Department
for Environment
Food & Rural Affairs

Pest specific plant health response plan:

Outbreaks of *Lycorma delicatula*

Figure 1. *Lycorma delicatula* adults. © Richard Gardner, Bugwood.org

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This publication is available at

https://planthealthportal.defra.gov.uk/pests-and-diseases/contingency-planning/

This contingency plan takes into account the environmental principles laid out in the Environment Act 2021. Of particular relevance are:

The prevention principle, which means that any policy on action taken, or not taken should aim to prevent environmental harm.

The precautionary principle, which assists the decision-making process where there is a lack of scientific certainty.

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Executive summary

Background		
Regulation	GB quarantine pest	
Key Hosts	*Acer*, birch, tree of heaven (*Ailanthus altissima*), walnut, willow and *Vitis*	
Distribution	China, Japan, Republic of Korea, Taiwan, USA, Vietnam	
Key pathways	Plants for planting, hitchhiking, wood products	
Industries at risk	Vineyards, top fruit, soft fruit	
Symptoms (2.4*)	• loss of vigour • deformation and stunting • wilting • bark splitting and weeping • branch dieback • honeydew egestion	
Surveillance		
Demarcated zones (5.31-5.36)	• **Infested zone** – the infested site or a minimum 100 m radius around all known infested plants • **Buffer zone** – 1 km from the infested zone	
Surveillance activities (5.16-5.18 and 5.37-5.42)	• Visual inspections • Physical traps (modified pecan weevil traps) • Adhesive tree bands • *Ailanthus altissima* sentinel trees	
Response measures		
Interceptions (5.1-5.7)	• Infested consignments should be destroyed or re-exported • Surveillance of at-risk areas within 1 km • Tracing exercises should be carried out where required • UKPHINs notification made (see 5.5)	
Outbreaks (5.37-5.66)	<u>Eradication</u> (5.46-5.54) • Restrictions on movement of host plants and plant products • Bioinsecticides or systemic insecticide treatments in infested zone • Destruction of infested plants • Removal of *A. altissima* trees in buffer zone • Installation of traps and sentinel trees for monitoring and attract and kill purposes • Monitoring of inanimate objects for egg masses	<u>Containment</u> (5.55-6.63) • Removal and destruction of heavily infested hosts identified during annual surveys • Monitoring of key at risk hosts • Continued trapping and use of sentinel trees/objects
Key control measures		
Biological	*Beauveria bassiana*	
Chemical	Systemic insecticide applications	
Cultural (5.14)	Removal of infested hosts; removal of *Ailanthus altissima*; restriction on movement of host plants, equipment and other materials; physical traps; adhesive tree bands; and physical removal of egg masses	
Declaration of eradication		
The outbreak can be declared eradicated (by the Chief Plant Health Officer) if *L. delicatula* has not been detected for a period covering at least two lifecycles of the pest, which would be a minimum period of two years.		

*Numbers refer to relevant points in the plan

Contents

1. Introduction and scope

1.1. This pest specific response plan has been prepared by the Defra Risk and Horizon Scanning team. It describes how the Plant Health Service for England will respond if an infestation of *Lycorma delicatula* is discovered.

1.2. The plant health authorities in Northern Ireland, Scotland, Wales and the Crown Dependencies have been consulted on this plan and will use it as the basis for the action they will take in the event of *L. delicatula* being detected in their territories.

1.3. This document will be used in conjunction with the *Defra Generic Contingency Plan for Plant Health in England* (https://planthealthportal.defra.gov.uk/pests-and-diseases/contingency-planning/), which gives details of the teams and organisations involved in pest response in England, and their responsibilities and governance. It also describes how these teams and organisations work together in the event of an outbreak of a plant health pest.

1.4. The aims of this response plan are to facilitate the containment and eradication of *L. delicatula* in the event of an outbreak and to make stakeholders aware of the planned actions.

2. Summary of the threat

2.1. *Lycorma delicatula*, the spotted lanternfly, is native to China and south-east Asia where it is considered a minor pest. The pest has been introduced to the Republic of Korea (2004), Japan (2008) and the USA (2014). Whilst it remains limited in distribution in Japan, the pest has spread significantly in the Republic of Korea and the USA. It is likely to have been introduced into these areas by hitchhiking, as egg masses are inconspicuous and can be laid on a variety of materials including inanimate objects as well as host plant material.

2.2. *Lycorma delicatula* is a highly polyphagous pest and feeds on a number of economically significant crop species including *Malus* (apple), *Prunus* (stone fruits), *Pyrus* (pears), *Rubus* (blackberries) and *Vitis* (grapevine) as well as other important UK species found in ornamental settings and the wider environment such as *Acer, Alnus* (alder), *Betula* (birch), *Fagus* (beech), *Juglans* (walnut), *Magnolia, Morus* (mulberry), *Pinus* (pine), *Platanus* (plane), *Populus* (poplar), *Quercus* (oak), *Rosa* (rose), *Salix* (willow), *Sorbus* (mountain ash) and *Syringa* (lilac). The pest has differing host ranges between its adult and nymphal stages, with earlier nymphal stages found on a broader range of herbaceous hosts. The host range narrows as the pest develops with females showing a preference for smooth barked trees with low canopies for egg laying.

2.3. One species in particular, *Ailanthus altissima* (tree of heaven), is considered a key host for the pest. This tree is native in China but considered an invasive species in many parts of Europe, due to its quick growing nature and ability to forms dense clonal thickets by suckering and suppressing other plant species via allelopathy (impacting other plants by the production of chemicals). Tree of heaven is present in southern parts of the UK following an accidental introduction in 1751 and is now mainly found in urban areas (particularly London), commonly spreading along railway lines. The invasive impacts seen in the UK are lower than other parts of Europe due to the cooler climate of the UK and the species being currently limited to urban environments. Despite this, it is included on the list of invasive species which are prohibited from being imported, kept, bred, cultivated, transported or sold in the UK - https://www.gov.uk/guidance/invasive-non-native-alien-plant-species-rules-in-england-and-wales#list-of-invasive-plant-species.

2.4. *Lycorma delicatula* is a sap sucking pest, feeding on phloem tissue which subsequently leads to a loss of vigour, deformation, wilting, bark splitting and weeping, stunting and branch dieback in host plants. The pest feeds in aggregations and in severe infestations can cause host mortality. Feeding results in large amounts of honeydew being egested which can become colonised by fungal sooty moulds and impair photosynthesis leading to early senescence. Weeping wounds from bark splits may also be colonised by invertebrates such as ants, flies and wasps, and these wounds along with honeydew may also result in fungal mats forming at the base of infested trees.

2.5. In introduced areas the pest has caused economic losses to vineyards, ornamental nurseries and sawmills, due to a combination of direct and indirect effects from the phloem feeding of the pest. Economic losses due to reduced yields and increased management costs are reported in both the Republic of Korea and the USA, and the pests wide host range means it could have further environmental impacts if introduced. The pest is also considered a nuisance pest, due to its large aggregations, with impacts in the USA seen in tourism, business and residential sectors.

2.6. In the UK, grapevines, orchard fruit and soft fruit have been highlighted as hosts particularly at risk. However, due to its polyphagy, the risk is not limited to these and other sectors such as ornamental growers and traders may also be affected.

2.7. The most likely pathway of introduction to the UK is considered to be hitchhiking, as this has been the major cause of long-distance large-scale spread of the pest. The egg stage is inconspicuous, and egg laying is not confined to plants with females also likely to oviposit on bark, stone, wood, metal, plastic and stiff fabrics. This means there is potential for introduction from the known distribution on a wide range of commodities.

2.8. In July 2024, *L. delicatula* was found for the first time in Europe. A report from a member of the public was posted on iNaturalist, following a finding of a single nymph in Madrid, Spain. As of September 2024, no interceptions or findings have been made of *L. delicatula* in the UK.

Figure 2. Images of *Ailanthus altissima* (tree of heaven). Mature tree (left), pinnate leaves (top right) and stem (bottom right) © GB Non-native species secretariat (available from: https://www.nonnativespecies.org/non-native-species/information-portal/view/101).

3. Risk assessments

3.1. *Lycorma delicatula* has an unmitigated and mitigated UK Plant Health Risk Register score of 18. Overall scores range from 1 (very low risk) to 125 (very high risk). These scores are reviewed as and when new information becomes available (https://planthealthportal.defra.gov.uk/pests-and-diseases/uk-plant-health-risk-register/viewPestRisks.cfm?cslref=27337).

3.2. Pest Risk Analyses of *L. delicatula* have been carried out by EPPO (2016), New Zealand (2020), Sweden (2023) and the UK (2023).

3.3. The EPPO PRA concluded that the pest would be able to establish in the EPPO region at least where *A. altissima* is present and cause impacts (EPPO, 2016), whereas the Swedish PRA concluded that the likelihood of establishment in Sweden was low but with a high level of uncertainty (Björklund & Boberg, 2023).

3.4. The UK PRA concluded that whilst the UK is on the edge of climatic suitability for the pest, it could establish given the presence of suitable hosts and cause a low level of impacts. The most likely pathway of introduction was concluded to be hitchhiking (Lindley-Klassen, 2023).

4. Actions to prevent outbreaks

4.1. *Lycorma delicatula* is a GB Quarantine Pest (Annex 2 part A of the GB Phytosanitary Conditions Regulations 2019/2072) and is therefore prohibited from being introduced into, or spread within, GB.

4.2. *Lycorma delicatula* is an EU Union Quarantine Pest and is therefore prohibited from being introduced into, or spread within, the Union Territory. It is also an A1 EPPO listed organism.

4.3. The Plant Health Service for England (including the Animal and Plant Health Agency (APHA), Defra and Fera Science Ltd.) should be aware of the measures described in this plan and be trained in responding to an outbreak of *L. delicatula*. It is important that capabilities in detection, diagnosis, and risk management are available.

5. Response activities

Official action to be taken following the suspicion or confirmation of an interception

5.1. If *Lycorma delicatula* is suspected by the Plant Health and Seeds Inspectorate (PHSI) to be present in a consignment moving in trade, the PHSI must hold the consignment until a diagnosis is made. *Lycorma delicatula* could potentially hitchhike on plants for planting or produce, but it is likely to disperse if disturbed, and as such the risk of hitchhiking as adults on plants or produce is considered low, with the major risk being the inconspicuous egg masses. Ideally, the consignment should be placed in a sealed cold store and any opened containers should be resealed (which could be via wrapping in plastic if this facility is available). Other consignments of host plants of significance that are at risk of cross-contamination should also be held pending a risk assessment on whether cross-contamination has or could have potentially occurred. Samples should be sent to Fera Science Ltd., Plant Clinic, York Biotech

Campus, Sand Hutton, York, YO41 1LZ (+44 (0) 300 100 0323), in a sealed bag or container, within at least two other layers of containment, which are not liable to be crushed during transit.

5.2. If *L. delicatula* is intercepted inland and there is the potential for spread from the imported consignment, host plants at risk of contamination should be surveyed on the site and again in the following year for signs of the presence of *L. delicatula*. When the site is in an area where hosts are grown (e.g. orchards and vineyards), the survey should include an area extending to 1 km of the affected site. The size of the survey area will be influenced by the local climatic and meteorological conditions, and the density of hosts (see 2.2).

5.3. When a finding of *L. delicatula* is confirmed, the PHSI should advise the client of the action that needs to be taken by way of an official notice. The consignment should be destroyed by either incineration, deep burial or another approved method (such as wood chipping) or re-exported in a sealed container. The method of destruction/re-export will be chosen on a case-by-case basis.

5.4. If there is a high risk of escape before destruction or re-export, fumigation and/or insecticides may be used under guidance from the Defra Risk and Horizon Scanning team.

- Prior to any insecticides being used, the risk posed by the insecticides to people and the environment will be assessed.
- Any applications should be made following the advice on the product label and be in accordance with HSE guidance. In some cases, there may be a requirement to carry out a Local Environment Risk Assessment for Pesticides (LERAP) depending on the product used and the situation of the finding.
- If the situation demands it, it may be necessary to require the use of plant protection products even for growers where only biological control agents are being used.
- If nursery plants or other crops are found to be infested or are suspected to be infested, growers may be required to apply the recommended plant protection products and make the applications using their own or contractor’s equipment. Records of applications must be kept, including details of the amount of product and water used.
- Before the use of plant protection products in the wider environment, any particular risks relating to each site (e.g. proximity to water bodies or footpaths) should be considered. Applications should not be made if the risks are considered unacceptable.
- If there is a finding within a SSSI, Natural England should be contacted to assess the threat of the pesticide application to the site.

- If a risk to bees is identified, bee advisors and local beekeepers should be contacted to inform them of any insecticide applications and their timing. Bee inspectors should be able to provide contact details.
- Adhesive tree band traps and/or sentinel trees should be installed and/or monitored to determine the efficacy of the treatments. If *A. altissima* is present some sentinel trees may be retained for monitoring purposes (see 5.41).

5.5. An UKPHINS (UK Plant Health Interception Notification System) notification should be made upon confirmation of an interception of *L. delicatula.* UKPHINS is the IT system for recording findings and non-compliance in order to maintain records and notify other National Plant Protection Organisations (NPPOs) of plant health issues.

5.6. If all or part of the consignment has been distributed to other premises prior to diagnosis, trace forward and trace back inspections should take place upon suspicion or confirmation of *L. delicatula*. Details of recent past and future consignments from the same grower/supplier should also be obtained. The time period from when these consignment details should be obtained will be dependent on the situation.

5.7. A pest alert and factsheet are available to raise awareness of *L. delicatula* and its symptoms. These should be distributed to relevant stakeholders where the pest has been found, and to those in the local area and those associated with the infested premises as appropriate. Both the pest alert and factsheet are available on the plant health portal

https://planthealthportal.defra.gov.uk/assets/factsheets/Pest-alert-Lycorma-delicatula-update.pdf

https://planthealthportal.defra.gov.uk/assets/factsheets/Lycorma-delicatula-Defra-fact-sheet-Revised2022.pdf.

Official action to be taken following the suspicion of a *L. delicatula* outbreak

5.8. Suspected outbreaks will be assessed on a case-by-case basis. An Outbreak Triage Group (OTG), chaired by the Chief Plant Health Officer (CPHO) or their deputy and including specialists from APHA, Defra and other relevant organisations, should be set up to assess the risk and decide on a suitable response. Where appropriate, the OTG will also decide who will be the control authority, and the control authority (the lead organisation responsible for the eradication or containment of the pest) will then nominate an Incident Controller. An Incident Management Team (IMT) meeting, chaired by the Incident Controller, will subsequently convene to produce an Incident Action Plan (IAP). See the *Defra Generic Contingency Plan for Plant Health in England for full details.*

5.9. The OTG will determine the alert status, which will consider the specific nature of the outbreak. These alert levels, in order of increasing severity, are white, black, amber and red (more details on these levels can be found in table 2 of the *Defra Generic Contingency Plan for Plant Health in England*. Under most scenarios, an infestation of *L. delicatula* is likely to be given a black alert status. A black alert status indicates a plant pest with potential for limited geographical spread leading to moderate economic, environmental or social impacts.

Restrictions on movement of material

5.10. *Lycorma delicatula* eggs, nymphs and adults can all be associated with plants for planting. Therefore, host plants for planting which may have been infested or are at risk of becoming infested should be prevented from leaving the affected site, other than under a statutory plant health notice for destruction by deep burial, incineration or another approved method. A comprehensive host list can be found on the EPPO Global Database - https://gd.eppo.int/taxon/LYCMDE/hosts).

5.11. Movement of equipment and/or machinery may result in the movement of life stages of *L. delicatula* from infested to non-infested sites. If this risk is considered to be high the movement should be restricted until it has been possible to inspect the equipment or machinery to check it is pest free or it has been cleaned. Cleaning of equipment and/or machinery should take place at the designated outbreak site to remove any life stage of *L. delicatula*.

5.12. Given the pest is known to lay egg masses on inanimate objects, movement of other materials in close proximity to the finding or likely to be at risk, off site such as fence posts, pallets, lampposts or products made of wood, metal, plastic etc. should be monitored as far as practically possible. Egg masses are more likely to be present between Autumn and Spring. Any egg masses found should be destroyed by scraping them off and placing into a container of soapy water.

5.13. Movement of people into the infested zone should be restricted, especially during the early investigation phase. Personnel should be briefed on the importance of good hygiene practice (see 5.15), to reduce the risk of carrying life stages of *L. delicatula* to other areas of the site or to other sites.

Preliminary trace forward / trace backward

5.14. If an infested consignment or batch is considered to be the source of the suspect outbreak, investigations regarding the origins of the infested consignment will be undertaken to locate other related and therefore potentially infested consignments moving to and from the site.

General biosecurity advice and advisory measures for growers

5.15. The following measures could be considered to minimise the spread of the pest:

- Training staff to identify *L. delicatula* and its symptoms including egg masses on non-plant material.
- All non-disposable material, equipment and machinery, should be thoroughly cleaned (e.g. using water at high pressure) to remove any life stages of the pest. The cleaning should be carried out within the infested area to prevent further spread.
- Restricting access to the infested site. Limiting the number of people entering will reduce the risk of spreading *L. delicatula* to other sites. Wherever possible, employees should work in the same area each day rather than moving between different areas of the site. The use of appropriate PPE should be considered along with the cleaning and disinfection of footwear when leaving infested areas. Keeping the windows and doors of any vehicles moving between sites closed, and inspecting the outside for signs of the pest will also reduce the risk of spread.
- Infested and suspect material as well as any potential hosts in close proximity which are found at nurseries, garden centres or other situations where they can be moved, should ideally be isolated and contained in a quarantine area where possible to prevent spread. In some scenarios this may not be possible or may increase the risk of transfer or spread of the pest, in which case restricting access to the infested material may be more suitable. Access to quarantine areas should be restricted to essential trained staff only.
- Trapping using adhesive tree bands and physical traps should be considered. Traps should be well maintained. Trap maintenance to avoid them becoming full or covered in debris. See Appendix A: Trapping for more details.
- Mechanically removing egg plaques has been shown to be an effective tool in the USA. This can be done using a stick, plastic card or similar to scrape eggs into a container filled with soapy water to kill the eggs.
- Any waste (plant or other potentially infested material) should be removed and destroyed in an appropriate manner.
- More control options that could be considered can be found in Appendix A: Control

Confirming a new outbreak

How to survey to determine whether there is an outbreak

5.16. Information to be gathered by the PHSI and/or FC on the suspicion of an infection of *L. delicatula*, in accordance with ISPM 6; guidelines for surveillance (https://www.ippc.int/en/publications/615/):

- The origin of the host plants and associated pathways, date of planting and plans for the date of succeeding crops.
- Details of other premises or destinations where the potentially infested host plants have been sent.
- Details of how waste material is disposed of.
- The layout of the premises and surrounding area, including a map of the fields/cropping, at risk growers, and details of neighbouring crops, including all potential hosts and weeds (e.g. presence of *Ailanthus altissima*).
- Details of the host grown including cultivar or variety, planting date, growth stage, likely harvest date and any other relevant information.
- Area and level of infestation, including a description of the symptoms seen (photos should be taken) and the location within the affected premise e.g. whether it is widespread across the planting, clustered in hotspots, or whether it is related to specific operations.
- The date and time the sample was taken.
- Current treatments/controls in place.
- Details of the movement of people, equipment, machinery etc. to and from the infested area.
- Cultural, biosecurity and working practices.
- The name, address, email and telephone number of the person who found the pest and/or its symptoms, and the business owner.

This information should be included on the plant pest investigation template.

5.17. Further to information gathering, surveys of other host plants in the vicinity should be carried out to confirm the extent of the infestation e.g. in surrounding vineyards, orchards, fruit farms, nurseries etc. growing hosts of *L. delicatula*. This should include samples and photographs of suspect *L. delicatula* and/or symptoms where possible. This initial survey will be used to determine if it is an isolated finding or an established outbreak.

5.18. Finance for the surveys will depend on the individual circumstances of the outbreak, and will be subject to discussion, usually between Defra policy and the PHSI.

Sampling

5.19. Host plants can be sampled using a beating tray and visually examined for symptoms of *L. delicatula* which are described in more detail in 2.4 and Appendix A: Symptoms/signs but may include:

- loss of vigour,
- deformation and stunting,
- wilting,
- bark splitting and weeping,
- branch dieback, and
- honeydew egestion leading to subsequent presence of sooty mould.

5.20. Following the capture/putative identification of *L. delicatula*, representative samples should be sent for confirmatory diagnosis as in point 5.1. Each sample should be labelled with full details of the sample number, location (grid reference), plant variety and suspect pest.

Diagnostic procedures

5.21. The initial findings of pests that are suspected to be *L. delicatula* should be confirmed using laboratory analysis, including morphological identification and molecular testing.

5.22. A diagnostic protocol for the identification of *L. delicatula* (EPPO PM7/144), is available here - https://gd.eppo.int/taxon/LYCMDE/documents. This contains detailed morphological descriptions of each life stage of *L. delicatula.* The protocol notes that the three other known species in the *Lycorma* genus look visually distinct from *L. delicatula.*

5.23. Molecular identification on all stages can be carried out using conventional PCR followed by Sanger sequencing analysis.

Criteria for determining an outbreak

5.24. If a breeding population of *L. delicatula* (including eggs and larvae) is detected at a location, and following initial surveillance is deemed not to be confined to a recently introduced consignment(s) then an outbreak will be declared. For example, if multiple *L. delicatula* adults, larvae and egg masses are found in a vineyard, orchard or fruit farm then this is likely to be classed as an outbreak.

5.25. If multiple adults of *L. delicatula* are detected at a location, and following initial surveillance are deemed not to be confined to a recently introduced consignment(s) but there is no sign of them being associated with a breeding population then the finding can be classed as an incursion. For example, if a limited number of *L. delicatula* adults are found in a vineyard, orchard or fruit farm.

5.26. If *L. delicatula* is detected at a port or is restricted to a consignment with no risk of spread, then an outbreak should not be declared. For example, if *L. delicatula* was detected in a consignment of table grapes in a cold store, an outbreak should not be declared and the finding can be considered an interception.

5.27. There are likely to be a number of scenarios in which the pest could be found, and the OTG will make the final decision on whether a finding is classed as an outbreak, an incursion or an interception.

Official Action to be taken following the confirmation of an outbreak

5.28. The scale of the outbreak will determine the size and nature of the IMT and action.

Communication

5.29. The IMT will assess the risks and communicate details to the IPPC and EPPO in accordance with ISPM 17: pest reporting (https://www.ippc.int/en/publications/606/), as well as within Government to Ministers, senior officials and other government departments, devolved governments, and agencies (e.g. the Environment Agency) on a regular basis as appropriate; and to stakeholders.

5.30. A generic communications plan is available for use across all plant health outbreaks. This is owned by APHA and FC communications teams and is intended to provide consistency across outbreaks. This plan can be tailored to the outbreak using pest and outbreak specific information. It includes a list of key stakeholders and templates for:

- Core Narratives
- Press releases
- Reactive lines
- Frequently Asked Questions

Demarcated zones

5.31. Once an outbreak has been confirmed, a demarcated area should be established around known infested plants. This will include two zones:

- An **infested zone** (i.e. the infested site(s)). This is where the presence of *L. delicatula* has been confirmed, and which includes all plants showing symptoms caused by *L. delicatula* and where appropriate, all plants belonging to the same lot at the time of planting. As a minimum, the radius of this zone will extend to 100 m around all known infested plants. For the purpose of vineyards, orchards and fruit farms, the whole site may be considered as an infested zone, unless the infestation is clearly restricted to a single variety, lot etc. Any decisions on strategy will be made by the IMT on a case-by-case basis.

- A **buffer zone**, which will initially be at least 1 km from the infested zone. The buffer zone may include other premises in which stock has been sent or received, and/or any other premises where there is a perceived risk such as other vineyards, orchards, fruit farms and nurseries or areas where there is a high density of *A. altissima*.

5.32. Initial maps of outbreak sites should be produced by officials.

5.33. Movement of potentially infested material out of the infested zone should be prevented. The PHSI will contact stakeholders within the demarcated areas to inform them of the requirements that will apply to them (see Pest Management Procedures). Controls on the movement of specified plants will be implemented by statutory plant health notices.

5.34. All batches of host plants in the demarcated area should be visually inspected, where feasible, for signs of the pest. This should focus on the hosts noted in point 2.2. Surveying rates should be determined by the IMT. If it is considered possible that the pest has been spread to other destinations, such as those identified in tracing exercises, these areas should also be surveyed. These zones should initially be treated as if they are part of the buffer zone.

5.35. The demarcated area should be adjusted in response to further findings. If *L. delicatula* is found within an area outside the infested zone, this should subsequently be designated as infested, and the buffer zone extended.

5.36. The PHSI will contact vineyards, orchard owners, garden centres, nurseries, private residents and other traders of host plants, as well as owners/managers/tenants of woodland areas, conservation areas and amenity land such as parks, within the demarcated areas to inform them of the requirements that will apply to them (see Pest management procedures). Controls on the movement of specified plants or wood will be implemented either by statutory plant health notices, or by a statutory

instrument, or a combination of the two, depending on the nature and scale of the incident. The location of any demarcated areas will be published on '.gov.uk' to inform all other stakeholders (including residents, businesses and landowners) within the demarcated areas of the requirements that will apply to them.

Surveillance of the demarcated zones

5.37. The first survey of the demarcated area should be carried out as soon as possible after the outbreak has been discovered. This should focus on visual inspections and the installation of traps or the use of sentinel *A. altissima* trees.

5.38. Visual surveys should be carried out as in 5.34.

5.39. Several types of trap have been tested for their potential use in surveying for *L. delicatula.* This includes light traps, flight interception traps, adhesive tree bands and physical traps (see Appendix A: Detection and inspection methods: Trapping and figure 6). Comparative trials have shown that physical traps based on a pecan weevil funnel trap are the best trap for detection at low pest densities. For good efficacy, these traps should;

- be installed on preferential trees such as *A. altissima, Juglans* spp., *Malus* spp., *Prunus* spp. or *Pyrus* spp.,
- be installed at 1 m above the ground,
- be checked at a maximum of two-week intervals and
- trap density should decrease with the distance from the infested zone to reduce the risk of attracting the pest to new areas.

5.40. Other traps such as flight interception panel traps and adhesive tree bands could be installed as they may be more readily available.

5.41. If *A. altissima,* the preferential host of *L. delicatula*, is present in the infested zone, some of these should be retained to function as a sentinel trees. These could be utilised in two ways:

- as a monitoring tool, by installing an adhesive tree band or physical trap as described in 5.39 to capture *L. delicatula* nymphs and adults; or
- as an attract and kill strategy – spraying the tree with a systemic insecticide to kill any *L. delicatula* feeding on the tree. Any insecticide applications should be made in line with point 5.4.

5.42. Surveys of the demarcated area will be carried out annually for at least two years after the year of the outbreak. Surveys should be performed in spring to look for

nymphs and in the winter for egg masses on both hosts and other inanimate objects such as trellis posts and pallets, the extent of which will depend on the outbreak situation. As a guide preferred egg laying spots are reported to have smooth surfaces and be red, brown or grey in colour.

Pest management procedures

5.43. *Lycorma delicatula* is a highly polyphagous, mobile pest and in certain scenarios eradication may not be possible or feasible. The pest management procedures may need to be reviewed and the emphasis of the outbreak management may need to be shifted from eradication to containment. This decision will be made by the IMT.

5.44. If the initial delimiting surveys detect infested or symptomatic hosts, then the decision to either attempt eradication or concentrate on containment measures will depend on the extent of spread of these findings within the buffer zone. Any decisions on changes of strategy may need to be escalated to the Lead Government Department (LGD) as required. If only symptoms are seen or if adults or larvae are found over a limited area, eradication measures should be followed. If adults or larvae are detected over a wide dispersed area during surveillance, efforts should be shifted to containment measures as eradication is unlikely to be successful. This is intended as a general guideline and should be continually reviewed, as many factors may hamper the chances of eradication.

5.45. Once the aim of the outbreak management has been determined by the IMT and or LGD, specific measures can then be taken either for eradication (see 5.46—5.54) or for containment (see 5.55-5.63).

Official pest management procedures in respect of eradication

5.46. The movement of host plants and plant products out of or within the demarcated area should not be allowed as in 5.10, with the exception of plants being moved for destruction under a statutory plant health notice.

5.47. The movement of machinery and equipment where the risk of moving life stages of *L. delicatula* to non-infested sites should be restricted as in 5.11.

5.48. The movement of people into the infested zone should be restricted as in 5.13.

5.49. If *L. delicatula* nymphs or adults are found in a commercial situation, such as a vineyard, orchard or nursery, all hosts within the infested zone should be treated with a systemic insecticide and/or biopesticides as soon as possible. The Defra Risk and Horizon Scanning team should be consulted about the most appropriate treatments, and any applications should be made in line with point 5.4.

5.50. Following treatment, all infested plants, where there is a risk of spread, should be destroyed as described in 5.64-5.66. If there are plants of particular historic or ecological importance in the infested area, the IMT will determine whether they can be excluded from the need for destruction as long as they can be treated using an alternative method.

- The removal and destruction of non-infested host plants within 100 m of the infested plants is dependent on the situation and will be considered on a case-by-case basis by the IMT.

- The removal of host plants will remain the responsibility of the occupier or other person in charge of the premises.

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

5.51. If *A. altissima* trees are present in the demarcated area, they should be systematically removed from the edge of the buffer zone in. A small number should be left in the infested zone as sentinel trees for monitoring of the pest and use as an attract and kill strategy if feasible (as noted in point 5.41). The number of trees will be dependent on the scenario and should be determined by the IMT. Any removal or destruction of *A. altissima* should be carried out in a manner which prevents incidental spread of the plant, as it is a listed invasive species. Following tree removal, the area the tree was removed from should be treated with herbicide to prevent regrowth. The Defra Risk and Horizon Scanning team should be consulted about the most appropriate treatments for any pesticide application, and any applications should be made in line with point 5.4.

5.52. If *A. altissima* trees are not present in the demarcated area a small number of other trees could be utilised as sentinel trees (see 5.51). The number of trees will be dependent on the scenario and should be determined by the IMT. Trees should be preferably one of the hosts listed in 2.2 or in the absence of these species, a selection of smooth barked trees in the infested zone, or sentinel trellis posts as in 5.53.

5.53. The movement of inanimate objects at risk of oviposition should be restricted as in 5.12. Inanimate objects such as fence posts, pallets, lampposts or products made of wood, metal, plastic etc. which could harbour egg masses should be inspected in the infested zone (as in 5.42). Any egg masses found should be destroyed by scraping

the egg mass off and disposing it into containers of soapy water. The installation of sentinel posts could also be considered as a way to monitor for egg masses during surveillance.

5.54. Official visual inspection and trapping, with the frequency determined by the IMT, should be carried out over the following two growing seasons to check for the presence of *L. delicatula*.

Official pest management procedures in respect of containment

5.55. The movement of host plants, plant products or inanimate objects at risk from oviposition out of or within the demarcated area should be agreed by the IMT.

5.56. Movements of machinery and equipment out of or within the demarcated area should be agreed by the IMT. Where movement of machinery and equipment is required, it should be cleaned as described in 5.15.

5.57. The movement of people into the infested zone should be restricted as in 5.13.

5.58. Any heavily infested plants, where there is a risk of spread, should be destroyed as described in 5.64-66. These plants should be determined during monitoring surveys.

5.59. If *A. altissima* trees are present in the demarcated area, they should be systematically removed from the edge of the buffer zone in and destroyed as in 5.51. A small number should be left in the infested zone as sentinel trees for monitoring of the pest and use as an attract and kill strategy if feasible (as noted in point 5.41).

5.60. At risk but uninfested plants should be closely monitored for signs of pest presence.

5.61. Traps and if feasible sentinel trees/objects should be used as described in 5.15 and 5.51-.5.52.

5.62. The radius of the infested area and buffer zone may be adjusted to reflect the density of potential and favoured hosts and the number of *L. delicatula* found.

5.63. In some situations, the IMT may determine that further recommendations such as those listed in 5.46-5.54 may be required, which may be used as further official actions under a statutory plant health notice.

Disposal plan

5.64. The primary means of disposing of infested material and plants is by incineration (licensed) or deep burial. Deep burial may be done at an approved landfill site, or on the site or other suitable nearby site, if practical and in agreement with the local Environment Agency. Incineration must comply with appropriate waste management regulations, Environment Agency in England, Scottish Environment Protection

Agency and Natural Resources Wales. If the material has to be moved off the premises, it should be contained within at least two sealed layers, if possible (e.g. small plant within two plastic bags).

5.65. Aside from incineration and deep burial, other viable methods of destruction may be suitable (e.g. wood chipping) but will need to be agreed upon by the IMT.

5.66. Any disposal of waste material must be done in accordance with the relevant legislation. Growers need to obtain permission for exemptions from the Agricultural Waste Regulations from the Environment Agency. No charges are made for these exemptions. Further information on activities that require a permit and those which require the registration of an exemption can be found on the EA website at: https://www.gov.uk/topic/environmental-management/environmental-permits.

6. Criteria for declaring eradication / change of policy

6.1. The outbreak can be declared eradicated (by the Chief Plant Health Officer) if *L. delicatula* has not been detected for a period covering at least two lifecycles of the pest, which would be a minimum period of two years.

7. Evaluation and review of the contingency plan

7.1. This pest specific contingency plan should be reviewed regularly to consider changes in legislation, control procedures, pesticides, sampling and diagnosis methods, and any other relevant amendments.

7.2. Lessons should be identified during and after any outbreak of *L. delicatula* or any other pests, including what went well and what did not. These should be included in any review of the contingency plan leading to continuous improvement of the plan and response to outbreaks.

8. Appendix A

Data sheet for *Lycorma delicatula*

Identity

PREFERRED SCIENTIFIC NAME	AUTHOR (taxonomic authority)
Lycorma delicatula	White, 1845

CLASS: Insecta
ORDER: Hemiptera
SUBORDER: Auchenorrhyncha
FAMILY: Fulgoridae
GENUS: *Lycorma*
SPECIES: *delicatula*

SYNONYMS
Aphaena delicatula
Lycorma delicatulum

COMMON NAMES
Chinese blistering cicada
Spot clothing wax cicada
Spotted lanternfly

(Source: CABI, 2019; MPI, 2020; EPPO, 2024)

Notes on taxonomy and nomenclature

Lycorma delicatula is native to Asia, and particularly China. It is often reported to be native to Taiwan and Vietnam, but this is disputed (MPI, 2020). The hemipteran pest is a clearly defined species initially described by Adam White in 1845 (EFSA, 2023), although three subspecies of the pest are now recognised (*L. delicatula delicatula, L. delicatula jole* and *L. delicatula operosa*) (MPI, 2020). Within the genus there are only three *Lycorma* species in addition to *L. delicatula,* all of which are native to Asia (*L. imperialis, L. meliae* and *L. olivaceae*) (EPPO, 2016).

Biology and ecology

Lifecycle

Lycorma delicatula is univoltine in both its native and introduced ranges, overwintering as cryptic egg masses which are oviposited directly onto or nearby suitable hosts. Eggs are laid in Autumn, with oviposition spots including hosts, non-host

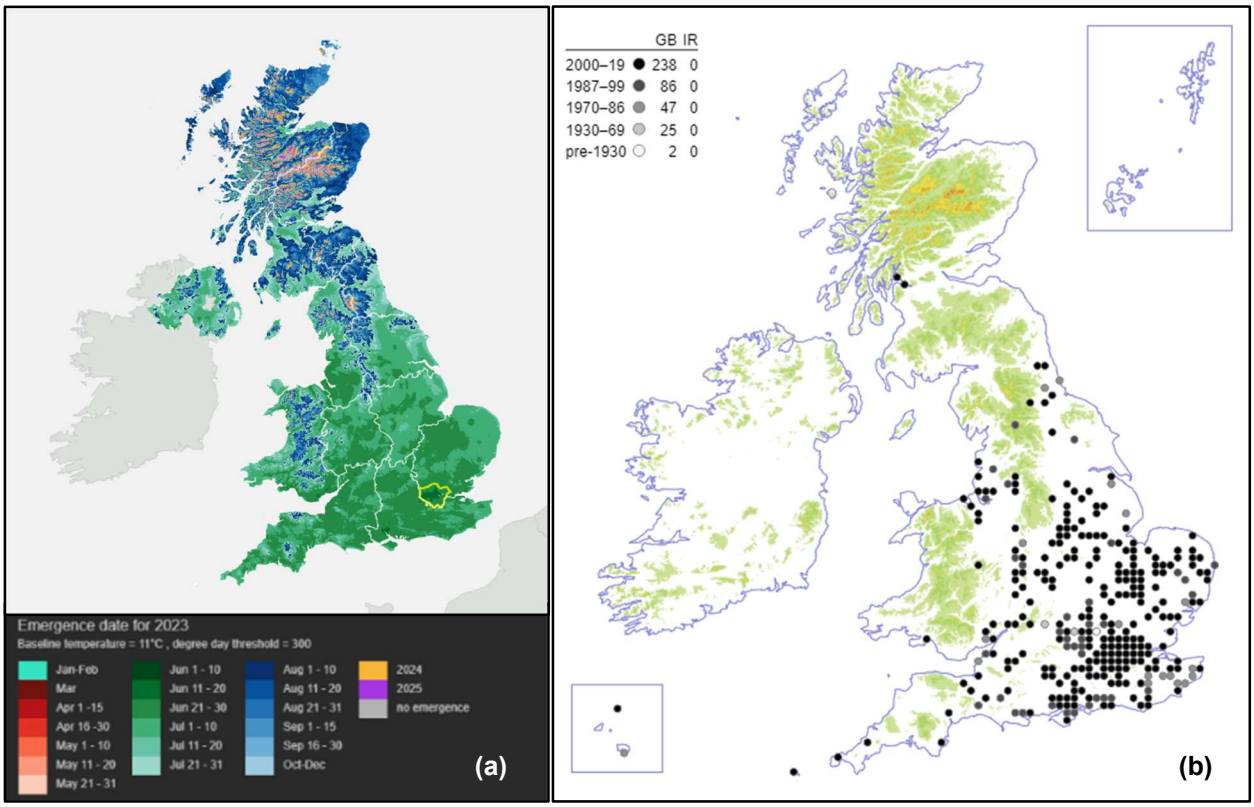
s and inanimate objects (such as stones, fence posts and walls) with the pest exhibiting a preference for smooth surfaces which are red, brown or grey in colour. Females lay between 30-50 eggs at one time, secreting waxy exudates onto masses to form an oothecum to prevent desiccation and provide camouflage from predators (CABI, 2020; EPPO, 2021; EFSA, 2023). Egg masses can remain present for up to six months, depending on climatic conditions, and are often clustered with the egg masses of other females (CABI, 2020). These appear to be climatically resilient, with one paper reporting a lower lethal temperature for eggs of -12.72°C following field studies in South Korea (Lee *et al.*, 2011)).

In the native distribution, nymphs hatch in the spring and disperse to find and infest nearby hosts. The host range of the pest is broader at this stage, with the earlier nymphal stages infesting small herbaceous plants which would be unable to support the later adult feeding masses. The pest undergoes four nymphal stages. During the first three stages the nymphs are black with white spots, growing larger with each instar, but the fourth instar develops red patches in addition to these spots. Nymphs are sap sucking, feeding on trunks, branches, shoots, leaves and petioles. During feeding if disturbed they fall to the floor and reclimb the host to continue feeding (EFSA, 2023). Fourth instars are more likely to feed on hosts such as *Ailanthus altissima* (tree of heaven), which contain defensive compounds that contribute to decreasing their palatability to predators (CABI, 2019; EPPO, 2021). Feeding on this host alongside a mix of others may also speed up the development to adult, with nymphs feeding solely on *A. altissima* or on a diet lacking this host developing more slowly. These studies have also shown that the fecundity and number of nymphs reaching adulthood is impacted if *A. altissima* is not available (Nixon *et al.*, 2022).

Once they have developed into adults, the host range of the pest narrows and adults are generally found on woody hosts such as trees and vines, continuing to feed via sap sucking. The reason for the host shift is due to the higher sugar content in the phloem and/or the availability of defensive chemicals within these hosts. Adults aggregate on specific host trees, giving a random distribution in a specific area and can move en masse into cultivated crops such as vineyards, orchards, fruit farms and nurseries in the autumn, if they are in areas with a low host density (EPPO, 2021; EFSA, 2023).

Lee *et al.* (2019) note that the species could become multivoltine in warmer climates, but this is unlikely to be the case for the UK, with the author suggesting the southern part of

the USA as a possible location for the development of a multivoltine lifecycle. The climate of this region significantly differs from the UK. A lower developmental threshold of 11.13°C is reported by Park (2015), with a 293.26 degree day requirement for egg hatch. Using an approximation of these figures (11°C and 300 DD) in the UK Climate-Pest Risk Web tool (https://www.metoffice.gov.uk/hadobs/biosecurity_uk_hist/), egg hatch in the UK is predicted to be between June and July in most of the UK (see figure 2(a)), which is around a month later than the current distribution (Inaoka *et al.*, 2021). This is shown against a



distribution map of the preferred host (*Ailanthus altissima*) in figure 2(b), and shows crossover between earlier emergence and host availability.

Figure 3. (a) Predicted egg hatch of *Lycorma delicatula* in the UK. This is based on the figures in Park (2015) but due to the limitations of the software the lower developmental threshold is set at 11°C with a 300 degree day requirement **(b)** distribution map of the preferred host *Ailanthus altissima* in the UK. (BSBI, 2024).

Lycorma delicatula is also reported to display a phenomenon known as permanent endothermy, the ability to maintain an elevated body temperature by generating heat. In the case of *L. delicatula* this ends shortly before oviposition but could potentially increase the pest's cold tolerance and allow it to establish in areas which were assumed to be outside of its range (Dinets, 2022; Lindley-Klassen, 2023).

The Defra PRA concluded that whilst the UK is on the edge of climatic suitability for the pest there is a higher risk of establishment in the south due to the warmer climate and host availability. Climate change was concluded to increase the risk of the pest's ability to build

significant populations in the UK, as was the pest's potential establishment in mainland Europe, which could lead to yearly incursions of *L. delicatula* in the UK by the pest hitchhiking from breeding populations in Europe (Lindley-Klassen, 2023).

Hosts/crops affected

Lycorma delicatula is highly polyphagous and as such can cause impacts in many scenarios (Inaoka *et al.*, 2021). An exhaustive host list can be found on the EPPO Global database - https://gd.eppo.int/taxon/LYCMDE/hosts, but the pest is known to feed on economically significant crop species including *Malus* (apple), *Prunus* (stone fruits), *Pyrus* (pears), *Rubus* (brambles) and *Vitis* (grapevine) as well as other important UK species found in ornamental settings and the wider environment such as *Acer, Alnus* (alder), *Betula* (birch), *Fagus* (beech), *Juglans* (walnut), *Magnolia, Morus* (mulberry), *Pinus* (pine), *Platanus* (plane), *Populus* (poplar), *Quercus* (oak), *Rosa* (rose), *Salix* (willow), *Sorbus* (mountain ash) and *Syringa* (lilac) (MPI, 2020; Defra, 2022).

The hosts that are infested vary depending on the life stage of the pest, with the broadest host range found during the nymphal stage, when the pest feeds on a wide range of herbaceous plants (EPPO, 2021). Preference for hosts at this stage has been linked to the presence of toxic metabolites which could be utilised by the nymphs in defensive strategies against predators. The host range of the pest narrows as adult females begin to lay eggs, with higher rates of oviposition found on smooth-barked hosts with low canopy cover such as *Acer*, although man-made items such as vehicles, furniture, farm equipment may be oviposited on by the females (MPI, 2020; Defra, 2022; Ramirez *et al.*, 2023).

One host in particular, *A. altissima*, is preferred by adults. This tree is native in China but considered an invasive species in many parts of Europe. The species is quick growing and forms dense clonal thickets by suckering and suppressing other plant species via allelopathy (impacting other plants by the production of chemicals). This makes it difficult to eradicate. It is mildly toxic, and the sap can lead to dermatitis in some individuals. Tree of heaven is present in southern parts of the UK (see figure 2(b)) following an accidental introduction in 1751 and is now mainly found in urban areas (particularly London), commonly spreading along railway lines. The invasive impacts seen in the UK are lower than other parts of Europe due to the cooler climate of the UK and the presence currently being limited to urban environments. Elsewhere its roots damage sewers, pavements and the foundations of buildings (Non-native species secretariat, 2024), and due to this, it is included on the list of invasive species which are prohibited from being imported, kept, bred, cultivated, transported or sold in the UK - https://www.gov.uk/guidance/invasive-non-native-alien-plant-species-rules-in-england-and-wales#list-of-invasive-plant-species.

The preference of *L. delicatula* for tree of heaven has led to it previously being considered as a classical biocontrol agent to manage the rapid spread of the plant in the USA. However, due to the polyphagous nature of *L. delicatula* it was never implemented (Lindley-Klassen, 2023).

Plant stage affected

All stages affected.

Plant parts affected

Leaves and stems.

Symptoms/signs

Symptoms become more pronounced as the pest develops, with the most significant damage caused by the later instar nymphs and adults. *Lycorma delicatula* is a sap sucking pest, feeding on phloem tissue which subsequently leads to a loss of vigour, deformation, wilting, bark splitting and weeping, stunting and branch dieback in host plants (EPPO, 2021; Defra, 2022). The pest feeds in aggregations and in severe infestations can cause host mortality (MPI, 2020).

The feeding by *L. delicatula* results in large amounts of honeydew being egested which can become colonised by sooty moulds and impair photosynthesis and lead to early senescence (Lee *et al.*, 2019; EPPO, 2021). Weeping wounds from bark splits may also be colonised by invertebrates such as ants, flies and wasps (Defra, 2022). Honeydew and the weeping wounds may also result in fungal mats forming at the base of infested trees (Dara *et al.*, 2015).

Figure 4. Symptoms of *Lycorma delicatula*. (left) Large adult feeding aggregation at base of tree (© Lawrence Barringer, Pennsylvania Department of Agriculture, Bugwood.org), (middle) weeping wounds caused by feeding of *L. delicatula* (© Pennsylvania Department of Agriculture (US) via EPPO Global database), (right) fungal mat formation at base of tree following accumulation and colonisation of honeydew and weeping wounds as a result of *L. delicatula* feeding damage (© Lawrence Barringer, Pennsylvania Department of Agriculture, Bugwood.org).

Morphology

The below is taken from the Defra factsheet on *L. delicatula* available from: https://planthealthportal.defra.gov.uk/assets/factsheets/Lycorma-delicatula-Defra-fact-sheet-Revised2022.pdf

Eggs

Grey, flattish, egg masses are laid on relatively smooth surfaces and depending on the substrate can be very difficult to spot (see figure 4).

Nymphs

The early-instar nymphs are black with white spots and are a few mm long. The later instars also have patches of red. These insects are unlikely to be confused with any other insect native to the UK (see figure 4).

Adults

Adults at rest (Fig. 1) have a blackish head and grey or pinkish wings with black spots and are 25mm long and 12mm wide. The tips of the wings are a combination of black rectangular blocks with grey outlines. When startled or flying the spotted lanternfly will display its hind wings that are red and black blocks with a white stripe between them. The red portion of the wing is also adorned with black spots. The abdomen is a yellowish white with bands of black on the top and bottom. Adult spotted lanternflies can move quickly and are strong jumpers, but weak fliers.

Figure 5. Life stages of *Lycorma delicatula.* (left) Egg mass on inanimate object (vineyard post), (right) nymphal and adult stages of *L. delicatula.* (© Pennsylvania Department of Agriculture (US) via EPPO Global database)

Detection and inspection methods

Visual inspection

For detection purposes, key adult hosts include *A. altissima* (if present), *Acer*, birch, walnut, willow and *Vitis*, whilst the nymphs can be found on herbaceous hosts and younger branches in spring, with later instars moving to the woodier hosts and trees such as *Acer, Ailanthus, Juglans* and *Vitis* (CABI, 2020; EFSA, 2023).

Eggs, including old egg masses can be detected across a wider timeframe, although they are often difficult to detect. As above, these may not be limited to plant hosts but could be laid on inanimate objects such as bark, stone, wood, metal, plastic and stiff fabrics (CABI, 2020).

CABI (2020) and Defra (2022) note that citizen science can be useful, with public awareness raising being effective given the distinctive features of the pest and its gregarious nature. Defra has produced a pest alert and factsheet which could be used for awareness raising in the UK:

Pest alert - https://planthealthportal.defra.gov.uk/assets/factsheets/Pest-alert-Lycorma-delicatula-update.pdf

Factsheet - https://planthealthportal.defra.gov.uk/assets/factsheets/Lycorma-delicatula-Defra-fact-sheet-Revised2022.pdf

Trapping

A multitude of traps have been tested for the monitoring and trapping of *L. delicatula*. This includes light traps, flight interception traps, adhesive tree band traps and physical traps. These are explored in more depth below.

Comparative testing by Nixon *et al.* (2023) found that physical traps such as circle traps were as effective as adhesive tree bands in areas of low pest density and as such these may be best suited for early detection. At high densities there was no significant difference in catch between the traps tested (circle traps, sticky bands and circle traps with replaceable bags). This corroborates testing carried out by Francese *et al.* (2020) who found that circle trunk traps caught more late instars and adults than adhesive or flight intercept traps, with the authors recommending their use based on effectiveness, ease of use and reusability.

Light traps

Light traps have been used in laboratory studies and have shown that the pest orientates towards shorter wavelengths of light, with UV (395-410nm) found to be attractive. This is contradicted by field studies in South Korea and the USA where no pests were captured in UV light traps in the field (Lee *et al.,* 2019).

Flight interception traps

Studies by Francese *et al.* (2020) compared flight intercept traps to adhesive and physical traps. The flight intercept traps used were intercept panel traps where the insects fly into a panel and slide into a collection device, and a large prism trap covered in adhesive. Neither of these strategies were as effective as the other trapping methods in the study.

Adhesive tree band traps

These traps exploit the pests behaviour by capturing adults and later instars as they migrate up the trunks of trees. Adhesive bands are installed at the base of trees and replaced as they become full. Challenges with this method include messy installation and the need for frequent replacement as they become covered in the target organism (in areas of high pest density), non-target organisms and debris. Fourth instars and adults have also shown an ability to escape or avoid capture (Francese *et al.*, 2020). Work by Choi *et al.* (2012) has shown that brown traps are more effective than blue or yellow.

A similar alternative are tree bands where the adhesive faces inwards towards the trunk. One example is the BugBarrier tree band (https://treebands.com/home) where cotton wool is first wrapped round the tree and the sticky plastic attached on top of this facing inwards. This minimises the bycatch of debris and other non-target organisms (CABI, 2020; Francese *et al.*, 2020; MPI, 2020).

Physical traps

The physical traps noted in the literature are often based on a modified pecan weevil trap (see figure 6) (circle or funnel trap) (MPI, 2020; Francese *et al.*,2020; Nixon *et al.*, 2020b). In these a net or screen funnel surrounds the tree, tapering to the top. This guides migrating pests into a non-return collecting vessel. Nixon *et al.* (2020b) have shown that the catch of these traps matches or exceeds that of adhesive traps whilst reducing the level of non-targets caught.

Further work by Nixon *et al.* (2023) showed that circle traps placed at 1m above the ground caught more adults than those placed 0.5m from the ground, with traps placed on the preferential host *A. altissima* and *J. nigra* catching more pests. Checking traps can be left for up to three weeks although two weeks was preferred as samples may degrade during this time.

Lures

Methyl salicylate lure (AlphaScents, West Linn, OR) has previously been shown to be attractive to all life stages of *L. delicatula*, when used in combination with physical and adhesive traps (Desko et al. 2020, Francese et al. 2020 via Lindley-Klassen, 2023). However, its success has been found to be limited in field situations, with work by Nixon *et al.* (2020b) finding no significant difference between baited and unbaited traps on nympha and adult catches. Research to identify other attractants is ongoing (Nixon *et al.*, 2023).

Figure 6. Example traps used against *Lycorma delicatula.* Adhesive trunk band (left), physical trap based on a pecan weevil trap (middle) and use of non-trees for trapping using adhesive bands and methyl salicylate lure (right) © Laura Nixon (USDA-ARS)

Environmental DNA (eDNA) analysis

Sampling honeydew and analysing for eDNA presence has been found to be an effective method for early detection, with EFSA (2023) noting that it could be applied in buffer zones of outbreaks. However, there could be significant cost implications associated with this surveillance method reducing its feasibility.

Distribution

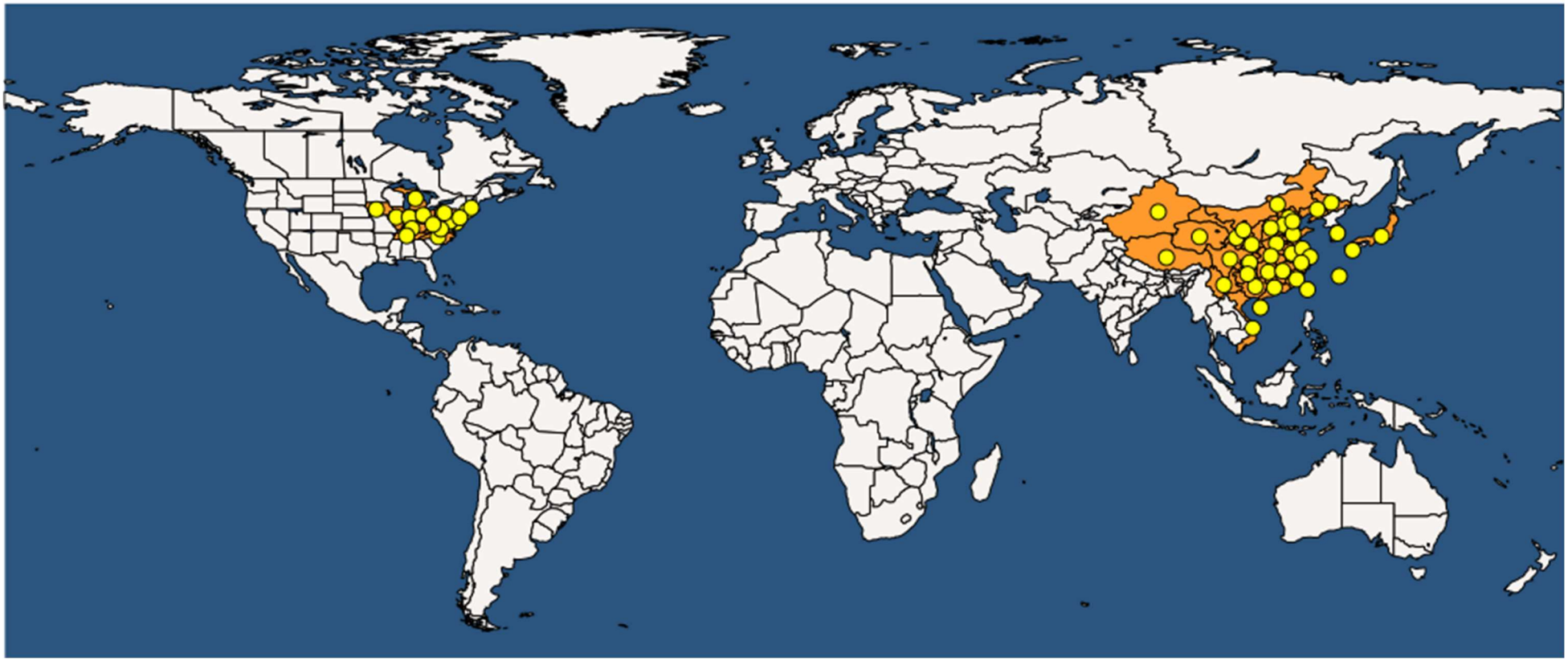


Figure 7. *Lycorma delicatula* distribution as of March 2024. (Source: EPPO, 2024). The link below provides up to date distribution data.
https://gd.eppo.int/taxon/LYCMDE/distribution

History of introduction/spread

Lycorma delicatula is native to China and south-east Asia. Within this region, the pest was introduced into the Republic of Korea in 2004 and Japan in 2008, although there are sporadic and questionable reports of the pest in both countries from the 1930s onwards (CABI, 2020). However, following its introduction in 2004, it has since become widespread in the Republic of Korea but remains limited in distribution within Japan (Honshu, Kyushu and Ryuku) (EPPO, 2021).

In 2014 it was introduced into Pennsylvania in the USA and has since spread throughout the northeast Mid-Atlantic region via natural dispersal and hitchhiking. It is currently present in the US states of Connecticut, Delaware, Columbia, Illinois, Indiana, Iowa, Kentucky, Maryland, Massachusetts, Michigan, New Jersey, North Carolina, Ohio, Pennsylvania, Tennessee, Virgina and West Virginia (EPPO, 2021; 2024).

As yet there have been no official reported findings of *L. delicatula* in Europe or the UK. However, in July 2024 a record of *L. delicatula* in Madrid was added to the iNaturalist observation website, but at time of writing it is too early to tell if this is a genuine record or how significant the finding is (https://uk.inaturalist.org/observations/230083010).

A distribution map of *L. delicatula* is provided in figure 5, and up to date distribution data can be found on the EPPO global database - https://gd.eppo.int/taxon/LYCMDE/distribution.

Means of movement and dispersal into the UK

Pathways assessed by Lindley-Klassen (2023) in the Defra Pest Risk Analysis (PRA) were hitchhiking, plants for planting and wood products imported from countries in the known distribution. The highest risk pathway was concluded to be hitchhiking as this has been the major cause of long-distance large-scale spread of the pest. This is particularly relevant for the egg stage which is inconspicuous. The other pathways could become more relevant if other countries with which the UK trades in large volumes become infested.

Once introduced, dispersal is likely to be associated with accidental movement on cargo or plants for planting as well as via natural dispersal, with Urban (2020) reporting that fourth instar nymphs travelled an average of 15 m in 15 minutes *in vitro* and Keller *et al.* (2020) reporting a maximum nymphal dispersal distance of 65 m over a 10-day period within a deciduous forest. Adults can disperse by flight although observations in the field suggest these are relatively short (under 30 m) (EPPO, 2021).

Hitchhiking

Hitchhiking is thought to be how the pest has spread from China to other regions of Asia and the USA. Whilst this is an unlikely pathway for nymphs and adults due to their need to feed on host material, eggs are not limited by this and can be laid on inanimate materials, providing a means of introduction from any infested country with any cargo shipment (MPI, 2020; Lindley-Klassen, 2023). This pathway was also considered by the Ministry for Primary Industries to be the most likely pathway for an introduction into New Zealand with a low likelihood (MPI, 2020).

Plants for planting

As the pest is polyphagous there is a wide range of hosts with which the pest could be associated. As with hitchhiking, the egg stage is inconspicuous and therefore more likely to remain undetected, whilst nymphs and adults may become disturbed or spotted during plant inspections (MPI, 2020). Due to legislative requirements, this pathway is more likely to be an issue for the UK if the pest becomes established in the EU as the requirements are generally higher from third countries (Lindley-Klassen, 2023).

Wood products

There is trade between the UK and the known distribution (USA and Asia) of wood products, but treatments such as debarking, chipping and heat treatment suggest that this pathway is unlikely. However, there is the possibility that eggs are laid on wood products following treatment which could allow for introductions into new areas (Lindley-Klassen, 2023).

Phytosanitary status

Table 1. Global phytosanitary categorisation of *Lycorma delicatula* (Source: EPPO, 2024).

Country/NPPO/RPPO	List	Year of addition
AFRICA		
Morocco	Quarantine pest	2018
AMERICA		
Canada	Quarantine pest	2019
EUROPE		
Switzerland	A1 list	2022
UK	Quarantine Pest	2023
RPPO/EU		
EPPO	A1 list	2016

Country/NPPO/RPPO	List	Year of addition
EPPO	Alert list (formerly)	2015-2016
EU	A1 Quarantine pest	2021

Control

Cultural controls and sanitary methods

Mass trapping

Once introduced, management is likely to be difficult and as such early detection is key via surveillance and in particular trapping. More information on this can be found in the Detection and inspection methods section. These traps may also be used for mass trapping to reduce population levels.

Work by Lewis *et al.* (2023) in Pennsylvania and Delaware has resulted in the development of a 'lamp shade trap' which was shown to be effective for trapping ovipositing females, who laid an average of 47-54 egg masses per trap in productive areas, with few egg masses found outside of the trap on the host tree. This utilises roofing material and upholstery batting material to funnel migrating females upwards into the trap to oviposit. These can periodically be removed, and the egg masses disposed of. A design for this trap can be found here - https://www.frontiersin.org/journals/insect-science/articles/10.3389/finsc.2023.1154510/full#supplementary-material.

Host removal

Both the New Zealand and UK Pest Risk Analyses (PRAs) note that the removal of key hosts such as *A. altissima* limits impacts of the pest. (MPI, 2020; Lindley-Klassen, 2023). Uyi *et al.* (2021) found that the fitness of the pest was reduced in the absence of *A. altissima,* and the lack of this host led to a reduction in egg masses, slower development and reduced survival. *Ailanthus altissima* is not an obligate host, and the authors note that in the absence of *A. altissima* other hardwood trees can be utilised by the pest but fitness is likely to be reduced, possibly due to the lack of defence alkaloids that can be sequestered from feeding on *A. altissima* (MPI, 2020; Uyi *et al.*, 2021). However, Urban & Leach (2023) report that more work is needed to substantiate host removal as an effective control measure, or whether removal of *A. altissima* increases the pressure on other nearby hosts.

Due to this host preference, there is a possibility of utilising this host as a trap or sentinel species. The USDA recommend removing 90% of *A. altissima* and retaining 10% as trap or sentinel trees (sprayed with a systemic insecticide) in their guidance for spotted lanternfly control for businesses - https://www.vdacs.virginia.gov/pdf/spotted-lanterfly-businesses.pdf (USDA, 2024). This removal can be systematically done by removing from

the perimeter of demarcated zones towards the centre to avoid further spread. Following tree removal, the site should be treated with herbicide to prevent regrowth.

Physical removal of egg plaques

Urban and Leach (2023) suggest the mechanical removal of the egg mass stage as a useful tool for small scale outbreaks with sufficient resource for surveying the outbreak area but given the cryptic nature of the egg masses it is likely to be impractical. That being said the use of egg-scraping cards has proved to be effective in Pennsylvania where they were distributed as an outreach tool, with 17,000 egg masses reportedly destroyed by the public in 2015 using these (EPPO, 2016). Feasibility is also likely to be an issue for methods such as exclusion netting and the use of jet washing of egg masses which would only be feasible in certain situations and unlikely to be implemented on a commercial scale.

Attract and kill strategies

The use of attractants and repellents is also discussed in the literature, with the exploiting of various biological traits being explored as a potential means of behavioural control. For instance, utilising the host preference of the pest by creating low densities of *A. altissima* and making systemic insecticide applications could be used as a potential attract and kill trap tree system (Lee *et al.,* 2019). This could help to target treatments which could subsequently reduce overall usage of insecticides.

Other work has found that *L. delicatula* adults are attracted to tall structures (Frank and Cowper, 2022; Urban and Leach, 2023). Frank and Cowper (2022) have reported sluggish and dead adults concentrated at the bases of skyscrapers and high-rise buildings in Philadelphia, suggesting that the buildings are behaving as ecological traps. Urban and Leach (2023) suggest this trait can be utilised to design attract and kill structures (alongside more traditional adhesive tree bands and circle traps). These can be arranged along habitat edges and again combined with insecticide applications to better target treatments.

Repellents

Conversely, work by Yoon *et al.* (2011) looked into potential repellents of fourth instar *L. delicatula.* They found that of the ten essential oils tested, lavender oil was the only one to result in a significant repellence of the pest *in vitro.* Following chromatographic and mass spectrometric analyses of the lavender oil, linalool was found to be the component which caused repellence to both females and nymphs. Further research into the use of attractants and repellents could help determine whether they could be built into effective push-pull strategies (Lee, 2019).

Vibroacoustics

Work by Rohde *et al.* (2022) has found that fourth instar and adult *L. delicatula* are attracted to broadcasts of 60-Hz vibroacoustic stimuli *in vitro.* There is potential that this is involved in aggregation and as such there may be potential in the future to use this for vibrational trapping, particularly if combined with semiochemicals or other stimuli used for aggregation.

Biological control

Predators

Various predators have been observed feeding on the pest including invertebrates, mammals and fish. However, the pest's ability to produce chemical defences following the sequestration of toxins from plant hosts may deter generalist predators and limit their impact (Dara *et al.,* 2015; Urban and Leach, 2023). Indeed Dara *et al.* (2015) report that birds have been observed to vomit following consumption of the pest.

Generalist invertebrate predators of *L. delicatula* have been identified in the Republic of Korea and the USA but it is reported that they are unlikely to have a significant impact on populations (CABI, 2020). These include *Apoecilus cynicus* (Hemiptera: Pentatomidae), *Arilus cristatus* (Hemiptera: Reduviidae), *Sphedanolestes impressicollis* (Hemiptera: Reduviidae), *Velinus nodipes* (Hemiptera: Reduviidae) and *Isnydus obscurus* (Hemiptera: Reduviidae) (Liu *et al.*, 2017; Lee *et al.*, 2019). None of these are present or have been approved for release in the EPPO region (EPPO, 2023).

Parasitoids

Three parasitoids of *L. delicatula* are highlighted in the literature; *Anastatus orientalis* (Hymenoptera: Eupelmidae), *Dryinus browni* (Hymenoptera: Dryinidae) and *Ooencyrtus kuvanae* (Hymenoptera: Encyrtidae) (CABI, 2020; MPI, 2020).

Anastatus orientalis is an egg parasitoid native to China. Species within the *Anastatus* genus are primary endoparasitoids which attack eggs of a range of species within the Diptera, Dictyoptera, Coleoptera, Hemiptera, Lepidoptera, Orthoptera and Mantodea families. As such, many species within the genus have been considered or have been released as part of classical biological control strategies against a range of pests including *L. delicatula, Lymantria dispar* (gypsy moth) and *Halyomorpha halys* (brown marmorated stink bug) (Gómez Marco *et al.*, 2023). Parasitism rates of *A. orientalis* against *L. delicatula* in China can reach up to 80% helping to keep the pest in check (Dara *et al.*, 2015; MPI, 2020; Mazoor *et al.*, 2021). However, host specificity testing in the USA found that *A. orientalis* was able to parasitise and develop within both Hemipteran and Lepidopteran eggs with seven families within these groups affected (Coreidae, Erebidae, Fulgoridae (the family in which *L. delicatula* sits), Lasiocampidae, Pentatomidae, Saturniidae and Sphingidae). This shows that the wasp is polyphagous, and releases

could therefore have potential non-target impacts and would need to be assessed critically (Gómez Marco *et al.*, 2023).

Dryinus browni is a nymphal parasitoid which has been found to attack 2nd and 3rd instar nymphs in China (MPI, 2020). The wasp lays eggs in the wing bud of nymphs and undergoes a single generation a year (Dara *et al.*, 2015). Parasitism rates are reported as between 12.5-43.5% (Yan *et al.*, 2017 via Lee *et al.*, 2019). The parasitoid is being considered as part of a USDA classical biocontrol research program (MPI, 2020). Another *Dryinus* species, *D. sinicus*, is also being studied as a potential biocontrol following its discovery in China (Urban and Leach, 2023).

Ooencyrtus kuvanae is an egg parasitoid native to Asia but which has been introduced to other regions such as Africa, Europe and North America for the control of gypsy moth. More recently it has been found to attack eggs of *L. delicatula* in North America (Liu and Mottern, 2017). Here, it has been shown to keep populations of *L. delicatula* in check but to a lower extent in comparison to *A. orientalis,* with mean rates of parasitism recorded across four separate sites as approximately 35.4% (Liu, 2019).

All the parasitoids above would need to be approved for release as a non-native classical biological control agent. Of these only *O. kuvanae* is currently approved for release in the EPPO region (for control of gypsy moth in Algeria, Czechia, Kazakhstan, Morocco, Moldova, Portugal, Russia, Spain, Ukraine and Uzbekistan) (EPPO, 2023). None are approved for release in the UK. More information on releases in England is available here - https://planthealthportal.defra.gov.uk/pests-and-diseases/uk-plant-health-risk-register/plant-health/non-native-biocontrol-agents.cfm.

Entomopathogens

Batkoa major, Beauveria bassiana, Metarhizium pemphigi and *Ophiocordyceps delicatula* have all been found to cause reductions in population levels of the pest in the field. Observations in 2018 of population decline in an outbreak of *L. delicatula* in Pennsylvania found adults to be infected with the entomopathogens *B. major* and *B. bassiana.* Those killed by the former remained on tree trunks, whilst the cadavers infected with *B. bassiana* fell to the ground (Clifton *et al.*, 2019). Further studies in the same area found *L. delicatula* infected by the additional entomopathogens *M. pemphigi* and *O. delicatula* but these were found at lower levels than *B. bassiana* and *B. major* (Clifton *et al.*, 2021). Of these *B. major* was found to cause the most significant declines (Clifton *et al.*, 2019; Urban and Leach, 2023), but given *B. bassiana* is available in commercial formulations this may be the most feasible treatment for management of the pest. Clifton and Hajek (2022) have tested the efficacy of *B. bassiana* products against *L. delicatula*, with the pest showing low rates of survival in lab bioassays. *Beauveria bassiana* is currently available for use in the UK, as part of formulated products which have approvals across a wide range of crops (HSE, 2024).

Chemical control

In the USA, chlorpyrifos, a broad-spectrum organophosphate, was very effective against egg masses (100% mortality) and paraffinic oil offered intermediate mortality (71%), whilst thiamethoxam (a neonicotinoid) and bifenthrin (a pyrethroid) offered control of 50% or greater of adults after two weeks (Leach *et al.* 2019 via Lindley-Klassen, 2022).

In studies from the Republic of Korea, 100% mortality of nymphs (after 48 hours) was found after exposure to 26 insecticides *in vitro.* These included organophosphates, carbamates, pyrethroids and neonicotinoids (Shin *et al.*, 2010 via Lee *et al.*, 2019). Effective actives from this and other trials in the Republic of Korea against the pest are reported to be chlorpyrifos, clothianidin, deltamethrin, dinotefuran, etofenprox, etofenprox + diazinon, dinotefuran and imidacloprid (Lee *et al.*, 2019). Many of these were ineffective against eggs with the most effective active against eggs found to be chlorpyrifos (Lee *et al.*, 2019; MPI, 2020). Of these actives, only deltamethrin and etofenprox are currently approved for use in the UK.

Natural pesticide options such as plant-based extracts (including pyrethrum, sophora and neem) were found to cause 95% mortality rates against adults but were less successful against nymphs and re-infestation rates were found to be high (Lee *et al.*, 2019; MPI, 2020).

Impacts

In its native distribution, *L. delicatula* is not considered a major pest possibly due to the suppression of populations by natural enemies. However, it can cause impacts on *A. altissima* in some regions, previously being considered a significant pest when the host was commonly used for forestry plantings. Reported impacts mainly come from areas of introduction, namely the Republic of Korea, Japan and the USA (EPPO, 2016).

Economic impact

In introduced areas the pest has caused economic losses to vineyards, ornamental nurseries and sawmills (Uyi *et al.*, 2021). This is due to a combination of direct and indirect effects from the pest's phloem feeding. In the UK, grapevines, orchard fruit and soft fruit have been highlighted as hosts particularly at risk. However, due to its polyphagy the risk is not limited to these, and other sectors such as ornamental growers and traders may also be affected (Lindley-Klassen, 2023).

In the Republic of Korea, the greatest damage has been seen to grapevines, with accumulated sooty mould reducing the photosynthetic capacity of plants (Urban, 2000). This damage has led to declines in the quality and yield of grapes and is reported to cause host mortality with losses of up to 80.8% in organic table grape production reported (20.9% losses in conventional vineyards) (EPPO, 2016; MPI, 2020).

In the USA Uyi *et al.* (2021) reports that the pest is projected to cause $42.6 million in damages per annum if it spreads across Pennsylvania. The author notes that in the ornamentals and forest product industries, the major economic impacts would primarily be due to the cost of management measures to comply with quarantine restrictions. This is also seen in Pennsylvania vineyards, with the average number of insecticide applications increasing from 4.2 to 14.0 per annum, although 90% yield losses due to direct pest damage have also been reported (Urban, 2020). Impacts on orchard fruits in the USA appear to be minimal (Urban, 2022; Urban and leach, 2023).

Environmental impact

Lycorma delicatula has a wide host range which would enable it to damage a large number of hosts in the wider environment. This is exacerbated by the differing diets of the nymphal stages (EPPO, 2021; Defra 2022). The preferential host is *A. altissima* which is considered an invasive species in the UK, so pest damage to this host or any control measures such as removing this host arising from the presence of the pest could be determined to be beneficial to the environment (MPI, 2020). However, in areas where *A. altissima* and the pest is present the host appears to be resilient (EPPO, 2016). In areas without this host, control measures will likely cause negative environmental impacts.

Social impact

Social impacts are linked to the polyphagous nature of the pest which enable it to feed on a wide range of plants which are grown by UK gardeners. Despite this, the Defra PRA concluded that *L. delicatula* would be unlikely to build to the population levels seen in the USA, where it has been reported as a nuisance pest across tourism, business and residential sectors (Urban and Leach, 2023). The social impacts are therefore likely to be lower in the UK, although there is some uncertainty associated with this. However, there is still likely to be some level of impact given it is a nuisance pest and may be seen in relatively large numbers. This is also the case in urban areas where aggregations form at the base of large buildings due to their cyclical climbing and falling behaviour (Defra, 2022; Lindley-Klassen, 2023).

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