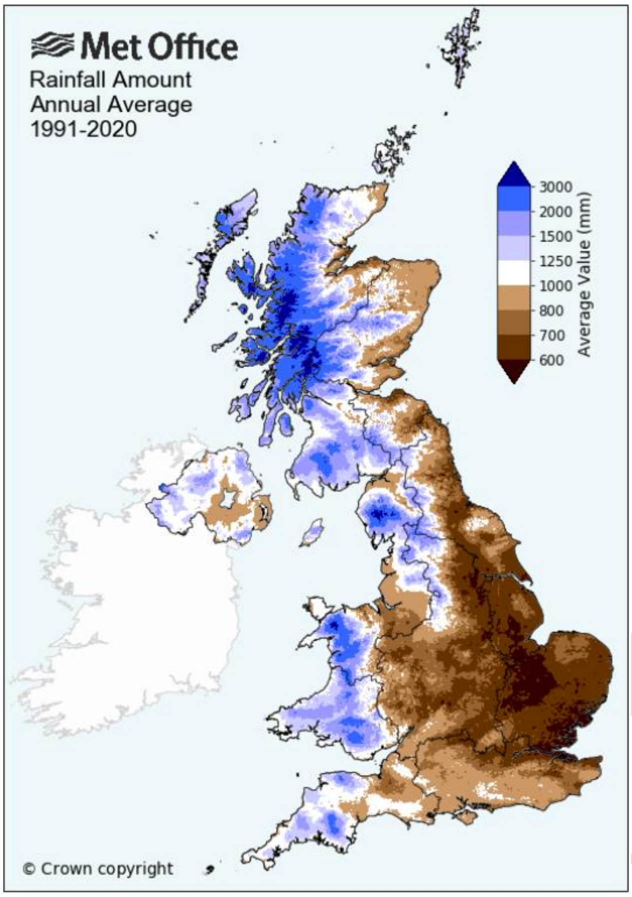

Figure 4. Annual average rainfall amount 1991-2020 in the United Kingdom

The Japanese area (Kanazawa) of slow population expansion has a mean annual precipitation of 2402 mm/year. Philadelphia has a mean annual precipitation of 1060 mm, and the UK average is 1442 mm/year. In the south of the UK, there is an average of 883.7 mm/year over the last decade (Met Office average of past decade from southeast, southwest, and central locations accessed 30/05/2022). There could be tentative links to high levels of precipitation and slower population growth.

A Japanese study found nine different *L. delicatula* lineages and that there were two differing lineages in Japan; one that matched the type found in South Korea, USA and central China and one that matched the type found in northwestern China (Nakashita *et al.* 2022). The *L. delicatula* populations that matched the lineage found in South Korea, USA and central China, were found in the southerly regions of Japan and in the original findings, in the slightly more northerly region in 2009. The northerly populations in Japan were slow to expand and have recently been found to have been largely replaced by those of the lineage found in northwest China (Nakashita *et al.* 2022). The lineage of *L. delicatula* may affect its ability to spread in different environments, whether it is more affected by precipitation, predators, or parasitoids.

After reviewing all models and studies above, there is still much uncertainty around spread and establishment. As hitchhiking is the most probable form of transport, *L. delicatula* would likely come into either a large city which has an urban heat island effect or into a port in the south of England (e.g. Southampton port, Felixstowe etc). Most of northern UK is on the outside of *L. delicatula*'s predicted range of establishment. Southern UK is more likely to be suitable though this is still debatable. Another factor to consider is that mainland Europe is a more likely amenable habitat and so populations of *L. delicatula* may arrive yearly by hitchhiking from breeding populations if *L. delicatula* establishes in continental Europe.

The build-up of undetected populations is also of concern as the first finding of *L. delicatula* in 2014 in Pennsylvania was of a population that remained undetected for 2-3 years and had spread to five adjacent townships (which are large usually rural land areas under one local government) within the area before being discovered at high levels

(Barringer *et al.* 2015). The slow build-up of populations should encourage survey work to be completed in areas thought to be a high likelihood of introduction (ports and transport links). Ongoing work by European project HOPPI is seeking to identify such locations where populations may be likely to begin and build.

Ailanthus altissima is known to be widespread throughout the European continent (EPPO, 2022) and if populations of *L. delicatula* became established in Europe, it seems likely that even if eradication of small populations in the UK were possible, there would be many reintroductions of every life stage from trade from Europe throughout the year in the form of either egg masses, nymphs or adults. These repeated introductions can be seen in the USA as *L. delicatula* spreads from state to state and there is difficulty in creating an effective quarantine zone (Cook *et al.* 2021, Dechaine *et al.* 2021, Keller *et al.* 2020).

The UK may become a more amenable environment in the coming years due to climate change. Coupled with the fact that this pest is still expanding its range and so models may underestimate the suitability of the UK, establishment may be possible.

Outdoors	Very unlikely	☐	Unlikely	x	Moderately likely	☐	Likely	☐	Very likely	☐
Confidence	High Confidence	☐	Medium Confidence	☐	Low Confidence	x				

Under Protection

There are many hosts at risk in the UK that are grown under protection, as *L. delicatula* is such a polyphagous feeder with a preference for *A. altissima*. There are a few known "hot hosts" such as cucumber and rose grown under protection that are informally said to be favoured in the USA (SLF Summit 2022). There have been no reports of extensive damage to crops grown under protection and as it is a controlled environment, it does not seem likely that *L. delicatula* would be able to build up large populations without being detected and managed. However, there is a likelihood of repeated reintroductions of *Lycorma delicatula* into crops grown under protection from populations in the wider environment. This would be difficult to control, especially in non-sealed production areas. It appears that *L. delicatula* could come in crops under protection but is not likely to establish in controlled environments.

Under Protection	Very unlikely	x	Unlikely	☐	Moderately likely	☐	Likely	☐	Very likely	☐
Confidence	High Confidence	☐	Medium Confidence	x	Low Confidence	☐				

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

There are a few factors that would influence the speed at which *L. delicatula* could spread throughout the PRA region. *Lycorma delicatula* are not strong fliers; their main method of spread is by their easily missed egg masses, often moved by human transport (Nakashita *et al.* 2022) therefore hitchhiking is the main concern for rapid dissemination throughout the UK.

The area where the pest was first introduced plays a large factor in whether it would survive, thrive and continue spreading. Its preferred host tree, *A. altissima* is prevalent in the south of England especially in the London region as seen in Figure 2. It is very difficult to estimate the prevalence of *A. altissima* in the UK as many of the trees can be found in untended urban areas as well as along transport corridors (trains, scrubland beside highways) and the latter could contribute to rapid spread of *L. delicatula*, should it be introduced. A 2021 paper published in Nature (Uyi *et al.* 2021) found a seven-fold increase in eggs laid if *L. delicatula* had access to *A. altissima* compared to areas with no *A. altissima.*

There is also worry about woodlands acting as reservoirs for populations. A study by Keller et al. (2020) found that nymph dispersal was highly significantly directional, but it is unknown why that was, as in the study, no *A. altissima* were growing in the vicinity. They found that the *L. delicatula* nymphs dispersed 10s of meters in a day through contiguous, deciduous forests and this distance continued until the nymphs found a suitable host tree (Keller *et al.* 2020). This suitable host is not necessarily *A. altissima,* as nymphs were observed on understory plants and other trees such as *Quercus alba, Carpinus caroliniana,* and *Acer saccharum.* It is known that nymphs, especially early instars, have a widely polyphagous diet (Song *et al.* 2018). There is much contradictory information about but there are fears that contiguous deciduous forests may act as reservoirs for *L. delicatula* populations in areas with susceptible crops or nurseries.

Natural spread is rated as **slowly** with **low confidence** as the climate of the UK will be a factor in how many adult mature to egg laying stage. Geographic spread with trade, will be **quick** and this is said with **high confidence** as there is ample evidence for this in every country that *L. delicatula* has been introduced into. Whether the UK will be able to sustain a population once *L. delicatula* are in the country is less certain and this may serve to limit the spread rates.

Natural Spread	Very slowly	☐	Slowly	x	Moderate pace	☐	Quickly	☐	Very quickly	☐
Confidence	High Confidence	☐	Medium Confidence	☐	Low Confidence	x				
With trade	Very slowly	☐	Slowly	☐	Moderate pace	☐	Quickly	x	Very quickly	☐

Confidence	High Confidence	x	Medium Confidence		Low Confidence	

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

Economic and Environmental Impact

Most of the recent literature looks at either South Korea or USA. In South Korea, the main industry that has been affected is the grapevine industry (Namgung *et al.* 2020). The main industries at risk in the USA are the grapevine industry, stone and soft fruit trees, and timber (USDA-APHIS 2018). *Lycorma delicatula* does not kill most of its hosts, instead causing damage with sucking wounds and sooty mould, but feeding damage does kill small tree saplings, some tree of heaven and grapevines (Leach 2021). There are also many ornamental hosts of *L. delicatula* see full list in Appendix 1.

The main host that is necessary for rapid population growth is *A. altissima,* so it is necessary to remember that though earlier nymphs are very polyphagous, older nymphs and adults are much less so. The main cost to ornamental growers and traders will primarily be in management practices to comply with quarantine and eradication efforts (Uyi *et al.* 2021). There is currently very little information on host damage of most plants that *L. delicatula* feed on, with most information available on *Vitis.* At a joint hearing of the Pennsylvania Senate and House Rural Affairs Committee, there were reports of heavily infested vines in a vineyard not surviving winter temperatures and the ones that did survive, not setting with fruit the following year (Urban 2020). Research has suggested that this late season phloem feeding on vineyards by adult *Lycorma delicatula* induces carbon limitation with potential effects in the following year in cases of severe belowground carbon depletion (Harner *et al.* 2022). This is similar to the *Vitis* damage seen in South Korea (Kim *et al.* 2013, Lee *et al.* 2019, Urban 2020). There is worry that *L. delicatula* populations that are currently in the American northeast, could possibly hitchhike and then spread across to the West Coast, which has many susceptible hosts including large wine growing regions, and apple orchards and this could devastate those industries (Huron *et al.* 2022). It is unknown if vineyards in areas without *A. altissima* have the same feeding damage.

In the USA, there is concern that though *L. delicatula* has not outright killed its host trees it does weaken them and this could make the trees more susceptible to other pathogens or pests (Urban 2020). There are weeping wounds left by feeding, so the trees could be more susceptible to opportunistic feeding and pathogen invasion (Lee *et al.* 2019).

Social impact

In the USA, there are social impacts due to the mass build-up of populations in urban areas especially around tall buildings. There can be large amounts of honeydew exuded and this can cause sooty mould to build up as well as attracting nuisance pests to the sticky sweet excretion (PDA , Spears & Mull 2019).

In the USA the public seem to be moving towards accepting that SLF has naturalised into the American fauna (Gruskin 2022, Nir 2022) indicating minimal social impact in some areas. In most newspapers however, *L. delicatula* are regularly featured with ways to kill them and why you should (Cullen 2022, Harris 2022, Jordan 2022).

There have been reports of beekeepers being affected by the prevalence of *Lycorma delicatula* in the area and impacts on late season foraging by honeybees on the honeydew *L. delicatula* produce. This affects the flavour profile of the honey and produces a distinctive taste which may increase or decrease the value of the honey (Underwood 2022).

Based on impacts in the USA and South Korea, the overall impacts are rated as **medium** with **medium confidence**. This is because *L. delicatula* is still spreading especially in the USA and has not yet reached the limits of its range and so though it is known to cause medium-large impacts in its current range, this could increase (or decrease) as it reaches new areas, specifically areas with high proportions of vineyards.

Impacts	Very small	☐	Small	☐	Medium	X	Large	☐	Very large	☐
Confidence	High Confidence	☐	Medium Confidence	x	Low Confidence	☐				

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

Economic Impact

The main industries at risk in the UK are soft fruit trees and *Vitis* with some concern for other industries as management and quarantine measures may be needed to prevent spread.

Figures 5 and 6 show the distribution of *Malus* and *Prunus* in the UK. The apple industry in the UK was worth around £239.3 million in 2020, and covered 8,845 hectares, with a combination of culinary apples and dessert apples. Total orchard fruit value (apples, pears and plums) in the UK was worth £340 million in 2020 and covered 23,090 hectares (DEFRA 2021). All orchard fruit listed is a host for *L. delicatula* and could be at risk if there were populations of *L. delicatula* in the UK.

There is a small but growing vineyard industry in the UK which could be at risk as much of the damage in South Korea is to grapes. WineGB released a press release detailing that approximately 3,800ha were planted as vineyards (as of 2021) with the hectarage doubling from only 1,438ha in 2012 (WINEGB 2021). This is the industry at greatest risk of economic impact due to *L. delicatula.* South Korea is in a different Köppen- Geiger climate category to the UK so effects may be dissimilar. However, when the effects have been seen in South Korea, it has been due to accumulated sooty mould stopping photosynthesis from occurring in the leaves (Urban 2020).

The economic impact on vineyards is difficult to quantify. Current estimates of economic damage are $50 million/year in Pennsylvania, with much of the costs being linked to fruit growers, especially grape growers (Duke 2020). There are reports of 90% vine loss in a vineyard the year after an infestation (SLF Conference 2021). However, this is not the case for every infested vineyard. Penn State Extension also reports that damage by *L. delicatula* feeding may only present the year after colder winter conditions where vines experience a high likelihood of freezing damage (Biddinger 2021). There are many factors to consider in the cost to UK vineyards. The cooler climate would likely lead to lower *L. delicatula* population levels but could lead to more vine damage.

The main cost to ornamental growers and traders will primarily be in management practices to comply with quarantine and eradication efforts (Uyi *et al.* 2021).There could also be economic issues due to quarantine and preventative measures imposed on other industries to prevent spread to nearby trading partners (i.e. the EU) if *L. delicatula* populations were found in the UK before the EU. This knock on impact was similarly seen in 2018 in the USA when eggs were found on Christmas trees and Christmas tree growers were alarmed at potential loss of sales (Urban 2020). The soft wood timber industry could also see economic impacts though this would mainly be due to quarantine measures as no effects on the quality of timber are currently being seen in the USA.

Therefore, the economic impact for the vine industry is set at **small** with **low confidence** and the economic impact for all other industries is set at the same, **small.** This is due to the effects on orchards, the timber industry, and other industries complying with quarantine or management practices, and this is said with **low confidence** due to a number of factors discussed above.

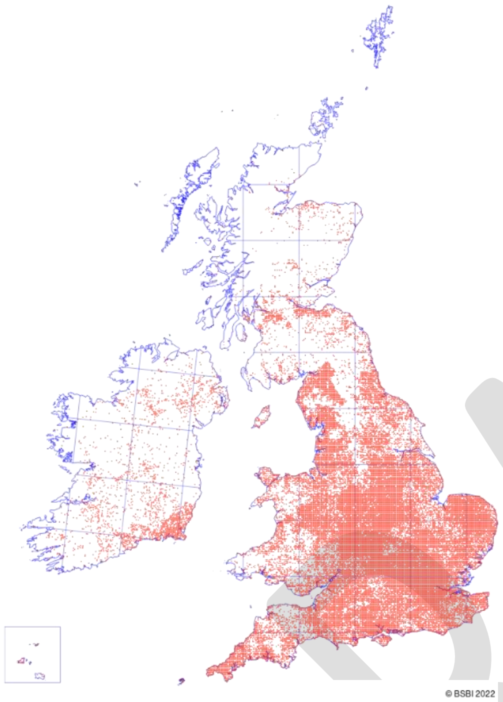

Figure 5. Presence of *Malus* sp. (BSBI)

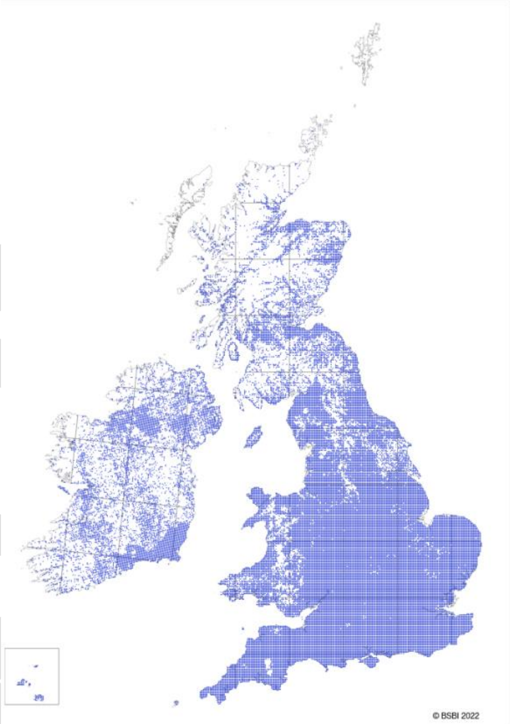

Figure 6. Presence of *Prunus* sp. (BSBI)

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

Environmental Impact

The environmental impact of *L. delicatula* is difficult to quantify, as many trees in the wider environment in the UK are also hosts of *L. delicatula.* It is assumed that similar to the USA, large host trees will suffer little damage from feeding and small saplings will be at risk if high numbers feed on them. There is little data on the effect *L. delicatula* may have on existing ecosystems in the United Kingdom, but it is not thought to be in conflict with any existing insects in the UK or to build up to large populations.

Environmental impacts are rated as **very small** as *L. delicatula* has not been seen to compete with any native species, does not kill mature trees and is unlikely to build up to large enough population levels to cause significant damage. This is said with **low confidence** due to not knowing how it would disperse in the UK if it came here. It is not known if it would build up in large numbers or have different hosts to those seen in the USA or Korea.

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

Social impact

It is unlikely that levels of *L. delicatula* will build up to population numbers seen in the USA due to the cooler summer climate in the UK and so the social impact may be less. If spring, summer and autumn temperatures increase in the UK, the populations may be able to build up to larger levels. The range of *L. delicatula* is also expanding, so this statement of low population levels, cannot be said with certainty. It is assumed that the public will react similarly to the USA and that there will be interest and appetite in a similar public health method to “See it? Squish it!” as in the US. If there are populations in large cities in the south such as London, there may be public concern as adult *L. delicatula* may build up at the base of large buildings as they exhibit cyclic ascending-descending behaviour (climbing up and falling down from the buildings).

Social impacts are set as **medium** as *L. delicatula* produces honeydew which can attract nuisance pests. This is said with **medium confidence** as the climatic conditions in the UK may not be as suitable for high population growth as seen in the current range in the USA.

Social Impacts	Very small		Small		Medium	x	Large		Very large	
Confidence	High Confidence		Medium Confidence	x	Low Confidence					

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

In a 2020 study by Brooks, *L. delicatula* was looked at as a potential vector of a *Verticillium nonalfalfae*, a biocontrol pathogen of *A. altissima.* However, *L. delicatula* was not able to vector this pathogen and there was no evidence of transmission of the pathogen in non-infected hosts (Brooks *et al.* 2020).

Current studies are looking at *L. delicatula's* ability to transmit Pierce's disease of grapevines (another name for *Xylella fastidiosa)*, early studies have shown that *L. delicatula* can transmit North American Grapevine Yellows (Christina Rosa, PPEM Department, Penn State-SLF summit 2022).

16. What is the area endangered by the pest?

The southern areas in the UK, specifically those where there is a high number of orchards and vineyards with lower rainfall and warmer temperatures. The same areas that are suitable for grape growing production and have *A. altissima,* will likely be at the greatest risk.

Stage 3: Pest Risk Management

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

Exclusion

Lycorma delicatula is a hitchhiking pest with almost limitless egg laying options so it is very difficult to prevent it from finding its way into the UK. Listing as a Quarantine pest enables statutory action to be taken against this pest, but exclusion via specific measures is difficult to enforce in the non-plant trade. It is acknowledged that any action taken is likely to not completely stop entry but does increase the barrier for entry of *L. delicatula.*

Preparation for eradication, containment and other management options should be focussed on instead.

Eradication and Containment

The early detection methods used in the USA where *L. delicatula* is absent, focus on mapping out areas with high density of *A. altissima* and using detection methods (sticky traps, surveys) in these areas (Rowe *et al.* 2020). These same detection methods should be applied in the UK.

If/when *L. delicatula* is to be found in the UK, <u>statutory action would be taken to destroy infested stock and quarantine areas set up</u>. Early detection of populations is essential for eradication so surveys and traps should be set up at ports and places of trade. Most of the literature seems to be focussed on trapping *L. delicatula* in host trees, rather than on placing traps elsewhere. However, "prism traps" are free standing traps which could be deployed at ports. It could also be useful to deploy other traps in areas with trees as close to ports as possible. Trapping at nurseries would be easier. Several different types of traps have been shown to be effective at catching larvae and adults, with on-trunk traps thought to be the most effective. However, consideration should be given to preventing trapping of non-target arthropods and small vertebrate species which could become trapped on sticky traps. Methyl salicylate lure (AlphaScents, West Linn, OR) (as measured under laboratory conditions at 22–23°C) has previously been shown to be attractive to all life stages of *L. delicatula*, when used in combination with traps (Desko *et al.* 2020, Francese *et al.* 2020).

It is thought that populations would increase in size over several years before detection, as seen in the USA and would be much more difficult to control if they spread. If there are populations found, measures should be taken to destroy its preferred host *A. altissima* in the area as this increases fecundity by up to seven times (Uyi *et al.* 2021) and this could slow the spread. *Ailanthus altissima* is already an invasive weed and if it spreads to levels seen in North America, this could create an even better environment for *L. delicatula* in the UK. Raising awareness for example through citizen science projects is very important as well as it is a likely scenario that a member of the public will find the first *L. delicatula* in the UK.

Non-statutory controls

Outdoors and Under Protection

Non-chemical options

In the USA there are various methods of management. APHIS is looking at detection surveys, such as visual inspection, sweep netting, and sticky bands to determine the presence of *L. delicatula.* There are also methods such as visual reconnaissance surveys, egg mass scraping, and sticky banding of trees. Management of pest populations can be done through sanitation of green waste, tree removal of both infested and host trees, and insecticide treatments that cause the trees to take up the insecticide and transmit it lethally to *L. delicatula* (USDA-APHIS 2018).

Uyi et al., 2021, found a seven-fold increase in egg masses laid when adults had access to *A. altissima* but no fitness reduction in the offspring of the eggs laid on trees other than *A. altissima* (Uyi *et al.* 2021). Therefore, the removal of *A. altissima* would help to decrease the number of *L. delicatula* that could possibly hatch every year but would not affect the fitness of *L. delicatula* that did hatch. It should be noted that the removal of *A. altissima* is notoriously difficult due to its aggressive clonal spread, prolific seed dispersal, shallow root system, fast yearly growth, and production of allelochemicals to limit neighbouring plant growth (Rebbeck & Jolliff 2018, Young *et al.* 2020). *Ailanthus altissima* is listed in the invasive non-native (alien) plant species list on the government website gov.uk and is prohibited from being imported, keeping, breeding, transport, selling or cultivating. This does not affect already planted trees.

More natural options for control of *L. delicatula* such as biocontrol have been explored and there have been some promising candidates. The egg-parasitoid wasp *Anastatus orientalis* (Hymenoptera: Eupelmidae) has been reported attacking *L. delicatula* in its native range in China, ranging from 30-80% parasitization (Malek *et al.* 2019) but is not recommended for use in the EPPO region. *Ooencyrtus kuvanae* (Hymenoptera: Encyrtidae), an egg parasitoid of *L. delicatula* which has been recommended for use as a biocontrol agent in the EPPO region (EPPO 2022b), has shown much lower parasitism rates (6-35%) but could still be used to keep populations in check, albeit in a less efficient way (Liu 2019).

In 2018 there was a report of a natural outbreak of the entomopathogens *Beauveria bassiana* and *Batkoa major* that led to the collapse of a population of *L. delicatula* in the USA. The pathogens killed the adult insects in parallel, with *L. delicatula* killed by *Batkoa major* on the trunk of the tree and *B. bassiana* killing the adults that were on the ground (Clifton *et al.* 2019). Between 2018-2020, there were another 20 outbreaks of these two pathogens in *L. delicatula* populations (two locations of *Batkoa major* and 18 of *B. bassiana*) (Clifton & Hajek 2022). This has been explored in further studies by Clifton et al., who focussed on spray applications of *B. bassiana,* due to its wide availability as a biocontrol agent (Eric Clifton, BioWorks, 24/08/2022, pers. comm.). The spray was used on *L. delicatula* to see if these results could be replicated in a laboratory environment and the results show low rates of survival at all stages (Clifton & Hajek 2022).

Currently (2022), two products which contain *B. bassiana* are registered in the UK. Naturalis-L is registered for all edible crops (protected) and all ornamental plant production (protected), and also has an extension of minor use (EAMU) registered for protected forest nursery stock.

Botanigard is also registered for use on several crops, the main ones of relevance here are: nursery fruit trees (permanent protection with full enclosure) and ornamental plant production (permanent protection with full enclosure). There are also EAMUs for several bush and soft fruit crops (protected and outdoor): Outdoor and outdoor with temporary rain covers apricot, Outdoor and outdoor with temporary rain covers cherry, Outdoor and outdoor with temporary rain covers peach and nectarine, Outdoor and outdoor with temporary rain covers plum, Outdoor and container grown nursery fruit trees, Outdoor and container grown ornamental plant production, Protected nursery fruit trees, Protected ornamental plant production.

Chemical options

In the USA, chlorpyrifos, a broad spectrum organophosphate, was very effective against egg masses (100% mortality) and paraffinic oil offered intermediate mortality (71%) (Leach *et al.* 2019). In trials, thiamethoxam (a neonicotinoid) and bifenthrin (a pyrethroid) offered control of 50% or greater of adults after two weeks (Leach *et al.* 2019). However, these plant protection products are not approved in the UK.

18. Acknowledgments

With thanks to Helen Anderson, Chris Malumphy and Laura Oporto-Lisboa, PhD student at University of Bath for climate modelling and Korean translation

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Name of Pest Risk Analysts(s)

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Appendix

Acacia sp.	Fraxinus americana	Prunus persica
Acer buergerianum	Fraxinus sp.	Prunus salicina
Acer negundo	Glycine max	Prunus serotina
Acer palmatum	Hibiscus sp.	Prunus serrulata
Acer pictum subsp. mono	Humulus lupulus	Prunus serrulata var. spontanea
Acer platanoides	Humulus scandens	Prunus x yedoensis
Acer pseudoplatanus	Juglans cinerea	Pseudocydonia sinensis
Acer rubrum	Juglans hindsii	Pterocarya stenoptera
Acer saccharinum	Juglans major	Punica granatum
Acer saccharum	Juglans mandshurica	Pyrus sp.
Actinidia chinensis	Juglans microcarpa	Quercus acutissima
Ailanthus altissima	Juglans nigra	Quercus aliena
Albizia julibrissin	Juglans regia var. orientis	Quercus prinus
Alcea rosea	Juglans sp.	Quercus rubra
Alcea sp.	Juniperus chinensis	Quercus sp.
Alnus hirsuta	Ligustrum lucidum	Rhus chinensis
Alnus incana	Lindera benzoin	Rhus typhina
Amelanchier canadensis	Liriodendron tulipifera	Robinia pseudoacacia
Amelanchier sp.	Lonicera sp.	Rosa multiflora
Angelica dahurica	Luffa sp.	Rosa rugosa
Aralia cordata	Maackia amurensis	Rosa sp.
Aralia elata	Magnolia kobus	Rubus crataegifolius
Arctium lappa	Magnolia obovata	Rubus sp.
Armoracia rusticana	Mallotus japonicus	Salix babylonica
Betula alleghaniensis	Malus domestica	Salix pierotii
Betula lenta	Malus sp.	Salix sp.
Betula nigra	Malus spectabilis	Salix udensis
Betula papyrifera	Melia azedarach	Salvia sp.
Betula pendula	Metaplexis japonica	Sassafras albidum
Betula platyphylla	Monarda sp.	Sorbaria sorbifolia
Broussonetia papyrifera	Morus alba	Sorbus commixta
Brucea javanica	Morus bombycis	Styphnolobium japonicum
Buxus microphylla	Nicotiana sp.	Styrax japonicus
Buxus sinica	Nyssa sylvatica	Styrax obassia
Callistephus chinensis	Ocimum basilicum	Syringa vulgaris
Camellia sinensis	Osmanthus sp.	Tamarix chinensis
Cannabis sativa	Ostrya virginiana	Tetradium daniellii
Carpinus caroliniana	Parthenocissus quinquefoli	Tetradium sp.
Carya glabra	Paulownia kawakamii	Thuja occidentalis
Carya ovata	Paulownia tomentosa	Tilia americana
Castanea crenata	Phellodendron amurense	Toona sinensis
Catalpa bungei	Philadelphus schrenkii	Toxicodendron radicans
Cedrela fissilis	Phyllostachys heterocycla	Toxicodendron vernicifluum
Celastrus orbiculatus	Picrasma quassioides	Ulmus pumila
Chamerion angustifolium	Pinus strobus	Ulmus rubra
Colutea arborescens	Platanus occidentalis	Ulmus sp.
Cornus controversa	Platanus orientalis	Vaccinium angustifolium
Cornus florida	Platanus x hispanica	Viburnum prunifolium
Cornus kousa	Platycarya strobilacea	Vitis aestivalis
Cornus officinalis	Platycladus orientalis	Vitis amurensis
Cornus sp.	Populus alba	Vitis labrusca

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