Department for Environment Food & Rural Affairs

Pest specific plant health response plan:

Outbreaks of *Popillia japonica*

Figure 1. A feeding aggregation of *Popillia japonica* adults. © Watts_Photos (2021) under licence (https://creativecommons.org/licenses/by/2.0)

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Any enquiries regarding this document should be sent to us at:

The UK Chief Plant Health Officer

Department for Environment, Food and Rural Affairs

Room 11G32

York Biotech Campus, Sand Hutton

York

YO41 1LZ

Email: plantpestsrisks@defra.gov.uk

www.gov.uk/defra

Executive summary

Background	
Regulation	GB Quarantine pest
Key Hosts (2.3*)	Highly polyphagous including but not limited to *Acer* spp., *Aesculus* spp., *Asparagus officinale*, *Betula* spp., *Castanea* spp., *Glycine* spp., *Hibiscus* spp., *Juglans* spp., *Malus* spp., *Platanus* spp., *Populus* spp., *Prunus* spp., *Rhododendron* spp., *Rosa* spp., *Rubus* spp., *Salix* spp., *Tilia* spp., *Ulmus* spp., *Vaccinium* spp., *Viburnum* spp., *Vitis* spp., *Zea mays,* other soft fruits and some ornamental herbaceous plants
Distribution	Canada, China, India, Italy, Portugal (Azores), Russia (Far East), Switzerland and the USA
Key pathways	Plants for planting and produce
Industries at risk	Amenity, garden centres, nurseries, wider environment
Symptoms (2.3)	<u>Adults</u>: Feeding damage to fruits, flowers and leaves <u>Larvae</u>: Feeding on roots leads to reduced host vigour, thinning and yellowing of turf, wilting, reduced yields and plant death
Surveillance	
Demarcated zones (5.33)	Infested zone = 100 m around known infested plants Buffer zone = ≥ 1 km
Surveillance activities (5.40-5.48)	• Visual surveys will be carried out in the infested and buffer zone for adults or larvae at the appropriate time of year • Pheromone trapping surveys
Response measures	
Interceptions (5.1-5.6)	• Infested consignments should be destroyed or re-exported • Tracing exercises carried out where required • UKPHINS notification made
Outbreaks (5.49-5.71)	<u>Eradication</u> • Movement restrictions • Removal and destruction of infested hosts • Case by case treatment of non-infested key hosts within 100 m • Foliar insecticide treatments • Pheromone trapping <u>Containment</u> • Movement restrictions • Removal and destruction of heavily infested hosts identified during annual surveys • Monitoring of key at risk hosts • Pheromone trapping Additional measures which may be of use in certain situations are also provided in 5.66-5.71
Key control measures	
Biological	*Steinernema carpocapsae* and *H. bacteriophora*
Chemical	The PHSI will advise on an appropriate insecticide treatment regime in consultation with the Defra Risk and Horizon Scanning team
Cultural	Destruction of infested hosts, pheromone trapping, rotivation, reduced irrigation
Declaration of eradication	
Eradication can be declared if no pest is detected for the duration of at least two lifecycles of the pest and this period will be a minimum of 4 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 *Popillia japonica* (Japanese beetle) 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 *P. japonica* being detected in their territories.

1.3 This document will be used in conjunction with the *Defra Contingency Plan for Plant Health in England* (https://planthealthportal.defra.gov.uk/assets/uploads/Generic-Contingency-Plan-for-Plant-Health-in-England-FINAL-2.pdf), 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 *P. japonica* and to make stakeholders aware of the planned actions.

2. Summary of threat

2.1 *Popillia japonica*, the Japanese beetle, is native to Japan where it is not considered a significant pest. The pest is also present in Russia, although this is in the far east and limited to the small island of Kunashir, 30 km from the Japanese coast (CABI, 2019; EFSA, 2018). It appears to have been introduced into the eastern states of the USA in the early 20th Century where it rapidly established and spread westwards, and is now considered a major pest of turf, crops and ornamental species (EFSA, 2018; Korycinska, 2015). It was likely to have been introduced with soil associated with iris bulbs, but it is also suspected there may have been earlier introductions via Japanese nursery stock. In the USA, it is subject to interstate control measures to prevent further spread to the central and western states and there has been some limited spread northwards into Canada (Korycinska, 2015) (Figure 8).

2.2 In Europe, the pest was accidentally introduced into the Azores in the 1970s, likely via US military aircraft, and has since spread throughout the archipelago (EFSA, 2019). In 2014, an outbreak near two airports in Northern Italy led to the initiation of control measures, although eradication has since been declared unfeasible by the European Commission. The pest remains under official control, in order to contain the pest and prevent its spread (EFSA, 2018). This is also the situation in Switzerland where the pest was found in 2017 close to the Italian demarcated zone and was reported in high numbers in 2020 (EPPO, 2020c).

2.3 *Popillia japonica* is a highly polyphagous plant pest, in both the adult and larval stages, and has thus far been recorded feeding on over 700 plant species (EFSA, 2018). Many of the key host plants in North America are also economically important UK plant species. Hosts of adult *P. japonica* of importance to the UK include *Acer* spp., *Aesculus* spp., *Asparagus officinale*, *Betula* spp., *Castanea* spp., *Glycine* spp., *Hibiscus* spp., *Juglans* spp., *Malus* spp., *Platanus* spp., *Populus* spp., *Prunus* spp., *Rhododendron* spp., *Rosa* spp., *Rubus* spp., *Salix* spp., *Tilia* spp., *Ulmus* spp., *Vaccinium* spp., *Viburnum* spp., *Vitis* spp., *Zea mays,* other soft fruits and some ornamental herbaceous plants (EPPO, 2020b). EPPO also suggest *Corylus avellana*, *Phaseolus vulgaris* and *Wisteria* spp. are major hosts (EPPO, 2020a).

2.4 Due to their limited mobility the feeding damage caused by larvae of *P. japonica* is often restricted to the oviposition sites. They feed on the roots of a number of grasses, weeds, and garden and nursery crops including ornamentals (CoL, 2020). They are considered a significant pest of lawns and turf (EFSA, 2018), but have also been reported as causing significant damage to nurseries, seedbeds, orchards, field crops, landscape plants, turf and garden plants and up to 50% of plants in strawberry beds (EFSA, 2019; EPPO, 2016; Fleming, 1972).

2.5 Adult beetles feed gregariously on leaves, fruits and flowers, whilst larvae feed on the host's roots before emerging from the soil. Adults are defoliators, often feeding in a top down nature as part of aggregations, completely skeletonising leaves which later become necrotic and prematurely senesce (CABI, 2019; EFSA, 2018) (Figure 6).

2.6 Larval feeding damage is non-specific mechanical damage which destroys roots or causes disruption to their normal function. Symptoms of root damage include reduced host vigour, thinning and yellowing of turf, wilting, reduced yields and plant death (EFSA, 2019; EPPO, 2020b). These symptoms may be exacerbated by birds and mammals digging up infested turf to find and eat the larvae. These symptoms may be confused with native pests including *Phyllopertha horticola,* the garden chafer, the adult of which also superficially resembles *P. japonica* (Figure 2).

2.7 *Popillia japonica* is considered to be one of the most widespread and destructive pests of turf, landscapes and nursery crops in North America (EPPO, 2020b; Potter & Held, 2002). It has been reported to feed on at least 295 species of plants, with losses attributed to larval damage equating to $234 million per year in the USA, and losses attributed to adult damage considered to be equivalent or greater (Klein & Lacey, 1999).

2.8 Whilst adults may be intercepted on plants for planting or harvested plant products, particularly now the pest is present in the EU, the risk of this pathway into the UK is considered to be low as adults are likely to be spotted pre-export during quality checks or disturbed during processing and packing (Korycinska, 2015). Larvae, on the other hand, are more likely to be introduced into the UK, as due to their cryptic nature they can enter in soil associated with plants. Soil from outside the EU is permitted if associated with plants to sustain their vitality and complies with the conditions in Annex 7A of The Plant Health (Phytosanitary Conditions) (Amendment) (EU Exit) Regulations 2020, although a lack of imports of this nature from North America or Japan mean a higher risk is posed from larvae entering in soil associated with imports of EU plants. In particular plants from the Azores and areas of Italy or Switzerland where the pest is present pose an increased risk, as fewer inspections for EU movements provide the pest with opportunities to spread and establish before detection. Introductions of the pest into the EU have also been attributed to the pest arriving as a contaminant on inanimate goods into ports of entry from areas where the pest is present, and disseminating to nearby hosts (CABI, 2019; Hamilton *et al.*, 2007; Korycinska, 2015).

2.9 Historically, there have been five interceptions of *P. japonica* at UK ports of entry, all associated with goods from the pest's known distribution. There have been no interceptions since 1970, although a *Popillia* sp. adult was intercepted on computer parts from Taiwan at Prestwick Airport in 2003. However, it is thought that this was one of a number of closely related East Asian species and not *P. japonica* (Korycinska, 2015).

3. Risk assessments

3.1 *Popillia japonica* has an unmitigated and mitigated UK Plant Health Risk Register score of 40 (as of December 2020). 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=6296).

3.2 Pest categorisation has been carried out by the European Food Safety Authority (EFSA, 2018), a pest risk analysis has been carried out by the UK (Korycinska, 2015), and *P. japonica* is included in commodity specific pest risk analyses produced by Australia (Department of Agriculture, Water and the Environment, 2011, 2014a, 2014b).

3.3 The categorisation and analysis conducted by EFSA and the UK concluded that *P. japonica* has the potential to establish and cause economic damage outdoors in the UK, but in a limited region and to a lower extent than areas where it is considered a major pest. This is because the beetle is likely to have an extended lifecycle in the UK and will not build up to sufficient numbers to cause significant damage.

3.4 CLIMEX modelling suggests that in the future, the effects of climate change could lead to a larger area of the UK being at risk of *P. japonica* establishment. This increased climatic suitability combined with an abundance of suitable hosts, in particular rich pastureland, means that in the future the UK is at an increased risk of *P. japonica* becoming a significant pest in the UK if introduced, especially as the control or eradication of established populations would be difficult. However, this modelling still concluded that a two year lifecycle is the most likely scenario in the UK (Kistner-Thomas, 2019).

4. Actions to prevent outbreaks

4.1. *Popillia japonica* is a GB quarantine pest (Schedule 1 of The Plant Health (Phytosanitary Conditions) (Amendment) (EU Exit) Regulations 2020) and is therefore prohibited from being introduced into, or spread within, GB.

4.2. *Popillia japonica* is an EPPO A2 listed pest and is therefore recommended for regulation by EPPO member countries. An EPPO standard has been produced with procedures for official control and is available using the link below. (https://gd.eppo.int/download/standard/687/pm9-021-1-en.pdf)

4.3. *Popillia japonica* is an EU Quarantine Pest and is therefore prohibited from being introduced into, or spread within the Union Territory.

4.4. The Plant Health Service should be aware of the measures described in this plan and be trained in responding to an outbreak of *P. japonica*. It is important that capabilities in detection, diagnosis, and risk management are available.

4.5. Due to the polyphagous nature of *P. japonica*, the surveillance, monitoring and precautionary measure requirements considered are limited to the hosts listed in 2.3 as they are alluded to as major hosts in the literature. The legislative requirements of these can be found in Appendix A.

5. Response

Official action to be taken following the suspicion or confirmation of *Popillia japonica* on imported plants

5.1. If *P. japonica* is suspected by the Plant Health and Seeds Inspectorate (PHSI) or Forestry Commission (FC) to be present in a consignment moving in trade, the PHSI or FC must hold the consignment until a diagnosis is made. Samples should be sent to Fera Science Ltd., Plant Clinic, York Biotech Campus, Sand Hutton, York, YO41 1LZ (01904 462000) or Forest Research, Alice Holt Lodge, Wrecclesham, Farnham, GU10 4LH (0300 067 5600), in a sealed rigid container, which is not liable to be crushed, within at least two further layers of containment. Damaged eggs, larvae or pupae should be submitted in tubes of 70% ethanol to prevent further degradation if possible.

5.2. In instances where either live adults or larvae are suspected, the inspector shall determine the level of plant health risk in the circumstances taking into account the weather conditions, the time of year and the likelihood of the pest escaping and order the appropriate remedial action. This may involve, if possible, the reloading of material back into the freight container and closing the doors or requiring the consignment to be covered to reduce the risk of insect escape.

5.3. When an infestation of *P. japonica* is confirmed, the PHSI or FC should advise the client of the action that needs to be taken by way of an official plant health notice. The consignment should be destroyed by either wood chipping, incineration or deep burial.

5.4. Where there is a high risk of escape before destruction, fumigation and/or foliar insecticides may be used under guidance from the Defra Risk and Horizon scanning team. Insecticides containing pyrethroids or insecticidal soaps as active ingredients have been shown to be effective against adults and are available for use on certain crops in the UK (EPPO, 2016; Korycinska, 2015; Potter & Held, 2002).

- Prior to any insecticides being used, the risk posed by the insecticides to people and the environment will be assessed.

5.5. If all or part of the consignment has not been held and has been distributed to other premises prior to diagnosis, trace forward and trace back inspections should take place upon suspicion or confirmation of *P. japonica*. Details of recent past and future consignments from the same grower/supplier should also be obtained.

5.6. The Defra pest factsheet to raise awareness of *P. japonica* and its symptoms should be distributed to packers/processors and importers where *P. japonica* has been found, and, where suitable, to those in the local area and those associated with the infested premises. The pest factsheet for *P. japonica* can be found on the Plant Health Portal - https://planthealthportal.defra.gov.uk/assets/factsheets/popillia-japonica-factsheet.pdf.

Actions to be taken following the suspicion of a *Popillia japonica* outbreak

Official actions

5.7. Suspect outbreaks will be assessed on a case by case basis. An Outbreak Triage Group (OTG), chaired by the CPHO or deputy and including specialists from APHA, Defra and other organisations, should be set up to assess the risk and decide on a suitable response. Where appropriate, the OTG will also decide who the control authority will be, and the control authority 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 to outline the operational plan. See the *Defra Contingency Plan for Plant Health in England* for full details.

5.8. The OTG will set an alert status, which will consider the specific nature of the outbreak. These 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, a suspected infestation of *P. japonica* in a nursery, or garden centre is likely to be given a black alert status, whereas an outbreak in the wider environment, orchard or an amenity or turf scenario may be given an amber alert status. A black alert status indicates a significant plant pest with potential for limited geographical spread whereas an amber alert status indicates a serious pest with potential for relatively slow but extensive spread and/or major economic, food security or environmental impacts.

5.9. When suspected adults or larvae of *P. japonica* are found in association with plants for planting or plant products of its host plants, these should be prevented from leaving the site, other than for destruction under statutory plant health notice by deep burial, incineration or another approved method.

5.10. If suspect adults or larvae of *P. japonica* are found at a nursery or garden centre when not associated with plant material, suspect material should be placed on hold pending further investigation. The precautionary measure of holding all key host plants and any other potential hosts on the nursery may also be taken in some cases at this stage (see 2.3).

5.11. If appropriate or if there is a high risk of escape the use of insecticides may be required as described in 5.4.

5.12. Eggs, larvae, pupae and adults have the potential to be transferred within soil associated with non-host material and on equipment and machinery. Movement of material, equipment and machinery from suspected infested areas should therefore be restricted. However, if movement is necessary, it should be done under a statutory plant health notice and the material, equipment and machinery should be thoroughly cleaned in the designated suspected infested or quarantine areas to remove any soil and life stage of *P. japonica* as described in 5.74.

5.13. Access to any suspected infested areas should be restricted to essential trained staff only. Wherever possible, work should be carried out within uninfested areas, before working in suspected infested areas and there should be a sign in/sign out sheet to record all movements.

Additional measures which may be applicable to certain scenarios

5.14. 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 and work carried out as described in 5.13.

Preliminary trace forward / trace backward

5.15. If an infested consignment or host is considered as being the source of the suspect outbreak, information regarding the origins of any infested consignments should be used to locate other related and therefore potentially infested consignments moving to and from the site. If applicable, the relevant NPPO should be contacted. For findings in the wider environment, where no trace forward or backward can be done, the most likely source should be identified and investigated.

5.16. In addition to tracing investigations relating to consignments, trace forward/back investigations linked to equipment, machinery and personnel in the infested premise or site should also be made.

Confirming a new outbreak

How to survey to determine whether there is an outbreak

5.17. Information to be gathered by the PHSI on the suspicion of an infestation of *P. japonica* in accordance with ISPM 6; guidelines for surveillance (https://www.ippc.int/en/publications/615/)

- The origin of the infested host plants or produce and their associated pathways.
- Details of other premises or destinations where the host plants/products have been sent, where *P. japonica* may be present.
- The layout of the premises and surrounding area (in relation to potential buffer zones of at least 1 km), including a map of the fields/cropping/buildings, at risk growers, and details of neighbouring crops, especially any commercial or non-commercial hosts in glasshouses.
- Details of the host variety, growth stage and any other relevant information.
- Description of the surrounding habitat, including all hosts.
- Area and level of infestation, including life stages and a description of symptoms (photos should be taken).
- The location of any known populations, including grid references.

- The date, time and location that any of the samples were taken,
- Current treatments/controls in place e.g. chemical treatments.
- 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/landowner.

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

5.19. Further to information gathering, samples of other infested plants should be taken to confirm the extent of the infestation. This will depend on where the finding is, e.g. other host material and boundaries in a nursery, or within 100 m of the finding in the wider environment. This initial survey will be used to determine if it is an isolated finding or an established outbreak.

5.20. 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

5.21. The adult is distinctive and can be found in high numbers on individual plants whilst feeding or mating (see Appendix A Morphology section). Above ground plant parts can therefore be visually inspected for these life stages. Heavy defoliation in a top down fashion, whilst not conclusive, is indicative of a *P. japonica* infestation. Adults are more visible on vegetation during cooler times of the day. For the Italian outbreak, sites are surveyed between June and August. However, emergence data from the Japanese island of Hokkaido, which is climatically similar to the UK shows emergence to be between the beginning of July and throughout August, with the maximum numbers being found in mid to late July, and it is suggested that this is when these surveys should be carried out in the UK (Clausen *et. al.*, 1927; Korycinska, 2015).

5.22. Eggs, larvae and pupae are found within the soil. In the area of the pest’s current distribution this is often associated with shadier or cooler areas of turf near to field edges and preferential host plants, which may be linked to soil moisture levels. However, this may differ in the UK climate. If areas of dead or dying turf are seen, the soil should be sampled by taking cores (no less than 12 cm in diameter) or cubic portions of soil (20 cm in depth, width and height) to inspect for larvae, pupae or eggs (EFSA, 2019). These are best taken during spring or autumn when the larvae are nearer the surface. The samples can then be crumbled onto a sheet or in a container and inspected for larvae which can be recorded and sent for identification as described in 5.1 (EPPO, 2016).

5.23. Trapping has been found to be effective and may be employed to attract any existing population within the infested area, especially if only symptoms of adult feeding damage are seen. These should be used with caution as laid out in 5.45.

5.24. Following the capture/putative identification of an adult, pupa or larva of the beetle, samples should be sent for confirmatory diagnosis as described in point 5.1. Each sample should be labelled with full details of the sample number, location (including grid reference if possible), variety, and suspect pest.

Diagnostic procedures

5.25. A diagnostic standard (PM7/074(1)) for identification of *P. japonica* has been produced by EPPO, available here - https://gd.eppo.int/taxon/POPIJA/documents. This contains a key to the European families of the Scarabaeoidea, enabling identification of the *Popillia* genus when used with keys proposed by Baraud (1992) and Arnett *et al.* (2002). This also contains detailed morphological descriptions of each life stage of *P. japonica*. No key to species is available as the genus *Popillia* is large, containing more than 300 species (EFSA, 2018).

5.26. There is a risk of adult *P. japonica* being misidentified as *Phyllopertha horticola* the garden chafer, a native species in the UK. Despite similarities in life cycle and biology, *P. horticola* lacks the white lateral tufts of hair on the abdomen and pygidium that are present on *P. japonica* (EFSA, 2019) (Figure 2).

Figure 2. (a) *Phyllopertha horticola* lacking lateral tufts of white hairs on the abdomen and pygidium © Camille Picard (2020) and (b) adult *Popillia japonica* with lateral tufts of white hairs on the abdomen and pygidium © Maurizio Pavesi (2020b)

5.27. A LAMP assay specific to *P. japonica* has been developed and validated by Fera Science Ltd. as part of the Future Proofing Plant Health project. In tests it was able to identify and differentiate *P. japonica* samples (from Canada, Italy and the USA) from samples of a range of UK native chafer beetles and *Popillia* sp., providing an assay specific to *P. japonica.* This assay is suitable for in field use (Malumphy *et al.*, 2017).

Criteria for determining an outbreak

5.28. If *P. japonica* beetles are detected at a location, and following initial surveillance are deemed to not be confined to a particular recently introduced consignment(s) then an outbreak will be declared. For example, if multiple specimens are found in the wider environment, then this would be likely to be classified as an outbreak. However, if they are restricted to a consignment of imported produce, then this would be classed as an interception. Symptoms are not distinctive enough to confirm an outbreak, so surveillance should be carried out until live stages are found or there is satisfactory evidence to conclude the pest is absent. There are likely to be a number of scenarios and the OTG will make the final decision on whether the finding is classed as an outbreak or an interception.

Official Action to be taken following the confirmation of an outbreak

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

Communication

5.30. 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 administrations, and agencies (e.g., the Environment Agency) on a regular basis as appropriate; and to stakeholders.

5.31. The Defra pest factsheet to raise awareness of *P. japonica* and its symptoms should be distributed to nurseries, garden centres, orchards, land owners and importers in the locality of where *P. japonica* has been found. It should also be distributed to members of the public in the local area and those associated with infested premises. The pest factsheet can be found on the Plant Health Portal - https://planthealthportal.defra.gov.uk/plant-health-api/api/pests/6296/notices/6714/documents/4225/document.

Demarcated zones

5.32. Studies have shown that 70% of *P. japonica* are recaptured within 50 m of a release point after 3 days, with the maximum distance from this point at around 1 km (EFSA, 2018; Lacey *et al.*, 1994). Flight distances are short with maximum flight distances approximately 500-700 m during a day. Adults tend to move between plants frequently and estimates of spread in the USA range between 3.2 and 24 km a year (EPPO, 2016). Adults are more likely to fly in higher temperatures, with an optimum temperature range of between 29-35°C, although they will fly if disturbed at lower temperatures. Other factors affecting flight include cloud cover, wind speed and time of the day. This makes it likely that there will be fewer days which are optimal for flight, and therefore a reduced potential for spread in the UK (Fleming, 1972; Klein & Lacey, 1999; Korycinska, 2015; Kreuger & Potter, 2001). In addition to this, as the pest is polyphagous it is not envisaged that the beetle would have to fly further than 100 m to find a suitable host. These factors indicate that natural spread is likely to be low, although it should be noted that the maximum flight distance in a day is reported as 500-700 m (EPPO, 2016).

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

- **The infested zone**, where the presence of *P. japonica* has been confirmed, and which includes all plants showing symptoms caused by *P. japonica* 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 purposes of garden centres and nurseries the whole site may be considered as an infested zone, with any decisions on strategy to be made by the IMT on a case by case basis.
- **The buffer zone**, which will initially extend to at least 1 km from the infested zone. This is due to the lower levels of activity expected in the UK when compared with rates of spread in the USA. However, the exact delimitation should be based on the level and extent of infestation, the distribution of host plants and evidence of establishment.

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

5.35. All host plants within the infested and buffer zone should be surveyed for signs of the beetle where feasible (see 5.21-5.24) by following the surveillance guidance in 5.40-5.48. If this is not possible, surveying should be targeted with the planning determined by the IMT.

5.36. Traps should be installed as described in 5.45 if not already in place.

5.37. If it is considered possible that the beetle 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.

5.38. The demarcated area should be adjusted in response to further findings. If *P. japonica* is found within an area outside the infested zone, this should be designated as infested and the demarcated area adjusted accordingly, or a new demarcated area established. In addition to this the buffer zone may be reduced if deemed appropriate by the IMT following targeted surveys which consider the time of year.

5.39. The PHSI or FC will contact garden centres, nurseries 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). This may be done by general notices online and or in the local media depending on the circumstances. Controls on the movement of specified plants 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' in order to inform all other stakeholders (including residents, businesses and landowners) within the demarcated areas of the requirements that will apply to them.

Surveillance of demarcated zones

5.40. The first surveys of the demarcated zone will be carried out as soon as possible after the outbreak has been discovered, with the type of survey (adult or larvae) being determined by the time of year.

5.41. Using the day degree projections in the Met Office pest emergence tool (Met office, 2020) based on the day degree model of 1422 day degrees above 10°C, the projected emergence date of Japanese beetles in the UK is between the beginning of July and throughout August. Trapping and visual surveying for beetles should therefore take place between July and September for sufficient beetles to be present for detection. Soil sampling for larvae should take place outside of this adult activity in spring or autumn when the larvae are closer to the surface, to avoid difficulties in sampling deeper overwintering larvae. These surveys should be carried out as described in 5.21 and 5.24.

5.42. The hosts surveyed in the demarcated zone will depend on the situation. However, inspection of the key hosts in 2.3 is advised. The focus of the survey should be on areas with large quantities of key hosts, such as nurseries, garden centres or orchards. Surveying should also include areas of grassland, particularly those which may provide preferential oviposition such as moist sites towards field boundaries or areas in close proximity to host plants. These can be surveyed for symptoms as described in 5.22.

5.43. If outbreaks are discovered in nurseries or garden centres all key hosts (see 2.3) should be inspected for signs of feeding damage and where feasible removed from pots and placed on to plastic sheeting to check for the presence of larvae. Any likely areas for oviposition surrounding the boundaries of the premises should be sampled for larvae as described in 5.22. Traps should be installed on the premises and monitored regularly for signs of adults. The number of traps should be determined by the size of the premises, see 5.45.

5.44. In amenity and turf landscapes or wider environment situations the initial focus should be on visual surveys of all key hosts and preferential oviposition sites in the infested zone. Surveys should then be carried out on any key hosts and preferential oviposition sites along line transects within the buffer zone. These transects should extend outwards from the infected zone, 1 km to the edge of the buffer zone, with the number of transects dependent on distribution of key hosts and preferential oviposition sites in the buffer zone and should ultimately be determined by the IMT. Key hosts, those showing signs of *P. japonica* damage and preferential oviposition sites along these transects should be inspected for signs of *P. japonica*. Traps should be installed as described in 5.45.

5.45. Traps may be useful as a control measure in isolated populations, as they will reduce the size of populations and therefore the potential for spread (EPPO, 2016). In established populations the use of traps for control is debatable, but they are useful for monitoring and surveillance. Traps using a mixture of PEG food-type lure (phenethyl propionate + eugenol + geraniol) and sex pheromone (Japonilure) have shown good success. These lures may need to be procured from the USA or EU countries, however in the short term PEG-food type lures for the control of garden chafers are available in the UK. Some general points for successful use of *P. japonica* traps are included below.

- **Trap density**
    - Traps can attract beetles from up to 1 km away (EPPO, 2016). Due to the highly attractive lures, traps using both lures should not be set up in areas where the beetle is not known to occur, including the buffer zone. Traps with both lures should only be placed in the infested zone.
    - If spread to the buffer zone is suspected, traps using only the sex pheromone can be set up, as this will only attract male beetles.
    - Evidence from other beetle species suggests that high trap densities can confuse beetles and reduce the efficiency of the traps (EPPO, 2016). Therefore, traps being used in delimiting surveys should be placed at least 200 m apart. If being used as a mass trapping control option in an infested zone, traps should be placed at least 50 m apart.
    - Placement of traps by those other than the PHSI or FC should be discouraged or prohibited to avoid attracting *P. japonica* to new areas.

- **Placement of traps**
    - Traps should be placed in direct sunlight.
    - Traps should be placed at least 3 m from host plants to avoid beetles being attracted to the nearby host to feed.
    - Trap height should be based on the hosts at the trap location. If turf and low growing hosts are present the funnel rim should be placed at host level. If only turf is present, or turf and host trees, traps are more effective if the funnel rim is 28-56 cm from the ground.
    - Traps should be placed at field edges as adult densities decrease towards field centres.
- **Maintenance**
    - Commercial traps are often marketed as lasting an entire season, however traps that are ventilated or emptied regularly appear to be higher yielding, as the odour of decomposing beetles is suggested to be a deterrent.

5.46. Trap density should decrease with the distance from the infested zone to reduce the risk of attracting beetles to new areas.

5.47. Following the initial survey work, surveys of the demarcated zone should be carried out annually and as a minimum. These subsequent annual surveys should include summer trapping and visual surveys for adults and associated damage. Where possible a further spring or autumn survey for larvae should also be carried out. These surveys should continue until no beetle has been detected for at least two lifecycles of the beetle

5.48. Further guidance on surveillance can be found in the EPPO procedures for official control (PM9/021) (https://gd.eppo.int/taxon/POPIJA/documents).

Pest management procedures

5.49. *Popillia japonica* 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.

5.50. 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. The decision framework (Figure 3) can be used as a guide, but 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.

5.51. 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 5.52—5.58) or for containment (see 5.59-5.65). Additional measures which may be useful as further tools in an eradication or containment strategy, but which may not be applicable or feasible in all situations are given in 5.66-5.71. These may be utilised and become official actions as deemed appropriate by the IMT.

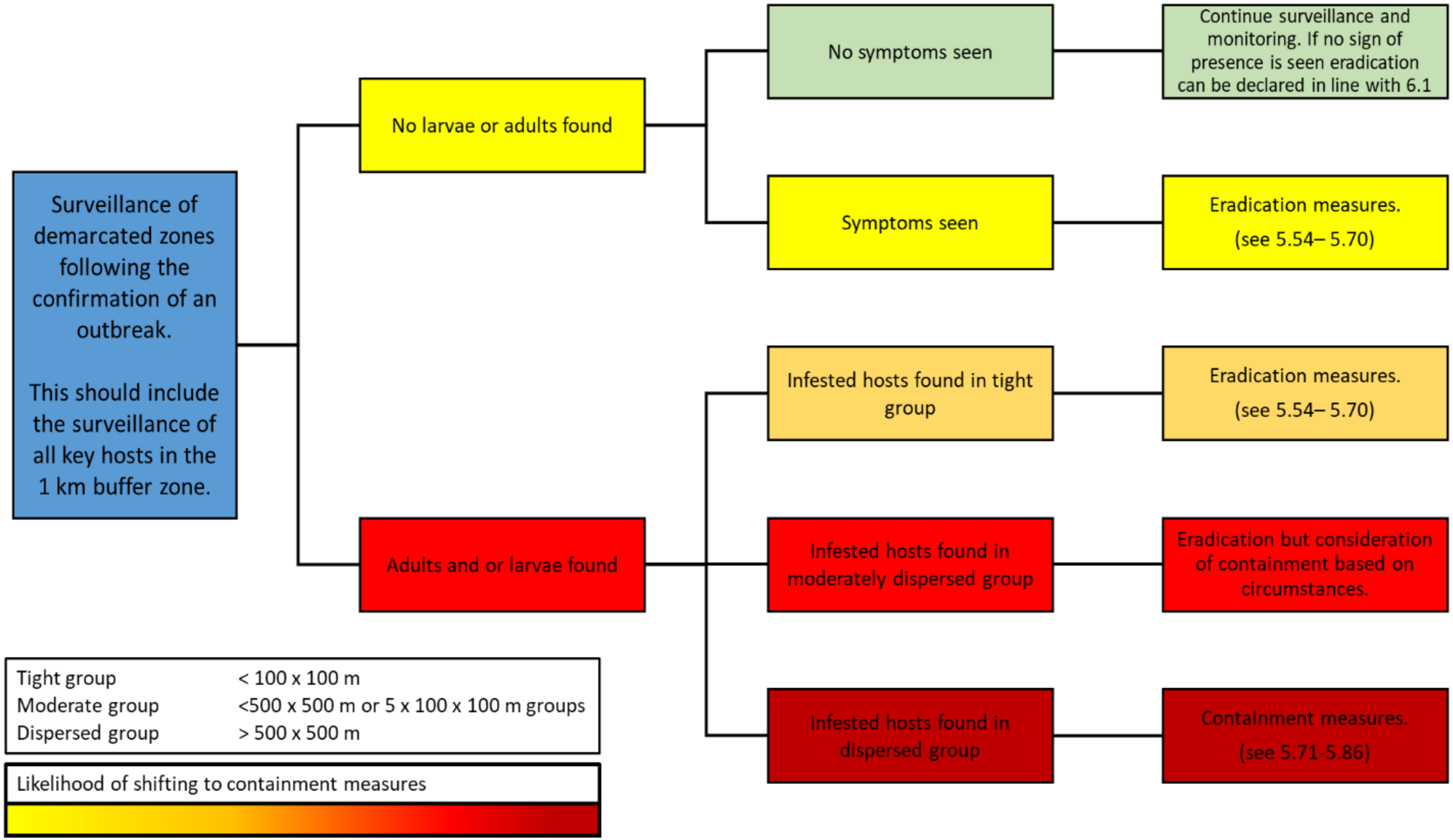

Figure 3. Decision framework for determining when it is appropriate to shift to containment measures.

Official pest management procedures in respect of eradication

5.52. The movement of host plants, plant products and soil out of or within the demarcated zone should at least initially be restricted, unless otherwise agreed by the IMT.

5.53. Where feasible the movement of vehicles, machinery and equipment into and out of the infested zone should be restricted or monitored to reduce the risk of the pest spreading as a contaminant. Where movement is necessary machinery and equipment should be cleaned as described in 5.12.

5.54. All infested plants (those with associated pests), where there is a risk of spread, should be destroyed as described in 5.72-5.74. If there are plants of particular historic or ecological importance in the infected 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 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.

5.55. Non-infested key host plants (listed in 2.3) or those showing symptoms of the beetle or infested plants where destruction is not deemed appropriate by the IMT within a radius of at least 100 m from any plant or plant product found to be infested will be considered on a case by case basis by the IMT. Control measures may involve destruction, foliar treatment, soil treatment or a mixture of these, with the size of the infested zone being based on the extent, age, the source of outbreak, host distribution, time of year and other relevant information. For instance, where adults are found feeding on mature hosts of social importance, it may be more appropriate to spray with a foliar insecticide as described in 5.4 than remove and destroy the host.

- If the situation demands it, it may be necessary to require the use of pesticides even in organic crops or those where biological control agents are being used.
- Growers will be placed under notice to apply the recommended pesticides and make the applications using their own or contractor's equipment. Records of applications will be kept, including details of the amount of product and water use. All pesticide applications will be made in accordance with pesticide approvals and 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.
- Before the use of insecticides in the wider environment, any particular risks relating to each site (e.g. proximity to water bodies or footpaths) will be considered. Applications will 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.

5.56. Samples of infested hosts should be sent as whole plants (i.e. including roots and associated soil or growing media) if feasible for laboratory diagnosis to establish the presence of soil-borne stages as described in 5.1.

5.57. Traps should be installed as described in 5.45 if not already in place.

5.58. In some situations, the IMT may determine that further recommendations such as those listed in 5.66-5.71 may be required, which may be used as further official actions under a statutory plant health notice.

Official pest management procedures in respect of containment

5.59. The movement of host plants, plant products and soil out of or within the demarcated area should be agreed by the IMT.

5.60. Movements of machinery and equipment out of 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 5.12.

5.61. Any heavily infested plants, where there is a risk of spread, should be destroyed as described in 5.72-5.74. These plants should be determined during annual monitoring surveys as described in 5.40-5.48.

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

5.63. Traps should be used as laid out in 5.45

5.64. 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 beetles or larvae that have been found.

5.65. In some situations, the IMT may determine that further recommendations such as those listed in 5.66-5.71 may be required, which may be used as further official actions under a statutory plant health notice.

Additional measures for use in containment and eradication strategies in certain scenarios

5.66. At risk but uninfested plants should be quarantined where possible to avoid spread as the pest is mobile. The area should be managed using the measures laid out in 5.14.

5.67. If required and feasible, the infested area or other susceptible hosts on the premises should be treated with a foliar contact insecticide. The PHSI will advise on an appropriate insecticide treatment regime in consultation with the Defra Risk and Horizon Scanning team, as in 5.55.

5.68. Due to the restrictions on insecticides to combat larval populations, applications of entomopathogenic nematodes can provide control on soil borne life stages of *P. japonica.* Use of *Steinernema* spp. and *Heterorhabditis bacteriophora* can be used to control larvae in turf and potted plants for planting. *Steinernema carpocapsae* and *H. bacteriophora* are available for use in the UK, although the latter is only available under licence. Infested or at risk plants may have their soil treated with an appropriate treatment such as entomopathogenic nematodes to reduce the risk of larval populations building up.

5.69. Avoiding irrigation where possible during peak emergence season (May-June) will aid the reduction of larvae in the soil, as females seek moist sites for egg laying (EPPO, 2016).

5.70. If appropriate, mechanical control measures such as rotivation can be used to disrupt the larval population by direct damage and reducing the suitability of the habitat[13]. This should be done in autumn before the larvae have burrowed deeper to overwinter. This should be done to a minimum depth of 10 cm (EPPO, 2016).

5.71. Movement of larvae is limited and is reduced in preferential habitats. Horizontal movement studies found that larvae moved 1.3 m out of a radius of 0.9 m in fallow land, but only 0.2 m outside of the same radius in preferential habitats (Fleming, 1972). Therefore, if feasible, herbicide applications using a product such as Glyphosate, in a 2 m radius of infested hosts could remove the larval food source and reduce populations.

Disposal plan

5.72. When deciding on the most appropriate method(s) of disposal, several factors such as the likelihood of *P. japonica* adults being present, the level of handling and transportation required and climatic conditions all need to be taken into account. For all methods, measures need to be taken to ensure that there is no risk of spread during transport, treatment or disposal. This may include keeping the distance of travel to a minimum. Material that can be moved safely should be destroyed by incineration at a licensed facility (if in small quantities) or by deep burial. Disposal and/or destruction should be under the approval of the PHSI, with any supervision decided on a case by case basis. If the material has to be moved off the premises, it should be moved under a statutory plant health notice and contained within at least two layers if possible, and placed in a sealed vehicle for transport. Deep burial may be done at an approved landfill site, on the outbreak site or another suitable site nearby, but only in agreement with the local Environment Agency. Incineration must comply with appropriate waste management regulations i.e. as specified by the Environment Agency in England.

5.73. Other viable methods of destruction should be agreed by the IMT which may be influenced by the time of year.

5.74. All objects designated as ‘infested’, such as equipment, machinery, storage facilities that may be contaminated with infested plant material or soil should be thoroughly cleaned to remove the pest using an appropriate technique e.g. using high pressure water/steam etc. This should be carried out at the outbreak site in agreement with a Plant Health and Seeds Inspector. Any waste material generated should be bagged and sent for deep burial or incineration.

6. Criteria for declaring eradication/change of policy

6.1 The outbreak will be declared eradicated (by the Chief Plant Health Officer) if *P. japonica* has not been detected for a period covering at least two lifecycles of the pest and this period will be a minimum of 4 years.

7. Evaluation and review of the contingency plan

7.1 This pest specific contingency plan should be reviewed regularly in order to consider any 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 *P. japonica* or other pest, 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 *Popillia japonica*

Identity

PREFERRED SCIENTIFIC NAME	AUTHOR (taxonomic authority)
Popillia japonica	Newman, 1838

CLASS: Insecta

ORDER: Coleoptera

SUBORDER: Polyphaga

SUPERFAMILY: Scarabaeoidea

FAMILY: Scarabaeidae

SUBFAMILY: Rutelinae

TRIBE: Anomalini

COMMON NAMES[1]

Japanese beetle (English)

(Bugguide.net, 2020; CABI, 2019; EPPO, 2020a)

Notes on taxonomy and nomenclature

Popillia japonica is in the Anomalini tribe within the subfamily Rutelinae (CABI, 2019). Some sources consider the subfamily, Rutelinae, as a family in its own right, and therefore the taxonomy may be reported as Insecta: Coleoptera: Scarabaeoidea: Rutelinae (Korycinska, 2015). The Catalogue of Life lists 324 species in the *Popillia* genus, although by far the most concerning to plant health and well-studied is *Popillia japonica* (CoL, 2020).

Biology and ecology

Life Cycle

In the beetle's native range, adult *P. japonica* emerge in late May to early July and have an average adult lifespan of 30-45 days, though this varies at different latitudes and temperatures, with lower temperatures extending the lifespan (Fleming, 1972). Adults feed on the above ground parts such as flowers and fruits and will rapidly skeletonize leaves of hosts (Potter & Held, 2002). Initially the beetles fly or crawl to the top of low growing hosts to feed before moving to preferential tree hosts, with most activity seen on warm, sunny days (EFSA, 2018). Temperatures above 35°C and high humidity reduce activity levels (Fleming, 1972).

The pest typically has one generation per year, but in cooler climates it may take 2 years to complete its life cycle, and 2 year lifecycles are predicted for England (see figures 4 and 5). Other parts of the UK may not be suitable for the pest to develop (Kistner-Thomas, 2018; Korycinska, 2015).

Soon after emerging and feeding, adults begin to mate, with females often doing so more than once during their lifespan. The sex pheromones produced by females are highly attractive to males, with emerging virgin females having particularly potent pheromones which males fly low over the soil to detect, resulting in congregations of 25-200 males per female (Fleming, 1972). This has led to the use of virgin females as trap lures in the USA (Ladd, 1970). Mating occurs on plants and occasionally the soil. Adults typically aggregate during both feeding and mating resulting in individual hosts becoming heavily infested.

Following mating, females lay eggs in the soil after burrowing up to 10 cm deep, normally in close proximity to a preferential host plant, with moist grassland being a favoured oviposition site (EPPO, 2016). Small groups of eggs, generally up to 6, are laid, before females move back to the surface to feed and mate again. Females return to the soil to lay further batches of eggs usually laying between 40-60 eggs in total (EFSA, 2018).

In a one year lifecycle larvae hatch from the eggs after approximately 2 weeks and feed on decaying matter and host roots in the upper 7.5 cm of soil. There are 3 larval instars, the first developing in 2-3 weeks, the second in a further 3-4 weeks (EFSA, 2018), before the third instar burrows further into the soil to overwinter at a depth of 15-30 cm in the soil (EPPO, 2020b). In the spring, when soil temperatures exceed 10°C larvae migrate upwards to 5 cm depth and feed within the soil. After feeding for a couple of weeks the larvae pupate and then emerge as adults.

This larval developmental period is extended in areas where the pest undergoes a two year lifecycle, and this is likely to be the case in the UK. In the northern

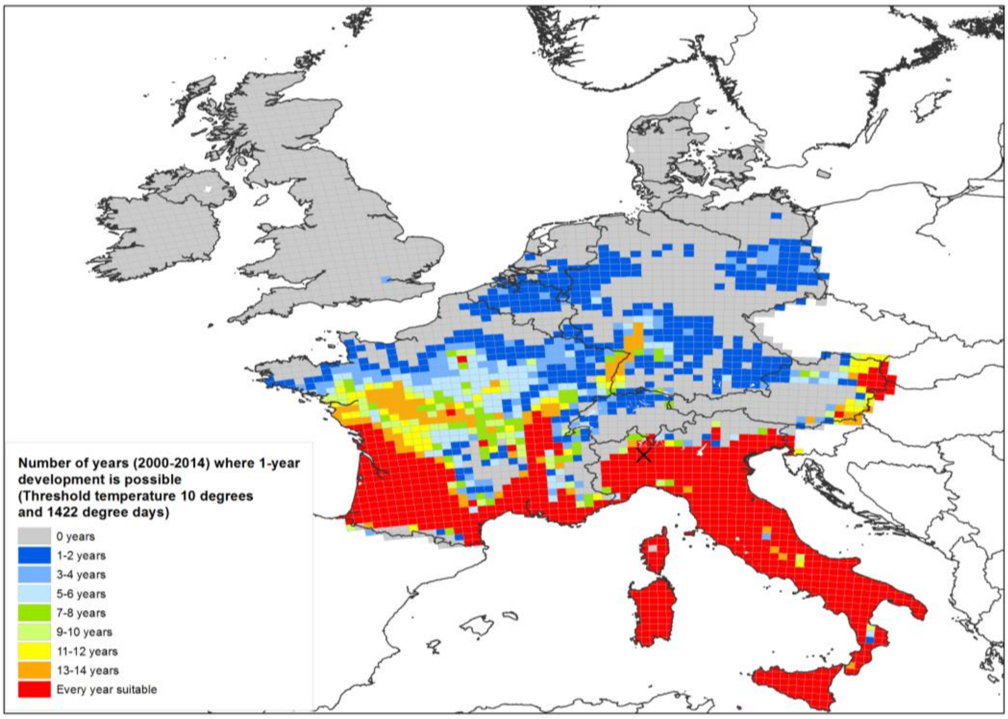

Figure 4. Number of years in a 15-year period where *Popillia japonica* could complete its life cycle in one year, using data from MARS-AGRI4CAST (2014) (as cited by Korycinska, 2015) for selected European countries (2000-2014, with a spatial resolution of 25 km squares) (Source: Korycinska, 2015)

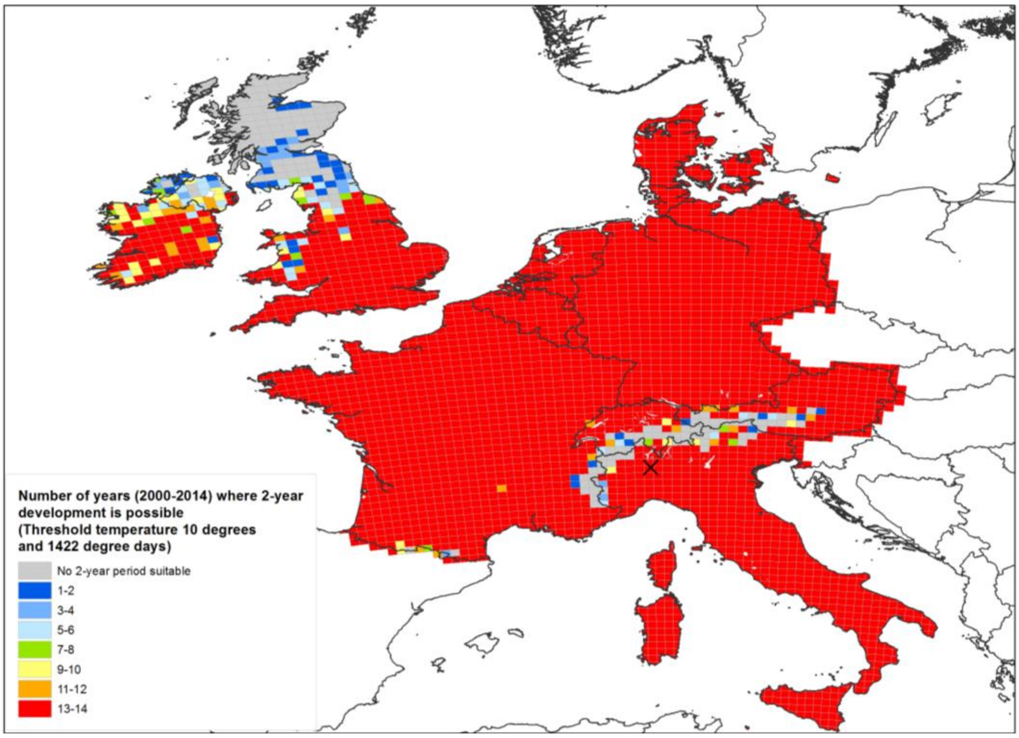

Figure 5. Number of 2-year periods where *Popillia japonica* could complete its life cycle in two consecutive years, using data from MARS-AGRI4CAST (2014) (as cited by Korycinska, 2015) for selected European countries (2000-2014, with a spatial resolution of 25 km squares). (Source: Korycinska, 2015)

Japanese island of Hokkaido, which has a comparable climate to the UK there is a greater adult emergence seen in alternate years, indicating that the larvae undergo a 2 year lifecycle. Data from Japan in the 1920s show that adults emerged between the beginning of July and throughout August, although the greatest numbers of beetles were seen in mid-July. This is likely to be similar in the UK (Clausen & Teranishi, 1927; Korycinska, 2015). A Met Office emergence tool is available for the UK, however the model the tool runs on has limitations and uses incorrect assumptions on oviposition timings. Therefore this data has been discounted (Met office, 2020).

Emerging adults remain in the soil and undergo maturation for 2-14 days, with the duration of the process being dependent on temperature. Once the adult beetle matures it tunnels to the surface, a process that takes one or more days dependent on soil type, leaving a spherical emergence hole at the surface. Emergence normally coincides with mornings or when the air becomes warm, with adults remaining in the tunnels if the weather is cool or raining (Fleming, 1972).

Hosts/crops affected

Popillia japonica is highly polyphagous in both the adult and larval stages and has thus far been reported to feed on over 700 plant species (EFSA, 2018). EPPO (2020a) reports that feeding has resulted in economic damage on 106 of the 295 recorded hosts in North America, with similar damage also likely on major hosts in the EPPO region. These hosts include *Acer* spp., *Aesculus* spp., *Betula* spp., *Castanea* spp., *Glycine* spp., *Juglans* spp., *Malus* spp., *Platanus* spp., *Populus* spp., *Prunus* spp., *Rosa* spp., *Rubus* spp., *Salix* spp., *Tilia* spp., *Ulmus* spp. and *Vitis* spp. (EPPO, 2020b). Many of these are widely distributed in the UK and would provide favourable hosts for *P. japonica*.

In addition, adults are also known to cause injury to a range of vegetable crops including *Asparagus officinale* and *Zea mays*, shrubs including *Althaea* spp., *Hibiscus* spp., *Rhododendron* spp., *Rosa* spp., *Vaccinium* spp. and *Viburnum* spp., and other soft fruits and ornamental herbaceous plants.

The larvae of *P. japonica* are regarded as a significant pest of lawn and turf (EFSA, 2018), and have been reported to attack a wide range of grasses, weeds and garden and nursery crops including ornamentals and vegetables (CoL, 2020; Fleming 1972). No specifics can be found on larval hosts but larvae are mainly linked to the oviposition site as larvae have a relatively low level of mobility, although it is variable depending on the hosts available.

Horizontal movement studies of larvae in the 1970s found that the greatest distance moved after 10 months beyond a 3 feet (0.9 m) circular release zone was 51 inches (1.3 m) in fallow land, as compared with only 7.2 inches (0.2 m) in a turf plot, (representative of a favoured habitat) (Fleming, 1972). Selection of oviposition sites is influenced by several factors including the proximity to the host the female is feeding on, the type of ground cover and condition of the soil, with preferential sites seeming to be grasslands in close proximity to adult hosts and shadier or cooler areas such as field edges (Fleming, 1972).

The beetle also has the potential to spread as a hitch hiking pest and is suspected to have been introduced into the Azores and Italy in this manner (Korycinska, 2015). A more complete host list is available at https://gd.eppo.int/taxon/POPIJA/hosts.

Plant stage affected

Adult and larval *P. japonica* feed above and below ground respectively during the active growing stages of hosts.

Plant parts affected

Adults feed above ground on leaves, fruits and flowers whilst the larval stages feed on the roots of hosts.

Symptoms/signs – description

Adult *P. japonica* are defoliators, feeding between veins to leave skeletonised leaves which later become necrotic and prematurely senesce (CABI, 2019). Feeding tends to be in a top down fashion, with upper leaves being completely skeletonised before the adults move down the plant (EFSA, 2018). Adults may also feed on flowers, fruit and shoots, with feeding often being gregarious resulting in large numbers aggregating on single hosts (EFSA, 2018).

Damage from larvae does not result in specific characteristic symptoms. The larvae feed on roots and therefore symptoms are consistent with disrupted normal function (EPPO, 2020b). Symptoms can include reduced vigour, reductions in yield and plant death. Moist, loamy grassland are preferential oviposition sites, and feeding by the larvae results in thinning, yellowing and wilting of grass before dead patches appear (EFSA, 2019).

Figure 6. Damage caused by *Popillia japonica*. (a),(b) Skeletonised leaves with adults © Maurizio Pavesi (2020a) and Martino Buonopane (2020) ,(c) feeding aggregation on apple shoots © M.G. Klein (2020) and (d) damage to turf © EPPO (2020d)

Morphology

Egg

Eggs are often variable in size and shape. Eggs may be spherical with a diameter of 1.5 mm, ellipsoidal with a length of 1.5 mm and 1.0 mm wide, or nearly cylindrical. These enlarge to nearly double the size during development of the embryo (EPPO, 2006).

The colour is also variable, but it is usually creamy white with hexagonal patterns on the surface (EPPO, 2006).

Larva

First instars are C-shaped, white and 1.5 mm in length with biting mouthparts, 3 pairs of thoracic legs and 10 abdominal segments. During development they may become yellow brown and turn a grey black colour in the posterior region of the abdomen post feeding (EPPO, 2006). The larvae are covered with brown hairs and short blunt spines and can be distinguished from other scarabaeid larvae by the v-shaped pattern of the last two rows of spines on the ventral surface of the last abdominal segment (EPPO, 2020b).

Second instars can be differentiated from the 3rd instars by head capsule size (1.9 mm wide, 1.2 mm long and 3.1 mm wide, 2.1 mm long respectively) (EPPO, 2006). Before pupating, their activity reduces before larvae stop feeding and evacuate any remaining excreta.

Pupa

Pupae are approximately 14mm long by 7 mm wide and start off pale cream to tan in colour. They gradually develop legs, wings, antennae and general shape of the adult form. As they reach maturity the metamorphosis into the adult form with fully developed body parts and distinctive metallic colouration is completed (EPPO, 2006).

Adult

Adult beetles are 8-11 mm long and 5-7 mm wide with males being smaller than the females (EPPO, 2006). Beetles have a shiny golden green thorax with 5 lateral tufts of white hair on the abdomen and two patches on the pygidium (last abdominal segment) (EPPO, 2006, 2020b). The shape of the tibia and tarsus on the foreleg can be used to differentiate males and females, with males having shorter and stouter tarsi and a sharper tibial spur on the foreleg (EPPO, 2006).

Figure 7. All life stages of *Popillia japonica* (left to right) egg, 1st instar larva, 2nd instar larva, 3rd instar larva, pupa, adult. © D. Shetlar (2015)

Similarities to other species/diseases/plant damages

The Japanese beetle may be confused with the garden chafer (*Phyllopertha horticola*), a beetle species present in the UK. The life cycle, biology and damage is similar but the adult lacks the lateral tufts of white hair on the abdomen and pygdium, as well as the metallic green thorax (EFSA, 2019) (Figure 2).

Detection and inspection methods

Due to the aggregations of beetles during feeding, adult beetles are easily detected on the flowers, fruits, leaves and shoots of host plants, and feeding holes or skeletonised leaves can be used as a diagnostic tool during the beetles' flight periods (CABI, 2019; EFSA, 2018). Feeding may also result in early senescence, whilst feeding on flowers results in large, uneven feeding damage (EPPO, 2020b).

Discoloured or dead turf grass, whilst not specific may indicate the presence of *P. japonica* larvae in the soil. Visible gouges may be left in turf by foxes, badgers, etc., digging in the turf to find and eat the larvae. The presence of larvae can be verified by sampling soil cores or cubic portions of soil 20 cm in depth, width and height, and inspecting and identifying any larvae present. Preferential oviposition sites are normally in shadier or cooler portions, and more likely to be present at field edges, which may be of use when targeting inspection areas (EFSA, 2019).

In the USA and the Azores, trapping using a PEG food-type lure (phenethyl propionate + eugenol + geraniol) and a sex pheromone have been utilised for monitoring and surveillance (EFSA, 2019), and can potentially be used for monitoring warehouses holding imported commodities (EPPO, 2006). Checking and maintaining traps frequently has been shown to increase yields, possibly due to the odour of decaying beetles masking the lures or because it makes traps undesirable to adults (EPPO, 2016).

Both trap height and host type can influence trapping yields. If turf and low growing hosts are present, the funnel rim of the traps should be placed at host level, however if only turf is present or turf and host trees are present, traps are more effective if the funnel rim is 28-56 cm from the ground. Other ways to maximise trapping yields are by placing the traps in direct sunlight and in close but not immediate proximity to host plants (3-6.4 m) (EFSA, 2019).

Once sampled, suspected *P. japonica* should be formally identified to confirm its presence. A diagnostic standard (PM7/074(1)) for identification of *P. japonica* has been produced by EPPO, which is available here https://gd.eppo.int/taxon/POPIJA/documents.

History of introduction and spread

Popillia japonica is native to Japan where it is not considered a significant pest, unlike those areas where it has been introduced. This may be due to climatic differences and Japan having less amenity turf than countries where the beetle has been introduced. Higher population densities are seen further North in Japan such as Hokkaido where grass and meadowland is more abundant, indicating the pest's preference for grassland (Clausen & Teranishi, 1927; Korycinska, 2015). Despite this the impacts of *P. japonica* in Japan are reported to be increasing due to the growing popularity of golf courses which provide good conditions for larvae. Whilst the pest is present in Russia, it appears to be limited to Kunashir Island, which lies less than 30 km from the Northern Japanese island of Hokkaido (CABI, 2019; EFSA, 2018).

Popillia japonica was introduced to North America in the early 20th century, quickly spreading and establishing (EFSA, 2018). The first recorded discovery was in New Jersey in 1916, probably introduced in soil associated with iris bulbs, although earlier introductions via other nursery stock from Japan is also likely (Korycinska, 2015). Populations rapidly grew and spread West due to extensive amounts of maintained turf and a lack of predators and parasites (CABI, 2019). The pest is now widespread in the Eastern states (except Florida), and despite interstate controls to prevent the spread from these states, it is present with a restricted distribution in central and western states (Korycinska, 2015).

The pest was accidentally introduced into Europe in the 1970s, potentially entering via a US military airbase in the Azores. Although beetles can only fly short distances, long distance spread is suspected to be possible as adults hitch-hiking on aircraft or as larvae associated with soil (EFSA, 2018). The first finding of the beetle was on the island of Terceira and, subsequently, on the Islands of Faial, Flores, Pico, São Jorge, Corvo and São Miguel within the Azores archipelago (EPPO, 2016).

In 2014, *P. japonica* was reported in Milan, Italy. The origin of the introduction is unknown, although two airports are close to the initial finding and may have offered a possible route of entry. Control measures were taken, and around 28,000 adults were trapped within the infested zone between August and October 2014 (Korycinska, 2015). The European Commission considered eradication to be unfeasible given the extent of the infestation and population size, resulting in the pest remaining under official control in Italy to contain the pest (EFSA, 2018).

In June 2017 *P. japonica* adults were found in a trap in Switzerland close to the Italian border and the demarcated zone of the Italian outbreak in Ticino Valley National Park (EPPO, 2017). In 2020 significantly high numbers of adults were found in 2 separate vineyards and in traps within a separate municipality. The status is officially declared as transient, actionable, under eradication (EPPO, 2020c).

Lithuania and Slovenia have declared absence of the pest following pest surveys whilst Belgium declares the pest absent on the basis that there have been no records of the pest in its territory (EPPO, 2020b).

Within the UK, a few historical interceptions have been recorded, but there have been no outbreaks. All of the interceptions were associated with goods at UK ports of entry, with the most recent being an adult *Popillia* sp. specimen intercepted at Prestwick Airport in July 2003. This was associated with computer parts from Taiwan, and as the pest is not considered present in Taiwan it may have been a closely related East Asian species rather than *P. japonica* (Korycinska, 2015).

Distribution

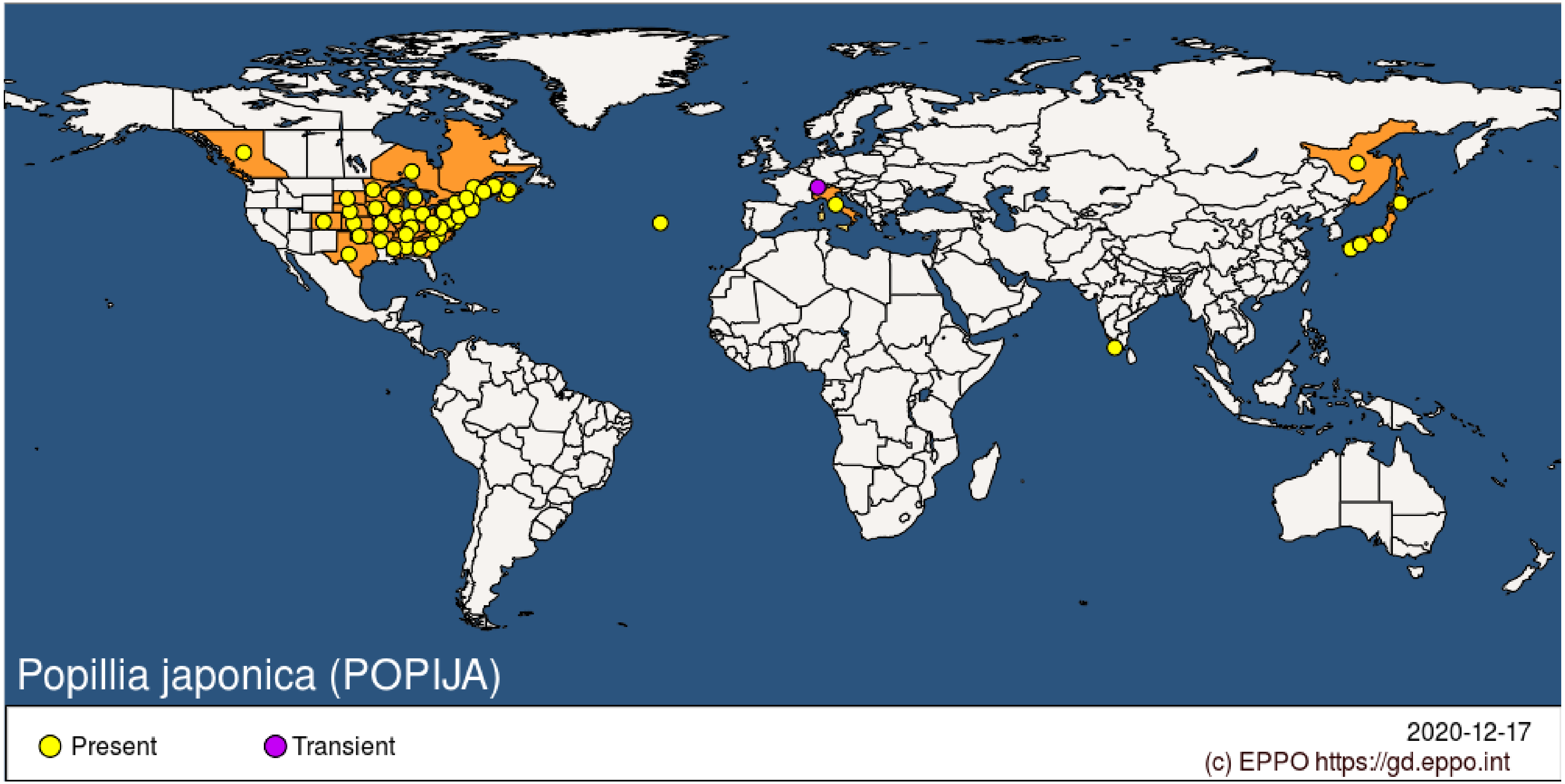

Figure 8. Distribution of *Popillia japonica* (full distribution details can be found here https://gd.eppo.int/taxon/POPIJA/distribution). © (EPPO, 2020a)

Phytosanitary status

Table 2. Global categorisations of *Popillia japonica* (Adapted from EPPO, 2020a)

Country/NPPO/RPPO	List	Year of addition
AFRICA		
Egypt	A1 list	2018
Morocco	Quarantine pest	2018
Southern Africa	A1 list	2001
Tunisia	Quarantine pest	2012
AMERICA		
Argentina	A1 list	2019
Brazil	A1 list	2018
Canada	Quarantine pest	2019
Chile	A1 list	2019
Mexico	Quarantine pest	2018
United States of America	Quarantine pest	1989
ASIA		
Bahrain	A1 list	2003
China	A2 list	1993
Israel	Quarantine pest	2009
Jordan	A1 list	2013
Kazakhstan	A1 list	2017
Uzbekistan	A1 list	2008
EUROPE		
Azerbaijan	A1 list	2007
Belarus	Quarantine pest	1994
Georgia	A1 list	2018
Moldova	A1 list	2006
Norway	Quarantine pest	2012
Russia	A1 list	2014
Turkey	A1 list	2016
Ukraine	A1 list	2019
RPPO		
APPPC	A2 list	1993
CAHFSA	A1 list	1990
CAN	A1 list	1992
COSAVE	A2 list	2018
EAEU	A2 list	2016

Country/NPPO/RPPO	List	Year of addition
EPPO	A2 list	1975
EU	A2 Quarantine pest (Annex II B)	2019
OIRSA	A1 list	1992

Popillia japonica is listed in Annex 2A of The Plant Health (Phytosanitary Conditions) (Amendment) (EU Exit) Regulations 2020. It is also found on a number of other quarantine lists (Table 2).

Means of movement and dispersal into the UK

Natural dispersal

Adults tend to only fly on warm, sunny days with temperatures between 29 and 35°C, and maximum flight is approximately 500-700 m during a day (EPPO, 2016). In mark-release-recapture studies, 70% of beetles were recaptured within 50 m of the release point and less than 1% were recaptured 1 km from the release point over a 3 day period (EFSA, 2018). Other studies suggest longer sustained flights are possible over water, with adult beetles reported to be capable of flying 8 km, although shorter flights are more typical (EPPO, 2016).

Adults tend to move between plants frequently and marking studies have found beetles 3.2 km away from their original point of capture (Fleming, 1972). Findings from studies on outward spread of *P. japonica* in the USA are variable with rates varying between 3.2 and 24 km per year. The introduced population in the Azores had a slow initial spread, but in subsequent years the infested area increased by a minimum of 2 km per year (EPPO, 2016).

Movement in trade

Plants for planting

The risk of adult Japanese beetles entering the UK associated with plants for planting from third countries is considered to be low due to stringent legislative requirements for many hosts and the high likeliness of becoming detected on the consignment or disturbed during transit and become disassociated with their host material (Korycinska, 2015). Any movement of adult beetles associated with plants for planting is also likely to be in relatively low numbers, as feeding aggregations of beetles and severe feeding damage will likely be rejected in trade. To date, there have been no UK interceptions of *P. japonica* on plants for planting from North America or Japan (Korycinska, 2015). Although soil is prohibited from outside of the EU, it is permitted if associated with plants to sustain their vitality and provided it complies with the conditions laid out in Annex 7A of The Plant Health (Phytosanitary Conditions) (Amendment) (EU Exit) Regulations 2020 to ensure freedom of pests and disease.

This is also a risk associated with plants imported to the UK from the EU countries with known populations due to the lack of any such requirements for the movement of soil between EU member states. Due to the size of the larger plants being imported, and the large soil volume associated, there is an inherent risk of *P. japonica* eggs, larvae and pupae entering within the soil or growing medium with plants for planting (Korycinska, 2015). These conditions would be suitable for the continuation of the beetle’s development, although not necessarily on a preferred host.

Spread via plants for planting is more likely on EU plants due to the large volume of UK imports from Italian nurseries, the polyphagous nature of the pest and EU plant movements being subject to fewer inspections than third country imports.

Harvested plant parts

Due to the polyphagous nature of *P. japonica*, it can be found associated with many hosts where harvested plant parts such as flowers, fruits and foliage are traded. However, due to the rapid feeding damage caused, such as skeletonization and surface damage, it is likely that damaged plant products would be discarded in quality checks or found during pre-export or import inspections (Korycinska, 2015). Adult beetles are also mobile, and they are likely to be disturbed during transit and either fall to the ground or fly if conditions are warm and sunny (EFSA, 2018). Although, this may become an issue during processing (e.g. of fruit), as beetles may drop into hoppers or collecting containers, increasing the likelihood of them finding a suitable host. The Defra rapid PRA considers this an unlikely pathway for introduction (Korycinska, 2015).

Contamination

This may be the pathway by which *P. japonica* first arrived in Europe; it is hypothesised to have arrived on military aircraft at a US Air Force base in the Azores, with the pest then dispersing into adjacent fields (CABI, 2019’ Korycinska, 2015). This is also the case for UK interceptions of the pest, with single adults being detected on military aircraft at Prestwick airport in 1952, 1953 and 1954. They have also been found associated with plant material, namely wheat from the USA at Avonmouth docks in the 1970s. Recent UK interceptions are limited to a finding of a *Popillia* sp. beetle, which was intercepted at Prestwick airport in 2003, being found associated with a consignment of Taiwanese computer parts. There is uncertainty as to whether it was *P. japonica* or a closely related species. Within the USA, USDA quarantine measures have been implemented to reduce the risk of accidental transport of adult beetles, as it has been noted that adults fly into planes during loading, particularly in areas where hosts of *P. japonica* are planted (CABI, 2019; Hamilton *et al.*, 2007; Korycinska, 2015).

Whilst a gravid female or both male and female beetles would need to be associated with the same movement, this may be possible as adults are often found gregariously and pheromones produced by virgin females are highly attractive to males meaning there is potential for females to already be fertilised before movement if mating occurs soon after emergence. Females also produce large numbers of eggs throughout their lifespan which may facilitate rapid population growth. On the other hand, temperature and soil conditions, particularly moisture, are important and may be limiting factors to establishment (CABI, 2019; Korycinska, 2015).

As most introductions occur at airports, Korycinska (2015) considers there to be a risk of transfer to neighbouring grassed areas depending on the season, as *P. japonica* likes large areas of turf which are often next to runways providing an attractive oviposition site where adults may establish. However, Korycinska (2015) also notes the findings by Hamilton *et al.* (2007) which suggest this is influenced by grass height, soil conditions, particularly moisture and other factors.

Control

Exclusion

Popillia japonica is a GB quarantine pest (Schedule 1 of The Plant Health (Phytosanitary Conditions) (Amendment) (EU Exit) Regulations 2020) and is therefore prohibited from being introduced into, or spread within, GB.

Cultural control

There are few cultural control options available for *P. japonica*. Reducing irrigation is one option, as females have a preference for moist sites for oviposition, and limiting soil moisture may therefore help to reduce egg laying in managed turf. However, in many instances this may not be feasible.

The EPPO standard for official control also suggests that mechanical cultivation such as powered rotavating can directly damage the larvae, whilst reducing habitat suitability. It is more effective if done in dry conditions and to a depth of 10 cm, which minimises the risk of larvae surviving the process in clods. This should be carried out in autumn, before the larvae burrow deeper into the soil to overwinter (EPPO, 2016).

An abundance of weeds in fields has been noted to increase the larval population tenfold, so good hygiene including the removal of weed species is recommended (Smitley, 1996). Other cultural control methods suggested in the literature include increasing cutting heights of turf, and strip intercropping with non-host crops which reduces the beetles' tendency to spread (Korycinska, 2015; Potter & Held, 2002). Physical removal by hand may provide some control for small plantings, and this is best done in the morning or below 21°C when the beetles are less active (CABI, 2019).

Host plant resistance

There is little conclusive evidence on specific host plant resistance to *P. japonica* with feeding more likely to be preferential (Potter & Held, 2002). Some cultivars within generally susceptible genera do show a lower susceptibility and may be used to replace damaged material to control adult populations. Examples of these genera include *Betula, Malus, Tilia* and *Ulmus* (CABI, 2019; Potter & Held, 2002).

Despite variations in tolerance, all common species of cool-season turf are susceptible (CABI, 2019). Studies using hosts infected with fungal endophytes, which can enhance resistance in perennial ryegrass or fescues to certain stem and leaf feeding insects, did not demonstrate any direct impacts against *P. japonica* populations (Potter & Held, 2002).

Trapping

A mixture of food-type and japonilure, the synthetic sex pheromone, is an effective bait, and yields are improved with frequent emptying of traps to remove the odour of decomposing beetles (Potter & Held, 2002). Mass trapping has been suggested to be successful in small scale specific circumstances, although the general consensus is that this is not viable when used as a tool for outbreak management of infestations (CABI, 2019; Potter & Held, 2002). In terms of control in agricultural systems, work by Piñero & Dudenhoeffer (2018) in the USA has shown ventilated trap designs to be efficient and to give effective control, with lower numbers of adults on crops and little foliar damage. However, further work is needed to validate mass trapping as an alternative to other control methods in the wider environment. In general, though, trapping used for monitoring, early identification of new infestations and delimitation of infestations is valid (CABI, 2019).

Trapping is used in the USA to certify plants moving from nurseries in infested states to unaffected states (Potter & Held, 2002). Trapping has also been a successful tool in Italy as part of outbreak management with 2100 traps catching 48 million adults in 2017, averaging 21,818 adults/trap. However, this was over an outbreak area of greater than 800 km (CABI, 2019), with an estimated population density of up to 500 larvae/m (CABI, 2019; Marianelli *et al.*, 2019).

As adults have an approximate maximum flight distance of 50 m, traps are best placed within 100 m of known infestations (Lacey *et al.*, 1994). One issue with traps is spill over - traps attracting more beetles than they catch, resulting in beetles proceeding to feed on nearby foliage (Korycinska, 2015).

Links to example traps are available below.

Popillia japonica specific traps available outside of the UK
https://trece.com/wp-content/uploads/PHEROCON-Japanese-Beetle-Information-Bulletin.pdf
https://www.amazon.com/RESCUE-Non-Toxic-Disposable-Japanese-Oriental/dp/B002713EEO
https://www.biologictrap.com/products/trap-16-biologic-trap-for-japanese-beetle

Phyllopertha horticola traps available in the UK
https://amenity.agrovista.co.uk/product/garden-chafer-traps/
https://www.dragonfli.co.uk/products/garden-chafer-beetle-trap-amp-attractant-lure
https://www.mosskillers.co.uk/product/garden-chafer-beetle-pheromone-trap

Biological control

Biological control of *P. japonica* commonly uses entomopathogenic nematodes, which have been used on a large scale by the Italian regional plant protection organisations in their management of the pest, in part due to the detection of the beetle in a natural park requiring the use of environmentally friendly control strategies where possible (Paoli *et al.*, 2017). Hundreds of hectares of infested meadows were treated, although due to the large scale of the outbreak, eradication is unlikely and control will need to be combined with other approaches (Marianelli *et al.*, 2019).

Entomopathogenic nematodes which have been studied or used in the management of *P. japonica* include *Heterorhabditis bacteriophora*, *Steinernema carpocapsae*, *Steinernema glaseri*, *Steinernema kushidai* and *Steinernema scarabaei* (EPPO, 2016; Korycinska, 2015; Marianelli *et al.*, 2018; Potter & Held, 2002). Of these, *H. bacteriophora* and *S. carpocapsae* are currently available for use in the UK with *H. bacteriophora* available under licence and showing good levels of larvicidal activity, achieving 46% larval mortality in large field plot trials (Korycinska, 2015; Marianelli *et al.,* 2018).

Other biocontrol options which have been used include *Paenibacillus papilliae* (milky disease bacterium) (EPPO, 2016; Potter & Held, 2002), *Bacillus thuringiensis* (Potter & Held, 2002), and entomopathogenic fungi (Klein & Lacey, 1999).

The bacterium *P. papilliae* (formally *Bacillus papilliae*) is a stomach acting biopesticide. Larvae ingest spores which subsequently germinate, eliciting body fat depletion and invade the insect's haemolymph (insect equivalent of blood), causing it to turn a milky white and eventually killing the insect. *Bacillius thurgiensis* is a commonly used biocontrol agent, and a novel isolate from Japanese soil has shown high levels of toxicity against *P. japonica* larvae. Both *P. papilliae* and *B. thuringiensis* have struggled on a commercial basis, however, and there have been doubts about the persistence of *P. papilliae* (Potter & Held, 2002).

The entomopathogenic fungi *Metarhizium anisopliae* and *Beauveria brongniartii* have both shown biocontrol potential for larvae and adults, although there are difficulties with the application of these to the larval stages. Klein and Lacey (1999) have tested a trap baited with both female and male lures which inoculates adults with *M. anisopliae* and releases them with the aim of naturally disseminating the pathogens into the larval habitats. This gives a specific application, as opposed to large scale applications from above the soil. *Metarhizium anisopliae* has been shown to kill both adult and larval stages and takes around 3-4 days for the onset of mortality. This study has shown the trap to disseminate the pathogen to adult beetles, the pathogenicity of the fungus to the beetles and the horizontal transmission of the fungus from the inoculated beetles to healthy adult beetles. Despite showing good levels of transfer and mortality, the trap has not been tested to see if it facilitates vertical transmission to the larval habitats by adults. Further work on other trap designs have also shown horizontal transmission to healthy adults resulting in mortality under field conditions (Benvenuti *et al.*, 2019). Work is also being carried out in the UK on similar technologies to combat UK pests (Pope *et al.*, 2018).

Field monitoring/economic threshold levels

Economic threshold levels are considered too variable to make monitoring a practical option in turf, with damage varying across species, soil types, soil moisture levels and management regimes. One study found that a minimum of 15-20 larvae per m^2 were required to cause any aesthetic damage in a range of grasses, with some species not seeing any reductions in quality at 60 larvae per 0.1 m^2. These studies were carried out in Kentucky and it was noted that damage was less evident as the temperatures became cooler later in the year (Crutchfield & Potter, 1995). These thresholds would therefore not be suitable in GB due to climatic differences, and a large amount of larvae would need to be present for damage to be seen.

In addition to this there has been no quantification of specific thresholds for wood landscape plants, and with the polyphagous nature of the beetle, a meaningful threshold may vary greatly between hosts (Potter & Held, 2002). However, as egg laying is usually in close proximity to hosts that attract adult feeding aggregations, monitoring these areas of infested or suspected parts may indicate when treatment would be required (EPPO, 2016; Potter & Held, 2002).

Chemical control

Insecticide applications

Popillia japonica management in the USA utilises insecticide applications both against the adults and as soil treatments to target larvae (Korycinska, 2015). Insecticides from the chemical groups of carbamates, organophosphates and pyrethroids as well as insecticidal soaps have been used to target adults (EPPO, 2016; Korycinska, 2015; Potter & Held, 2002). In the UK several active ingredients in the carbamates and organophosphates are available, however chloropyrifos which is widely used in the USA is not. There are also active ingredients in the pyrethroid group of insecticides available in the UK including pyrethrins and deltamethrin.

Active ingredients which have been used for larval control include imidacloprid, chlorpyrifos, bifenthrin, tefluthrin and halofenozide. Of these, imidacloprid is often chosen due to its long persistence, and is used as a preventative treatment for a range of scarabaeid larvae (Potter & Held, 2002). However, only products containing tefluthrin are available for use in the UK. Applications are often combined with watering to leach the residues into the root zone of the soil. The effectiveness is variable, but can be effective if applied soon after egg hatch (EPPO, 2016).

Herbicide applications

As the movement of larvae is limited the application of herbicides could help to remove food sources for larvae and ultimately reduce populations. The horizontal movement studies by Fleming (1972) found that larvae moved a maximum distance of 1.3 m out of a radius of 0.9 m, which could mean the use of herbicides in a radius around preferential oviposition sites could aid control.

Long lasting insecticide-treated nets (LLINs)

This relatively recent technology is used to combat malaria and other vector borne diseases in tropical and sub-tropical areas, with UNICEF providing 23.9 million LLINs across 28 countries in 2017. Nets are constructed of polyester or polythene and impregnated or coated with insecticides, often pyrethroids which are protected from rapid degradation and may remain active for months or years. They have been used as plant protection tools in agriculture, horticulture and forestry against a range of pests including aphids, whiteflies, beetles and stink bugs (Marianelli *et al.*, 2018). Studies by Marianelli *et al* (2018) tested a variety of nets and found that ZeroFly® manufactured by Vestergaard™ gave 100% mortality rate in tests with varying exposure rates, and as little as 5 seconds. These results indicate their potential to be included in an IPM strategy for *P. japonica*, possibly combined with trapping to avoid continuous emptying of traps. However, the non-target effects should be considered, given the broad spectrum of the insecticides used.

These are not currently available in the UK, and the approval process could take time.

Impacts

Once introduced, the polyphagous and gregarious nature of *P. japonica* may mean that it will be difficult to eradicate. The potential for misidentification with the native *P. horticola* may also lead to introductions becoming established before the pest is detected (EFSA, 2019; Korycinska, 2015). The Defra PRA concludes the potential economic, environmental and social impacts in the UK to be low with medium confidence (Korycinska, 2015).

Temperature and soil moisture are important factors in the spread of *P. japonica* (Potter & Held, 2002), and the life cycle of *P. japonica* in the UK is expected to take a minimum of 2 years in the south and longer than this further north if establishment in these regions is possible at all. It is therefore considered that any impacts of *P. japonica* would be relatively low, as introduced populations would take longer to build up (Korycinska, 2015). This consideration is consistent with countries that have populations of *P. japonica* and have cooler climates, which generally do not consider *P. japonica* to be a significant pest (CABI, 2019; EFSA, 2018; EPPO, 2020b, Korycinska, 2015).

Recent CLIMEX modelling work by Kistner-Thomas (2019) suggests that the effects of climate change could lead to a larger area of the UK being at risk of *P. japonica* establishment. This increased climatic suitability combined with an abundance of suitable hosts, in particular rich pastureland means that GB is at risk of *P. japonica* becoming a significant pest in GB if introduced, especially as the control or eradication of established populations would be difficult. However, this modelling still concluded that a two year lifecycle is the most likely scenario in GB.

Where the pest is currently considered significant the main impacts are considered to be social or economic, due to the polyphagous feeding of the adults on widely grown crops like fruit trees, soybean and maize as well as larval damage on areas of maintained turf such as golf courses and managed parks (CABI, 2019; Korycinska, 2015).

Economic impact

Popillia japonica is highly polyphagous, feeding on at least 295 species of plants in North America (EPPO, 2009), resulting in it being considered one of the most widespread and destructive insect pests of turf, landscapes and nursery crops since being introduced in the early 1900s (EPPO, 2020b; Potter & Held, 2002). Both the larvae and adults cause damage, with reports of larval damage equating to $234 million per year in the USA and damage caused by the adult being reported to be equivalent or greater than this figure (Klein & Lacey, 1999). Despite the wide host range, including hosts of importance to the UK, the impact seen in areas with a similar climate to the UK suggests that the economic impact would be low (Korycinska, 2015).

Environmental impact

The climatic limitations of the pest mean it is unlikely to have a great impact on the UK environment directly. However, treatments of infestations may impact indirectly on local habitats and should be chosen with care.

Social impact

Crop losses may cause indirect impacts on businesses of economically important host crops as well as directly by damaging turf in amenity plantings.

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10. Authors and reviewers

Authors

Original: Simon Honey (Defra) (2021)

Revised by: Simon Honey (Defra) (2022)

Reviewers

Jane Barbrook (APHA)

Matthew Everatt (Defra)

Dominic Eyre (Defra)

Neil Giltrap (Defra)

Anastasia Korycinska (Defra)

Nick Mainprize (Forestry Commission)

Jozef Ostojá-Starzewski (Fera Science Ltd.)

Laura Stevens (Defra)

Melanie Tuffen (Defra)