EUROPEAN AND MEDITERRANEAN PLANT PROTECTION ORGANIZATION

ORGANISATION EUROPEENNE ET MEDITERRANEENNE POUR LA PROTECTION DES PLANTES

Pest Risk Analysis for

Agrilus mali (Coleoptera: Buprestidae)

A larva of *Agrilus mali* (China) (photo courtesy of Y.-L. Zhang, Ecology and Nature Conservation Institute, Chinese Academy of Forestry, China)

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The risk assessment follows EPPO standard PM 5/5(1) *Decision-Support Scheme for an Express Pest Risk Analysis* (available at http://archives.eppo.int/EPPOStandards/pra.htm), as recommended by the Panel on Phytosanitary Measures. Pest risk management (detailed in ANNEX 1) was conducted according to the EPPO Decision-support scheme for quarantine pests PM 5/3(5). The risk assessment uses the terminology defined in ISPM 5 *Glossary of Phytosanitary Terms* (FAO, 2018a; available at https://www.ippc.int/index.php).

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Based on this PRA, *Agrilus mali* was added to the EPPO A2 List of pests recommended for regulation as quarantine pests in 2024. Measures for *Malus* plants for planting (except seeds, tissue culture, pollen), round wood and sawn wood (with or without bark), and cut branches are recommended.

Pest Risk Analysis for *Agrilus mali* (Coleoptera: Buprestidae)

PRA area: EPPO region

Prepared by: Expert Working Group (EWG) on *Agrilus mali*

Dates: 30 May – 2 June 2023.

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All personal communications in this PRA were obtained in 2022-11 to 2023-06 from the following experts: E. Jendek (Czech University of Life Sciences, Czech Republic), O. Kulinich (All-Russian Center for Plant Quarantine, Russia), D. Opatowski (NPPO of Israel, Israel), G. Tanabekova (Al-Farabi Kazakh National University, Kazakhstan), M. Volkovitsh (EWG member, Russia), X.-Y. Wang (EWG member, China), T. Wöhner (EWG member, Germany).

The first draft of the PRA was prepared by the EPPO Secretariat.

*Note: In this PRA, all elements considered relevant are presented in the text. However, readers wishing a rapid overview can focus on the **bold highlighted text.***

For the determination of ratings of likelihoods and uncertainties, experts were asked to provide a rating and level of uncertainty individually during the meeting, based on the evidence provided in the PRA and on the discussions in the group. Each EWG member provided anonymously a rating and level of uncertainty, and proposals were then discussed together in order to reach a final decision.

Following the EWG, the PRA was further reviewed by the following EPPO Core Members for PRA: N. Björklund, D.J. van der Gaag, A. Korycinska, G. Schrader, J. Tuomola, and well as by the EPPO Secretariat (R. Tanner).

The PRA, in particular the section on risk management, was reviewed and amended by the EPPO Panel on Phytosanitary Measures on 2023-10. EPPO Working Party on Phytosanitary Regulation and Council agreed that *Agrilus mali* should be added to the A2 List of pests recommended for regulation as quarantine pests in 2024.

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Summary of the Pest Risk Analysis for *Agrilus mali* (Coleoptera: Buprestidae)

PRA area:
EPPO region (Albania, Algeria, Austria, Azerbaijan, Belarus, Belgium, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Georgia, Germany, Greece, Guernsey, Hungary, Ireland, Israel, Italy, Jersey, Jordan, Kazakhstan, Kyrgyzstan, Latvia, Lithuania, Luxembourg, Malta, Moldova, Montenegro, Morocco, Netherlands, Norway, North Macedonia, Poland, Portugal, Romania, Russia, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Tunisia, Türkiye, Ukraine, United Kingdom, Uzbekistan).

Describe the endangered area:
In the EPPO region, the pest may be able to establish wherever *Malus domestica* and *Malus sieversii* are present. However, the northern limit of the potential area of establishment cannot be defined precisely (see Section 9.4). Within the potential area of establishment, it is expected that the largest impact would occur in *M. sieversii* wild apple forests in Central Asia. In addition, impact is expected in the rest of the potential area of establishment but would likely be lower in areas close to the northern limit of establishment.

Main conclusions:
Overall assessment of risk:
Agrilus mali is native to Eastern Asia. Within the EPPO region it is present in Russia (East Siberia and Far East) and outside the EPPO region in Asia (China, Democratic People's Republic of Korea, Republic of Korea, and Mongolia).

Agrilus mali attacks several species of *Malus* (Rosaceae – including cultivated apple *M. domestica*, as well as the wild apple *M. sieversii*). Several Rosaceae species in the genera *Prunus*, *Sorbus*, *Cydonia*, and *Pyrus* are unconfirmed hosts. *Agrilus mali* infests mainly branches as well as the trunks of young trees (with thin bark).

The likelihood of entry into Kazakhstan through natural spread is considered very high (low uncertainty), because of the very close proximity and continuous presence of *M. sieversii* between places in northern Xinjiang (Yili Valley, China), where *A. mali* is present, and Kazakhstan. For the rest of the EPPO region, natural spread is not considered as a significant pathway for entry. Entry into Kazakhstan via hitchhiking on other commodities or in vehicles has a low likelihood with moderate uncertainty.

For all EPPO countries, the most likely commodity pathways for entry are: host plants for planting (except seeds, tissue cultures, pollen); round wood and sawn wood of hosts (with or without bark); and cut branches. Long distance dispersal via vehicles is not expected to be a likely entry pathway.

For EPPO countries other than Kazakhstan, the likelihood of entry was overall moderate with a moderate uncertainty (for countries where import of *Malus* plants for planting is not prohibited) and low with high uncertainty (for countries where import of *Malus* plant for planting is prohibited; corresponding to the rating for cut branches), and linked to commodity pathways only.

The likelihood of establishment of *A. mali* outdoors in the EPPO region is considered very high with low uncertainty. *Malus domestica* is widely distributed in the EPPO region and *M. sieversii* is widely present in Central Asia and the climatic conditions are not considered to be a major limiting factor for the establishment of the pest where *Malus* hosts are present. The pest has a life cycle which can be completed within 1 or 2 years depending on climatic conditions. The northern limit of the potential area of establishment cannot be defined precisely. The critical parameters would, however, be the presence of hosts and whether cool summer temperatures allow emergence and reproduction of adults (thermal requirements are not known).

The magnitude of spread was rated as moderate with a moderate uncertainty. The pest has limited natural dispersal capacity but there may be longer 'jumps' through human-assisted means (traded commodities or vehicles), that could lead to multiple outbreaks and increase the magnitude of spread. *Malus* plants for planting in trade are likely to be young plants, which can be infested, but the likelihood of spread is expected to be reduced due to management at the nurseries.

The impact (economic, environmental and social) in the pest's native range in China was rated for *M. sieversii* as high with a low uncertainty and for *M. domestica* moderate with moderate uncertainty. Limited or no data were found on the situation and/or impact on other hosts, or in other areas where the pest occurs (Mongolia, Russia, Democratic People's Republic of Korea, Republic of Korea). The magnitude of potential impact in the EPPO region was rated for *M. sieversii* as high with low uncertainty and for other *Malus* hosts (including *M. domestica*) as moderate with high uncertainty. The potential impact was rated especially high for *M. sieversii* forests in Kazakhstan because this species is a valuable genetic resource.

In China, sanitation pruning and chemical insecticide applications are the most efficient control measures in orchards. Sanitation pruning could also be applied in the EPPO region. If *A. mali* is introduced again into the EPPO region, available insecticides are very limited, and biological control agents are not yet available.

Because of the high damage recorded in China and of the importance and widespread distribution of hosts in the EPPO region, the EWG recommended that phytosanitary measures may be considered.

In the context of climate change, the area of potential establishment of *A. mali* might extend northwards and to higher altitudes. Increased temperature, frequency and duration of severe droughts might increase the negative impact of the pest.

Phytosanitary Measures to reduce the probability of entry:
Risk management options have been identified and evaluated for host plants for planting, cut branches, round wood and sawn wood of hosts. The EWG recommended that they should be applied to the genus *Malus* (Section 7). If more scientific information confirming new host status become available, the same measures should be recommended for these additional hosts. With the currently available information, some countries may decide to regulate unconfirmed hosts to achieve a higher level of protection (Table 7.1). A number of apple wood commodities from China are available to consumers on the internet for the purpose of barbecue and smoking, and the EWG recommended that such internet trade should be placed under scrutiny. ISPM 15 phytosanitary measures are considered to be sufficient for wood packaging material.

Phytosanitary risk for the endangered area: (*Individual ratings for likelihood of entry and establishment, and for magnitude of spread and impact are provided in the document*) • **The phytosanitary risk was rated based on the higher risk in Kazakhstan, and was considered High.** • **For countries that prohibit the import of *Malus* plants for planting, the phytosanitary risk was rated Low.** • **For all other countries, the phytosanitary risk was rated Moderate.**	High X	Moderate ☐	Low ☐
Level of uncertainty of assessment: (*see Section 17 for the justification of the rating. Individual ratings of uncertainty of entry, establishment, spread and impact are provided in the document*) **The uncertainty was rated Low for Kazakhstan, and Moderate for all other EPPO countries.**	High ☐	Moderate ☐	Low X

Other recommendations:
The EWG recommended possible topics for research focusing on tools for identification, better understanding of biological parameters, unconfirmed hosts, attractants and repellents, clarifying the pest's impact in some parts of its native range, biological control, sentinel trees, etc. (detailed in Section 18).

Stage 1. Initiation

Reason for performing the PRA: *Agrilus mali* Matsumura, 1924 (Coleoptera: Buprestidae, an apple buprestid) is a wood boring insect that is primarily known for attacking apple (*Malus* spp.). It is native to the Eastern part of Asia (Northeastern China, Russian East Siberia and Far East, Eastern Mongolia, and Korean peninsula) (Volkovitsh et al., 2020a; EPPO, 2020). In Northeastern China, in the past, *A. mali* was considered a sporadic pest in the major apple production areas (e.g. Shaanxi and Shandong). In 1993, it was discovered in Northwestern China, in an apple (*Malus domestica*) orchard in Xinyan county (Xinjiang[1]), and since then it rapidly spread in wild apple (*Malus sieversii*) forests in the Yili Valley of the Tianshan Mountains. In this area, extensive mortality of wild apple trees has been reported. Considering the potential damage *A. mali* could cause to *Malus* and possibly other Rosaceae species that have been recorded as hosts, the EPPO Panel on Phytosanitary Measures recommended to include this pest in the EPPO Alert List (EPPO, 2020). In May 2022, the Panel on Phytosanitary Measures suggested *A. mali* as one of the priorities for PRA, and the EPPO Working Party on Phytosanitary Regulations selected it for PRA in June 2022.

The EPPO standard PM 5/5 *Decision-Support Scheme for an Express Pest Risk Analysis* (EPPO, 2022) was used, as recommended by the Panel on Phytosanitary Measures. Pest risk management (detailed in ANNEX 1) was conducted according to the EPPO Decision-support scheme for quarantine pests PM 5/3(5).

PRA area: the EPPO region as per 2023 (map at https://www.eppo.int/ABOUT_EPPO/eppo_members).

Information about some elements of the biology and ecology of *A. mali* were not found, despite including literature from China (in English or Chinese) where this pest is currently causing damage. Consequently, in some cases information on other extensively studied *Agrilus* species with similar biology, for example the emerald ash borer *A. planipennis* and the bronze birch borer *A. anxius*, has been used in this PRA. These species have been subject to EPPO PRAs (EPPO, 2011, 2013a).

Stage 2. Pest risk assessment

1. Taxonomy

Taxonomic classification. Domain: Eukaryota; Kingdom: Metazoa; Phylum: Arthropoda; Class: Insecta; Order: Coleoptera; Family: Buprestidae; Genus: *Agrilus*; Subgenus: *Sinuatiagrilus*; Species: *Agrilus mali* Matsumura, 1924 (Jendek & Grebennikov, 2011; Volkovitsh et al., 2020a).

Subgenus *Sinuatiagrilus* Alexeev, 1998 includes the following species: *mali*, *mendax, sachalinensis*, *sinuatus*, *zhelochovtsevi* (Alexeev, 1998); with *Buprestis sinuata* Olivier, 1790 as a type species (Alexeev, 1998; Jendek & Grebennikov, 2011).

Type specimens of *A. mali* have not been found.

Although it was suggested that *A. mali* may be conspecific with *A. sachalinensis* (as *A. sinuatus sachalinensis*) (Jendek & Grebennikov, 2011), there is currently no evidence that this is the case, nor that *A. mali* and *A. sinuatus* are synonyms (as confirmed by Dr. Jendek to Dr. Wang in November 2022).

Synonyms. *Agrilus jenissejensis* Obenberger, 1924 (Jendek & Grebennikov, 2011). *Agrilus enisejensis* and *Agrilus jenisejensis* (Jendek & Grebennikov, 2011) are considered as misspellings (M. Volkovitsh, pers. comm., 2023).

English common names. Apple buprestid (Volkovitsh et al., 2020a; Musolin et al., 2022), apple jewel beetle (Wang et al., 2014d).

EPPO code. AGRLMA

[1] Xinjiang Uyghur Autonomous Region (XUAR), abbreviated in this PRA to Xinjiang.

2. Pest overview

2.1. Morphology

The morphological characters of *A. mali* are summarized in Table 2.1. More details and pictures are provided in Annex 2. Additional pictures can be viewed in EPPO Global Database (https://gd.eppo.int/taxon/AGRLMA/photos).

Table 2.1. Morphological characteristics of *Agrilus mali* (for additional details see Annex 2).

Stage	Description (e.g. colour, shape)	Size
Eggs	Milky white when laid, then yellowish brown after a few days. Oval or ellipsoid (Linyi Agro-Forestry Bureau, 1973).	Ca. 1.0–1.5 mm long, 0.7–1.0 mm wide (Ji et al., 2004; Guo & Ma, 2010; Feng et al., 2013; Guli & Wang, 2013; Bozorov et al., 2019; Li, 2019).
Larvae	Larva is typical for the genus *Agrilus*. Milky white, yellowish or brown, with 13 segments (3 thoracic and 10 abdominal) (Linyi Agro-Forestry Bureau, 1973). Head is small and brown, almost completely retracted into prothorax, transparent; external brown part is a peristome bearing mouth parts. Elongated, flattened, slender, with very broad prothorax. End of body nearly triangular, with a pair of toothed brown tail irons (terminal processes) at the end (Linyi Agro-Forestry Bureau, 1973; Chamorro et al., 2015). Ji et al. (2004) reported 5 larval instars. It is noted that normally *Agrilus* spp. have 4 instars (Chamorro et al., 2015 for other *Agrilus*). This PRA refers to the final instar larvae where relevant.	First larval instar ca. 2.2–3.0 mm long (Wang, 2013). Final larval instar up to 16.0–22.0 mm long, 1.7–2.5 mm wide (Linyi Agro-Forestry Bureau, 1973; Wang et al., 2013).
Pupae	Milky or creamy white at the initial stage, gradually deepened in the later stage, and turns blackish brown before emergence of an adult (Linyi Agro-Forestry Bureau, 1973; Li, 2019). Exarate, spindle or fusiform.	Up to 6.0–10.0 mm long, and 2.0–4.0 mm wide (Linyi Agro-Forestry Bureau, 1973).
Adults	Body is unicolor, metallic purple- or coppery-red, underside sometimes with greenish reflection; head flattened in dorsal view; elytra with three pairs of white tomentose spots (Annex 2: Fig. A2.1.A, B and C). The body is densely covered with small incised dots on all parts. Long and columnar (Han, 2002; Ji et al., 2004; Bozorov et al., 2019; Li, 2019)	6.1–8.7 mm long, 2.0–3.0 mm wide (Volkovitsh et al., 2020a).

2.2. Life cycle

Voltinism of *A. mali* varies in different locations from 1 generation per year to 1 generation every 2 years. In this PRA, the lifespan of adults was considered to be up to 60 days if apple leaves are available, and 4–7 days without food. The flight period is 14.0–19.5 days (laboratory rearing at 25 °C). Females can lay up to 60–70 eggs across the oviposition period of 10–20 days. Eggs are laid in cracks on the sunny side of branches, close to the base of buds and twigs. In the univoltine life cycle, larvae of earlier instars overwinter under the bark. In other *Agrilus* species, larvae may overwinter in the xylem and resume feeding in the cambium after the winter, but this has not been described for *A. mali*. In the cooler regions where the pest needs more than 1 year to complete its development, there might be 2 overwintering periods: the 1st by younger larvae and the 2nd by mature larvae (likely the final instar). The diapause of the earlier instars is obligatory, and it is not known how the 2nd diapause is induced.

Adults emerge through the bark from D-shaped exit holes (average ca. 0.2 cm; Zhang et al., 2021). After emergence and before reproduction, adults feed on the edge of leaves (Ji et al., 2004), and also buds or young bark (Sokolov et al., 1995), on which bite marks can be seen. After supplementary nutrition (1 or 2 weeks; Li, 2019) the adults begin to mate and females start to lay eggs.

Availability of fresh host leaves is crucial to maturation and survival. In an experiment with field cages, Cui et al. (2019) reported that adult females lived up to 56.8 (± 4.5) days on average when provided with wild apple foliage, while without access to leaves the lifespan was less than 5 days (for both sexes). Li et al. (2017) reported that in laboratory starvation tests at 25 °C, the average adult lifespan was in the range of 4–7 days. In a laboratory experiment, the flight period was described as 14.0–19.5 days (laboratory rearing at 25 °C; Ding, 2019).

In this PRA, the lifespan of adults was considered to be up to 60 days if apple leaves are available, and 4–7 days without food.

Adult females can lay up to 60–70 eggs across the oviposition period (Ji et al., 2004). The egg-laying period has been reported as 10–20 days in Li & Zhang (2017); the EWG noted that this seems short compared to the maximum longevity of females. Within a population, eggs are laid over a period of more than one month (Nikritin & Shutova, 1985; Cui et al., 2019 citing Wang, 2013) and such prolonged oviposition shapes the pattern of progeny development. In a laboratory rearing experiment at 25°C, fecundity is reported as ca. 21 eggs per female on average over 14.0–19.5 days (Ding, 2019).

Eggs are mostly laid on rough places such as the cracks on the sunny side of branches, close to the base of buds, base of twigs, etc. (Ji et al., 2004). They are generally laid as single eggs or in groups of 3–6 eggs (Clausen, 1931; Han, 2002; Ji et al., 2004; Guo & Ma, 2010; Feng et al., 2013; Li & Zhang 2017; Li, 2019). Under natural conditions, eggs usually hatch after 10–21 days of development (Nikritin, 1994; Nikritin & Shutova, 1985; Ji et al., 2004); under laboratory conditions, at 25ºC, embryo development takes 13–20 days (Ding, 2019).

After hatching, larvae bore into the host epidermal tissue for feeding (Li & Zhang 2017). The 1st instar larvae produce irregular, winding and crossing galleries. First larval instars start feeding on the phloem to reach the cambium where they mostly feed (X.-Y. Wang, pers. comm., 2023), forming serpentine galleries (Zhang et al., 2021). Larvae can also feed deeper and go into the outer xylem tissues (sapwood) (Bozorov et al., 2019) and possibly even deeper in heartwood, especially in smaller branches (X.-Y. Wang, pers. comm., 2023).

Pupation occurs when the final instar larvae bore into the outer xylem (Lu et al., 2022 citing Wang et al., 2013). Bozorov et al. (2019) mention that larvae, after feeding on the phloem, cambium and outer xylem tissues, enter the ‘woody portion’ to build pupal chambers. The final instar larva also bore an exit channel which ends under the thin layer of bark and serves for adult emergence (Nikritin & Shutova, 1985; Nikritin, 1994). Pupal chambers are formed in the xylem and average 0.83±0.02 cm in length (data from field measurements; Zhang et al., 2021). The pupation takes between 10–15 days (Chen & Zhang 2007). Under laboratory conditions (25°C) pupation was slightly shorter (10–12 days; Ding, 2019). After the final moulting, adults usually stay in the pupal chambers for 8–10 days (Ji et al., 2004). Then they make their way through the existing exit channel and bark and crawl out of the branches.

Voltinism of *A. mali* varies in different locations depending on latitudes, altitudes, and possibly weather conditions from 1 generation per year to 1 generation every 2 years (Nikritin & Shutova, 1985; Nikritin, 1994; Sokolov et al., 1995; Li & Zhang, 2017). Li & Zhang (2017) note that voltinism reports differ even for the same provinces.

Bozorov et al. (2019) outlined the seasonal cycle in Gongliu and Xinyuan counties of the Tianshan Mountains (Xinjiang, China) as follows (Table 2.2). In late July until the beginning of September, females laid eggs from which hatched larvae bore into the branches. Larvae fed and formed galleries until the end of June of the next year, before pupating. Depending on environmental conditions and stem age, the pupation period occurred over a period of 2–3 months beginning from late April to the end of July. Adult emergence occurred in the beginning of June and continued to the end of July. A similar life cycle is reported in Ji et al. (2004) or Lu et al. (2022), also in Xinjiang.

Table 2.2. Timing of the life cycle in Xinjiang, China (1 generation per year; based on Bozorov et al., 2019)*.

Stages	**Months**											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Eggs							X	XXX	X			
Larvae**								XXX	XXX	XXX	XXX	XXX
	XXX	XXX	XXX	XXX	XXX	XXX						
Pupae				X	XXX	XXX	XXX					
Adults						XXX	XXX					

* a symbol ‘X’ represents presence of the pest in each 10-day period of the month.
** two rows for the larval stage demonstrate that larval development starts in one calendar year and finishes in the next year.

Phenology of the pest is dependent on weather conditions, in particular on the accumulated degree-days in the area where the population is located. The seasonal development will advance in spring and early summer and activity will last longer in autumn if climate change makes the temperature higher during these periods (Lu et al., 2022).

Many publications suggest that in the univoltine life cycle, larvae of earlier instars overwinter under the bark (Linyi Agro-Forestry Bureau, 1973; Chen & Yao, 1997; Wu et al., 1997; Liu, 2010; Feng et al., 2013; Wang et al., 2014c,d; Cui et al., 2019), although sometimes mature larvae (likely the final instar) are mentioned in this context (Sun et al., 1979). In other *Agrilus* species, larvae may overwinter in the xylem and resume feeding in the cambium after the winter (M. Volkovitsh, pers. comm., 2023), but this has not been described for *A. mali*. In the cooler regions where the pest needs more than 1 year to complete its development, there might be 2 overwintering periods: the 1st by younger larvae and the 2nd by mature larvae (likely the final instar) (Sun et al., 1979; Nikritin, 1994; Feng et al., 2013; Li & Zhang, 2017). Lu et al. (2022) suggest that diapause is obligatory, but this is likely referring to the 1st overwintering; it is not known how the 2nd diapause is induced.

2.3. Environmental requirements

Very little information is available on the temperature requirements of *A. mali*. In particular, no information obtained under laboratory conditions is available on the lower or upper developmental thresholds of individual stages, nor on the number of accumulated degree-days (sum of effective temperatures, SET) needed for larval development, adult maturation or the complete life cycle. Data are also lacking on the requirements of *A. mali* adults in relation to relative humidity.

Lu et al. (2022) developed a CLIMEX model and used the following main parameters (among others):
- lower temperature threshold for growth = 10 °C (to match the known distribution in southern China),
- lower optimum temperature = 24 °C (estimates from *A. planipennis*),
- upper optimum temperature = 30 °C (estimates from *A. planipennis*),
- upper temperature threshold for growth = 35 °C (estimates from *A. planipennis*),
- degree-day threshold for a full generation (above 10 °C) = 450 degree-days,
- temperature threshold for cold stress = –34 °C (Table 1 in Lu et al., 2022).

The model was adjusted based on the known distribution of *A. mali* and considered the area where 450 degree-days are accumulated within a year (what corresponds to a univoltine life cycle of the pest) and did not take into account that the pest can accumulate 450 degree-days during its 2nd year of development. Some parameters were estimations based on the data obtained in experiments conducted with another species (*A. planipennis*), which limits reliability and predictive quality of the model for *A. mali* as parameters can be different (see Section 9.1).

2.4. Dispersal capacity of adults

***Agrilus mali* is a relatively poor flyer in comparison to other *Agrilus* species and its dispersal capacity is low. Adults were observed to fly 1–5 m under field conditions in daytime on sunny days. In a flight mill experiment, 11-day-old adults had the strongest flight ability (a maximum flight distance of 416 m) and then it gradually decreased with further increase of age. Females of *A. mali* are reported to be more**

capable of flying than males. In an experiment, on average, over a 15-day period a female could cover a distance of approximately 2.8 km.

Although data on the flight capacity of *A. mali* are limited, the species has been described in several sources as a relatively poor flyer in comparison to other *Agrilus* species and its dispersal capacity is considered low (Chen & Yao, 1997; Wu et al., 1997; Ji et al., 2004; Lu et al., 2022). The pest is also referred to as being sedentary (Sun et al., 2022). Adults are thermophilic, generally flying only during the warmest part of the day, and are not active in the morning and evening or on cloudy days (Chen & Yao, 1997).

Adults of *A. mali* were observed to fly 1–5 m under field conditions, in daytime on sunny days (Sun et al., 1979). In comparison, adults of *A. planipennis* typically fly in 8–12 m bursts, but long distance flight of more than 1 km is possible (Haack et al., 2002 citing Yu, 1992 and Minemitsu Kaneko, Japan Wildlife Research Center, Tokyo, Japan, pers. comm., 2019).

In a flight mill experiment under controlled conditions (temperature 28°C, 35–45% RH, light intensity of 600–700 lx, and photoperiod 14L:10D), the flight ability of *A. mali* first increased after adult emergence; 11-day-old adults had the strongest flight ability; and then it gradually decreased with further increase of age (Ma et al., 2020). At the age of 11 days, the highest flight distances per day were reached, with a maximum flight distance of 416 m. It should be noted that 3-day-old un-fed adults flew much less than fed adults (Ma et al., 2020; figures are from the abstract, but recalculated using meters and minutes for this PRA); female adults of *A. mali* are reported to be more capable of flying than male adults (Ma et al., 2020, 2021).

Ma (2020) provided data obtained in the laboratory on the average daily flight distance for the first 15 days of *A. mali* adult life (Tables 2-1 and 2-3 in Ma, 2020). On average, over a 15-day period a female can cover a distance of approximately 2.8 km (recalculated; data for days 10, 12, and 14 were missing, but approximated based on the neighboring days) (Ma et al., 2020). For comparison, the average flight of *A. planipennis* in a flight mill experiment was > 3 km with 20% of mated females able to fly > 10 km in 24 h and 1% > 20 km (Taylor et al., 2010). It should be noted, however, that flight mill data always tend to overestimate the natural dispersal of tested insects.

In the study performed in an apple orchard using the method of marking and re-catching, most of the adults were re-captured just 5 m from the release point, the longest distance was 35 m from the release point, and no adults were captured at the distance of 40 m during a period of 12 days (Ma et al., 2021). Similarly, for *A. planipennis*, when host plants are available, dispersal remains limited: it can be assumed that approximately 90% of the individuals disperse less than 100 m during one season (Mercader et al., 2009).

Regarding *A. planipennis*, Siegert et al. (2014) utilized dendrochronological reconstruction to determine the early spread. They reported that during the first years the pest gradually radiated from the epicenter of the infestation at a rate of 3.8 km per year, however, after a few years, this rate abruptly increased to approximately 13 km per year. In another study conducted within an intensive quarantine zone (subject to management measures), Sargent et al. (2010) measured that 'the leading edge of *A. planipennis* moved on average about 1 km each year and the furthest dispersers traveled about 1.37 km during a year'. Based on the general and specific scenarios considered in the EFSA expert knowledge elicitation, the maximum distance expected to be covered in one year by *A. planipennis* was approximately 1.3 km (with a 95% uncertainty range of 0.04–7.5 km) (EFSA, 2019b). However, in this assessment the following scenario was used: 'host availability is not a limiting factor for pest establishment after a dispersal event' (EFSA, 2019c). Thus, the situation considered was a situation with continuous availability of hosts. It was earlier strongly suggested that if hosts are not available or sparse, adults of *A. planipennis* can fly over much longer distances (EPPO, 2013a).

For *A. anxius*, the natural spread rate of an isolated focus was estimated to be 1 km/year (EFSA, 2019b).

In general, *Agrilus* beetles have the potential to fly considerable distances. However, they rarely do so, as they usually only fly short distances when suitable hosts are found in their immediate surroundings (Dunbar & Stephens, 1976). From the data available, *A. mali* seems to have weaker flying ability compared to *A. planipennis* and *A. anxius*. In the context of the limited information obtained under natural conditions, for the purpose of this PRA it is assumed that *A. mali* is similar to other *Agrilus* species, and it might be expected that *A. mali* is capable of natural dispersal of approximately 2–3 km per year, but there is a high degree of uncertainty about this estimate.

2.5. Nature of the damage

Damage is due to larval feeding on the phloem, which results in disruption of nutrient and water transportation and can result in death of the whole tree. Feeding by adults on leaves causes little damage.

Larval feeding on the phloem results in the disruption of nutrient and water transportation, causing the bark to become sunken (subcortical necrosis) and cracked longitudinally (Ji et al., 2004, Zhang et al., 2021). The damaged branches of apple trees usually wither in a short time (Annex 3). Larval galleries can completely destroy all of the available phloem when larval densities are high. Serious infestations of *A. mali* can cause early leaf drop, death of branches, reduction of fruit production due to a reduction of the tree vigour, exposure to colonisation and damage by fungal pathogens, and even death of the whole tree (Annex 3; Han, 2002; Liu et al., 2014b).

Feeding by adults on leaves causes little damage (Ji et al., 2004).

2.6. Characteristics of attacked trees and location of the pest in the tree

***Agrilus mali* attacks branches and twigs of grown-up trees, some publications also mention trunks (of younger trees). Infestations are mostly reported on branches of 10–55 mm diameter. The pest attacks both apparently healthy and weakened trees. Stress factors can make the trees more susceptible to attack. Population density might be very high: well over 100 individuals per cultivated tree.**

Agrilus mali is reported to attack branches and twigs (e.g. Ji et al., 2004; Wang, 2013; Peng et al., 2019; Zhang et al., 2021). Some publications also mention trunks (e.g. South China Agricultural University, 1981; Wu et al., 1997).

On large trees, infestations of the trunk appear to be rare (Feng et al., 2013 – 'very rarely'; Bozorov et al., 2019 – 'rarely'). Bozorov et al. (2019) note that eggs are usually laid on young branches or new shoots, possibly because the layer of bark is thinner than on old trunks. Larvae starting galleries in branches normally would not reach the trunk, however, few eggs may be laid occasionally on the base of branches and then larvae can reach the trunk (Wang, 1995). Because the pest attacks branches and twigs, Lu et al. (2022) notes that columnar apple trees and trellis orchards may be at greater risk than standard apple trees.

The pest can also attack young apple trees (trees up to few years old) in orchards or nurseries (Sun et al., 1979; Nikritin, 1994; Wang, 1995; Ji et al., 2004), and infestations of the trunk of young trees have been reported (Nikritin, 1994). Note that the words 'young apple trees' is often translated from Chinese literature into English as 'seedlings'.

According to various field studies in China, *A. mali* infestations are mostly reported on branches of 10–55 mm diameter, but galleries have also been found in field studies in shoots of smaller diameters (down to 4 mm; Sun et al., 1979; Wang, 2013; Zhang et al., 2021) or larger diameter (up to 70–100 mm – Wang, 2013; Zhang et al., 2021). Regarding smaller diameters branches, it is likely that females might use them when other substrate (e.g. branches of preferred diameters) is not available (e.g. see: Ding, 2019). Sun et al. (1979) notes that small shoots are rarely infested, only when population density is high, and that most infested small shoots would wither. Thus, it is unlikely that larvae would successfully complete development in shoots of small diameter and spread of the pest through scions is unlikely.

In this PRA, it is understood that on mature trees, branches and twigs are mostly attacked (rarely trunks) but that on young trees, trunks (with thin bark) can be infested.

The pest attacks both apparently healthy and weakened trees. Stress factors can make the trees more susceptible to attack (Sun et al., 2022).

Population density might be very high: infestations of well over 100 individuals per cultivated *M. domestica* tree have been reported (more than 500 insects per plant on average [Yang & Chen, 1956]; up to 147 insects per plant [Plant Protection Research Group, 1977]; 300 insects per plant [Nikritin, 1994]).

2.7. Detection and identification

Signs and symptoms of infestation:

- dieback (=drying) of individual branches or sections of tree crowns;
- D-shaped exit holes (the width ranges from 0.11 to 0.28 cm; mean 0.19±0.01 cm) (Zhang et al., 2021); such holes may be few at first and they may be situated high in the canopy (i.e. not easily visible) on larger trees;
- red and later yellowish/brown liquid which exude from the ventilation holes of galleries on branches after infestation, and congealed after exposure to the air; this liquid is called 'oozing red oil' (Chen & Yao, 1997; Han, 2002; Liu et al., 2013);
- bark of infested areas (above galleries) blackens and dries (Bozorov et al., 2019);
- bark cracking is visible as scars that range 0.6–6.8 cm in width (2.89±0.11 cm), and 1.94–45.92 cm^2 in area (10.39±0.66 cm^2) (Zhang et al., 2021); in length, the visible portion of galleries on the cambium when the bark is removed range from 3.6 to about 26 cm and usually does not cross over other galleries (data from field measurements; Zhang et al., 2021);
- serpentine larval galleries filled with frass, which are typical for the genus *Agrilus*;
- presence of epicormic branches (epicormic shoots or water sprouts);
- presence of feeding damage on the leaves, buds or young bark (the result of maturation feeding of adults).

The signs and symptoms above are not specific to *A. mali* at a global scale (except, potentially, the 'oozing red oil' on *Malus* plants). However, depending on which *Agrilus*-species are present in a certain country it may be possible to use D-shaped exit holes with a width of 0.11–0.28 cm as a sign rather specific to *A. mali* infestations on certain tree species.
See also Annex 3.

Additional considerations

All life stages (except adults) remain hidden (eggs in bark cracks; larvae and pupae in the cambial region and xylem), making their detection more difficult. Trees infested by *A. mali* can apparently look healthy or slightly weakened for some time and present clear symptoms only if they are heavily attacked.

First emergence, and therefore the first appearance of D-shaped exit holes, can only be observed 1 to 2 year(s) after the first infestation. Symptoms on infested trees as listed above are more easily observed in subsequent years after initial attack.

Dry thin bark with cracks/scars above larval galleries might be visible, but experience is needed to recognize these symptoms.

Several *Agrilus* species present in the EPPO region have common hosts with *A. mali* (incl. *M. domestica* for *A. sinuatus, A. roscidus, A. malicola;* unconfirmed hosts for *A. macroderus, A. mendax* – see Annex 4 – Bílý, 2002; de Jong et al., 2014; Jendek & Poláková, 2014; M. Volkovitsh, pers. comm, 2023) and may cause similar symptoms. D-shaped exit holes are produced by all species from the subfamily Agrilinae, in Europe particularly the genera *Agrilus*, *Coraebus*, and *Meliboeus* (EPPO, 2019 citing E. Jendek, pers. comm., 2018). The presence of holes may also be the result of attack by other insects (D-shaped holes in the case of *Agrilus* spp.; round or oval holes in the case of cerambycids and scolytids).

Thus, first signs or symptoms may not be quickly detected in an area following an introduction of *A. mali*, especially if population density is low.

Detection methods

In China, field surveys are used to detect stressed trees, trees with dieback or dead trees (EPPO, 2019 citing X.-Y. Wang, pers. comm., 2018).

Different coloured sticky traps (green, purple, white, and yellow) have been used to capture *Agrilus* adults of other species. The green colour is assumed to mimic green foliage, whereas purple is believed to have a similar reflectance as trees' bark. Attraction to a specific trap color may depend on the species concerned and the sex, as well as where the trap is positioned in the tree (Petrice & Haack, 2015). Wang (2013) found that yellow and white sticky traps were the most attractive colours for *A. mali*. In China, yellow or light green sticky traps with cis-3-hexenol are commercially available and used for monitoring *A. mali* in the field (Ma et al., 2021).

Males of several species of *Agrilus* (*A. angustulus, A. biguttatus, A. cyanescens, A. subcinctus, A. sulcicollis*, and *A. planipennis*) are attracted to dead *Agrilus* adults when used as decoys and placed on host plants suggesting a common behavioural template for visual mate-finding among buprestids (Lelito et al., 2007, 2011; Domingue et al., 2011). 3D-printed decoys have also been used for *A. planipennis* (Domingue et al., 2015). Therefore, adding dead adults as decoys or silhouettes of an adult *Agrilus* may possibly be used to improve the attractiveness of traps.

As for *A. planipennis*, there is no reliable single method to detect *A. mali* at its low population levels. General monitoring methods such as trapping, visual examination for external symptoms on trees and tree sampling may be used, but they may not allow detection of low levels of infestations (EPPO, 2013b).

Careful visual examination of the plants (mostly branches, as trunks are very seldom infested) for presence of symptoms may enable the detection of the presence of the genus *Agrilus* in particular if D-shaped exit holes are present.

Girdled trees have been found to be more attractive to the pest (Zang et al., 2017), and may be used in specific situations (e.g. for monitoring purposes; Gninenko et al., 2012; Musolin et al., 2021).

Identification

The keys to distinguish adults of *A. mali* from its relatives in Far East of Russia (*A. sachalinensis*, *A. zhelochovtsevi*) are given in Alexeev (1989) and Alexeev and Volkovitsh (1989) (from *A. zhelochovtsevi*).

There are currently no keys to distinguish *A. mali* from its European congeners (Jendek & Grebennikov, 2011). However, *A. mali* adults can be distinguished from European species of *Agrilus* based on the morphological characters given in Volkovitsh et al. (2020a), in Section 2.1 and in Annex 2. The presence of 2 or 3 pairs of tomentose spots and morphology of the aedeagus are the most important characters to distinguish *A. mali* from other members of subgenus *Sinuatiagrilus* in the Palearctic (in Europe *A. sinuatus* and *A. mendax*). *Agrilus sinuatus* has only one poorly visible or missing pair of tomentose spots on the posterior third of the elytra and the tegmen of the aedeagus very slightly expanded, almost subparallel (Annex Fig. A2.1 and Volkovitsh et al., 2020a). *Agrilus mendax* (on *Sorbus*) is much longer (>10 mm), has no tomentose spots and the aedeagus is much more expanded toward apex (Volkovitsh et al., 2020b).

Based on the current literature, *A. mali* larvae cannot be distinguished from all other *Agrilus* species by their morphology (M. Volkovitsh, pers. comm., 2023).

Molecular identification
A rapid assay using recombinase polymerase amplification and lateral flow dipstick was developed for *A. mali*, and did not detect *A. viduus*, *A. fleischeri* or *A. planipennis* (Li et al., 2023).

The Barcode of Life Data Systems (BOLD; https://www.boldsystems.org/index.php/Public_SearchTerms) currently hosts 12 sequences for *A. mali* from China (accessed on 21.04.2023). However, there is no indication that there is sufficient evidence to distinguish between closely related species, especially inside the subgenus *Sinuatiagrilus* (including *A. sinuatus* and *A. mendax*). Bozorov et al. (2019) showed that the COI sequences of *A. mali* and *A. mendax* were very similar.

The National Center for Biotechnology Information (NCBI: https://www.ncbi.nlm.nih.gov/) has a genome sequence as well as 429 nucleotide data units on *A. mali*: https://www.ncbi.nlm.nih.gov/search/all/?term=Agrilus%20mali (accessed on 21.04.2023). Currently there are no published molecular markers that can distinguish different species in the *Sinuatiagrilus* subgenus.

3. Is the pest a vector?

There is no evidence of *A. mali* being a vector or carrier for other pests, although some fungi were found associated with *A. mali* (Zhou et al., 2020). Unlike the adult stage of bark and ambrosia beetles that vector mutualistic fungi, *A. mali* adults (the mobile phase of the pest) do not enter the tree.

Yes ☐ No ✓

4. Is a vector needed for pest entry or spread?

Yes ☐ No ✓

5. Regulatory status of the pest

In the EPPO region, *A. mali* has been designated as an A2 pest by the Eurasian Economic Union (whose members are Armenia, Belarus, Kazakhstan, Kyrgyzstan, and the Russian Federation; they have a common United List[2]). Within Russia, however, there is currently no requirement for a Phytosanitary Certificate for moving host material between different parts of the country (O. Kulinich, pers. comm., 2023). *Agrilus mali* has been designated as a quarantine pest by Uzbekistan, Azerbaijan, and Moldova (EPPO, 2020), and the Republic of North Macedonia (North Macedonia, 2021). It is currently neither regulated by the European Union, nor by Israel (D. Opatowski, Israel NPPO, pers. comm, 2023). No information was sought for other EPPO countries.

Information about the regulatory status of *A. mali* elsewhere in the world was sought (2022-11). *Agrilus mali* is regulated in Ecuador (Ecuador Ministry of Agriculture, 2017), Indonesia (Indonesia Ministry of Agriculture, 2015), Chile (as *Agrilus* spp. [except *A. diaguita*, *A. sulcipennis*, *A. thoracicus*] – Chile Ministry of Agriculture, 2018) and New Zealand (Biosecurity New Zealand, 2023). The information consulted is not exhaustive and it may thus be regulated in more countries.

Within China, *A. mali* is regulated in some provinces (e.g. Xinjiang; Liu et al., 2013). The State Forestry Administration of China (2013) lists *A. mali* as a domestic dangerous pest as it causes damage in China, even though this pest is distributed in many provinces in the country (X.-Y. Wang, pers. comm., 2022).

6. Pest distribution

***Agrilus mali* is native to Asia and it is one of the most widespread species of *Agrilus* in that region being present in 27 countries/sub-country division (e.g. province) (Jendek & Grebennikov, 2023). Within the EPPO region it is present in Russia (East Siberia and Far East), and outside the EPPO region in Asia (China, Democratic People's Republic of Korea, Republic of Korea, and Mongolia). Details are given in Table 6.1 and visualized in Figs 6.1 (general) and 6.2 (China).**

Table 6.1. Distribution of *A. mali* (details and uncertainties).

Region	Distribution	Additional details, references and uncertainties
EPPO region	Russia	Far East and Eastern Siberia. General references: Arnoldi et al., 1955; Gurjeva, 1974; Nikritin, 1994; Jendek & Grebennikov, 2011. Regions: Amurskaya Oblast’, Chitinskaja Oblast’, Republic of Buryatia, Khabarovskiy Krai, Primorskiy Krai, Zabaykalskiy Krai (Alexeev, 1989; Jendek & Grebennikov, 2011; Volkovitsh et al., 2020a; Musolin et al., 2022).

[2] The A2 list contains pests with a limited distribution within the EAEU. Currently the pest is only recorded from the Far East and East Siberia of the Russian Federation.

Region	Distribution	Additional details, references and uncertainties
Asia	China	Provinces: - Beijing (Sun et al., 1979; South China Agricultural University, 1981; Sun, 1983), - Gansu (Chen and Yao, 1997; Li, 1998), - Hebei (Yang & Chen, 1956), - Heilongjiang (Yang & Chen, 1956; Sun, 1983; Jendek & Grebennikov, 2011), - Henan (Li & Zhang, 2017; Hua, 2002), - Hubei (Xiang, 1997), - Inner (=Nei) Mongolia (Li, 1988; Jendek & Grebennikov, 2011), - Jiangsu (Wang, 1995), - Jilin (Kang et al., 1984), - Liaoning Matsumura, 1924; Wang et al., 2020), - Ningxia (Tang & Sun, 2001; Li & Zhang, 2017), - Qinghai (Li, 1998; Li & Zhang, 2017), - Shaanxi (Sun et al., 1979), - Shandong* (Linyi Agro-Forestry Bureau, 1973; Sun et al., 1979; Jendek & Grebennikov, 2011), - Shanxi (Zhang, 2008), - Sichuan (Li & Zhang, 2017), - Tianjin (Sun et al., 1979; Sun, 1983), - Tibet (Xizang; Jendek & Grebennikov, 2011; Volkovitsh et al., 2020a), - Xinjiang** (Li & Zhang, 2017; Wang et al., 1995), - Yunnan (Li & Zhang, 2017). * Sun et al. (2022) could not collect *A. mali* during a 5-year period (likely 2018–2022) in Shandong Province and questions its current presence there. ** Xinjiang (Yili Valley, Tian Shan Mountains – since 1993) was considered in the literature as a part of the invasive range (Jendek & Grebennikov, 2011; Volkovitsh et al., 2020a; Lu et al., 2022). A recent study of Sun et al. (2022) utilizing genetic methods suggest that at least in the western Tianshan region, the pest has possibly been present for a long period and may not have been introduced recently. However, the strong damage observed to the wild native *M. sieversii* is more suggestive of a novel introduction (M. Volkovitsh, pers. comm., 2023).
	Democratic People's Republic of Korea	Pyongyang (possibly a part of the invasive range) (Matsumura, 1924; Jendek & Grebennikov, 2011; Volkovitsh et al., 2020a).
	Republic of Korea	Gyeonggi-do, Gyeongsangbuk-do, Taegu, Inchon, Seoul (possibly a part of the invasive range; Matsumura, 1924; Jendek & Grebennikov, 2011; Volkovitsh et al., 2020a).
	Mongolia	Dornod Aimag, Tav Aimag (Alexeev & Volkovitsh, 1989; Jendek & Grebennikov, 2011; Volkovitsh et al., 2020a).

Doubtful record

China. Guangxi is reported in literature as a province where *A. mali* was registered (Hua, 2002; Li & Zhang, 2017), however, it is considered doubtful as this province is not suitable (too hot) for *Malus* (X.-Y. Wang, pers. comm., 2023).

Japan. Some sources mention Japan as a part of the distribution of *A. mali* (e.g. Cui et al., 2019). However, according to Li & Zhang (2017) and Volkovitsh et al. (2020a), based on available material and literature data, as well as consultations with a Japanese buprestid expert, the record in Japan is not confirmed. When preparing this PRA, no precise record on distribution or occurrence of *A. mali* in Japan was found. Sun (1983) mention there is no record of the presence of *A. mali* in Japan.

Situation in Kazakhstan. Because of proximity to China (in particular to Xinjiang), the presence of the pest has been investigated in Kazakhstan. *Agrilus mali* was not found during studies on the insect fauna of *M. sieversii* in Northern Tianshan (Southeastern Kazakhstan, which borders Kyrgyzstan) and the Zhongarian-Alatau range (Eastern Kazakhstan, which borders China) in the period 2018–2020; it was also not found during *A. mali* specific surveys in border areas of Kazakhstan and Xinjiang (Jashenko & Tanabekova, 2019; Tanabekova, 2021). Up to 2023-01, *A. mali* has not been recorded in Kazakhstan (G. Tanabekova, pers. comm., 2023).

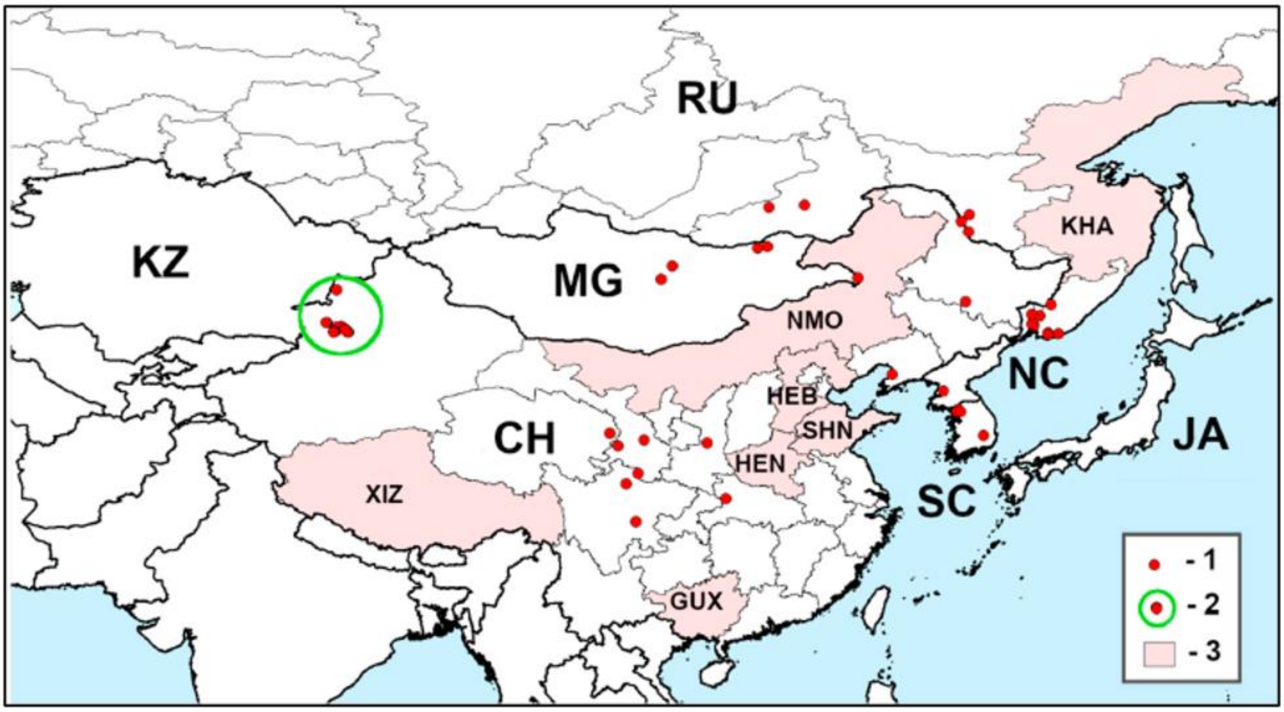

Figure 6.1. Range of *Agrilus mali*. 1 – documented localities, 2 – outbreak sites of *Malus sieversii* in Xinjiang, 3 – reported administrative units for which exact localities were not found. CH – China, JA – Japan, KZ – Kazakhstan, MG – Mongolia, NC – Democratic People's Republic of Korea, RU – Russia, SC – Republic of Korea; GUX – Guangxi*, HEB – Hebei, HEN – Henan, KHA – Khabarovskiy Krai, NMO – Nei Mongol, SHN – Shandong, XIZ – Xizang (from Volkovitsh et al., 2020a).
*For Guangxi: see Doubtful records above this figure.

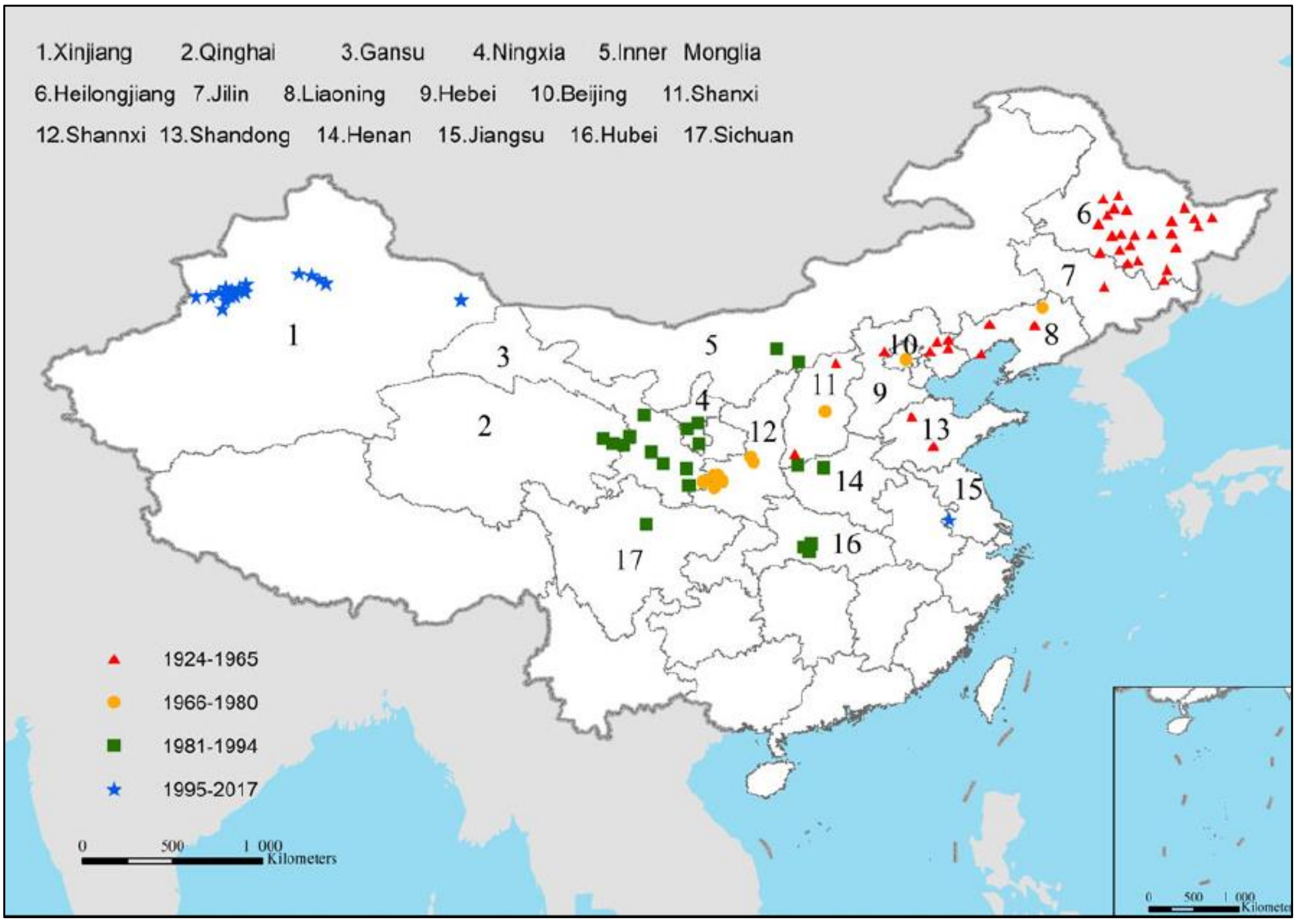

Figure 6.2. Records of *Agrilus mali* in China and possible invasion history in China from 1920s to 2022 (from Lu et al., 2022) based on GBIF, published papers (Zhang et al., 2019) and collections (Lu et al., 2022). Key provinces mentioned are numbered (from Lu et al., 2022).

Note: The documented localities of *A. mali* in the Xinjiang (China) (blue stars and #1 on the map), in which massive outbreaks in the wild apple, *M. sieversii*, were observed, are situated rather far from its earlier known main range and often regarded as a currently forming invasion range resulting from introduction in the 1990s. However, Sun et al. (2022) question this based on genetic data suggesting that the pest was there before the 1990s. Furthermore, Sun with colleagues could not collect *A. mali* during a 5-year period in Shandong Province (#13 on the map) and questioned its current presence there. Thus, dates in the map must be treated with caution.

7. Host plants and their distribution in the PRA area

The hosts of *A. mali* are listed in Table 7.1. *Agrilus mali* attacks several species of *Malus* (Rosaceae – including cultivated apple *M. domestica* [synonym: *Malus pumila*], as well as wild apple *M. sieversii* – see notes below Table 7.1). Two other species of *Malus* and few Rosaceae in the genera *Prunus*, *Sorbus*, *Cydonia*, and *Pyrus* are mentioned in the literature, but are considered unconfirmed hosts (no detailed studies available; X.-Y. Wang, pers. comm., 2022). There is an uncertainty whether these plants are hosts, but they are still assessed as hosts in the PRA.

Table 7.1. Hosts of *Agrilus mali.*

Host	Presence in PRA area (Yes/No/Not known)	References for host status	Confidence index* and/or life stage
Malus (apples)			
Malus spp. (apples)	Yes	Jendek & Grebennikov, 2011; Jendek & Poláková, 2014; citing many original sources; Volkovitsh et al., 2020a	3 Larvae, pupae, adults
Malus domestica (synonym: *Malus pumila*) (cultivated apple)	Yes. Possibly native to Kazakhstan, Kyrgyzstan, Uzbekistan (outside the EPPO region also: China, Tajikistan, Turkmenistan). Introduced very widely in the EPPO region and elsewhere.	Matsumura, 1924; Yang & Chen, 1956; South China Agricultural University, 1981; Niu, 2000; Hua, 2002, Jendek & Poláková, 2014 (both as *M. domestica* and *M. pumila*); Wang et al., 2014d; Zhu, 2003; Li & Zhang, 2017 (a review); Volkovitsh et al., 2020a	3 Larvae, pupae, adults
Malus sieversii (wild apple)	Yes. Native to Central Asia, found in Kazakhstan, Kyrgyzstan, Uzbekistan (outside the EPPO region also: Tajikistan, China, and Afghanistan). Used in the EPPO region as the main source of genetic for breeding programs.	Liu *et al.*, 2005, 2013, 2014b; Wang, 2013; Chang, 2017; Yan et al., 2017; Peng et al., 2018; Bozorov et al., 2019; Cui et al., 2019; Volkovitsh et al., 2020a; Zhang et al., 2021; Lu et al., 2022	– Larvae, pupae, adults
Malus baccata (Siberian crab apple)**	Yes. Native to Russia (outside the EPPO region also: Mongolia, China, Korea, Bhutan, India, and Nepal). Introduced to Europe. Available for purchase.	Li & Zhang, 2017 (a review)	– [no details]
Malus spectabilis (Asiatic apple)	No evidence found of presence in the wild or in commercial cultivation. Evidence found of presence in botanical gardens, private orchards, bonsai. Available for purchase.	Hua, 2002; Li & Zhang, 2017 (a review)	– [no details]
Malus asiatica (Chinese pearleaf crab apple)	No evidence found of presence in the wild or in commercial cultivation. Evidence found of presence in botanical gardens, private orchards, bonsai.	Wang et al., 2014d; Li & Zhang, 2017 (a review – as *M. asiatica* and *M. asiatica* var. *rinkii*)	– [no details]

Host	Presence in PRA area (Yes/No/Not known)	References for host status	Confidence index* and/or life stage
	Available for purchase.		
Malus prunifolia (plumleaf crab apple)	No evidence found of presence in the wild or in commercial cultivation. Evidence found of presence in botanical gardens, private orchards, bonsai. Available for purchase.	Sun et al., 1979; Li & Zhang, 2017 (a review)	– Larvae, pupae
Malus yunnanensis (Yunnan crabapple)	No evidence found of presence in the wild or in commercial cultivation. Evidence found of presence in botanical gardens, private orchards, bonsai. Available for purchase.	Sun et al., 1979; Sun, 1983	– Larvae, pupae
Malus halliana (Hall crabapple)	No evidence found of presence in the wild or in commercial cultivation. Evidence found of presence in botanical gardens, private orchards, bonsai. Available for purchase.	Cui et al., 2016	– Adults (feeding experiments on leaves) [not confirmed host]
Other Rosaceae			
Prunus armeniaca (apricot)	Yes. Possibly native to Central Asia (outside EPPO also: China). Introduced very widely in the EPPO region and elsewhere. The most commonly cultivated apricot species.	Hua, 2002	– [not confirmed host]
Prunus persica (peach)	Yes. Native to central and eastern Asia. Introduced very widely in the EPPO region and elsewhere. Very widely cultivated.	Hua, 2002	– [not confirmed host]
Sorbus pohuashanensis (rowan)	No evidence found of presence in the wild or in commercial cultivation. Evidence found of presence in botanical gardens, private orchards. Available for purchase.	Li & Zhang, 2017 (a review)	– [not confirmed host]

Host	Presence in PRA area (Yes/No/Not known)	References for host status	Confidence index* and/or life stage
Cydonia oblonga (quince)	Yes. Likely native to Asia. Introduced in the EPPO region (the Mediterranean countries) and elsewhere very early. Widely cultivated.	Li & Zhang, 2017 (a review)	– [not confirmed host]
Pyrus spp. (pear)	Yes. Likely native to Eurasia. Introduced in the EPPO region (the Mediterranean countries) and elsewhere very early. Widely cultivated.	Hua, 2002; Jendek & Poláková, 2014 (citing Alexeev, 1979 (as *jenissejensis*); Alexeev, 1979; Alexeev, 1989; Alexeev & Volkovitsh, 1989)	3 [without references to laboratory tests] [not confirmed host]

* The confidence index is taken from Jendek & Poláková (2014). It is developed for *Agrilus* species and ranges from 0 to 3 for different species, where '3' is the highest level of confidence based on the presence of larvae or repeated captures of adults on leaves. For *Pyrus* spp. (pear), Jendek & Poláková (2014) reported the confidence index '3' (the highest level of confidence), but without references to any laboratory tests; EWG considered records not fully reliable and the host – not confirmed.
** As the range of *M. baccata* matches the range of *A. mali* (see Fig. 6.1), *M. baccata* might be a native host of *A. mali* (M. Volkovitsh, pers. comm., 2023).

Some *Malus* species are able to hybridize (T. Wöhner, pers. comm., 2023) and it is not clear if some hybrids are hosts for *A. mali*.

It is not known if *A. mali* can attack and develop on other species currently not recorded as hosts, such as other *Malus* species, *Prunus*, *Sorbus*, *Cydonia*, and *Pyrus* species, or other Rosaceae. It is likely that other *Malus* species are suitable hosts, because several species are recorded as hosts in China, but the uncertainty is very high for other genera.

Notes on the hosts that are not confirmed

- References to *Sorbus* may refer to *Agrilus mendax* (Volkovitsh et al., 2020a,b).
- Li & Zhang (2017) mention that the literature reports *Prunus persica*, *Prunus salicina*, *Prunus* spp., and *Pyrus* spp. as hosts of *A. mali,* but most likely confuse *A. mali* with *Lamprodila limbata* (in the text as *Lampra limbata*) and *Coraebus rusticanus*.

Erroneous host records:

- In Chinese references, usually only the common names of hosts are indicated, and then they might be translated incorrectly.
- Records of *A. mali* on *Juglans regia*, *Salix babylonica*, *Ceraras* spp. (misspelled *Prunus cerasus*), *Crataegus* spp., and *Emmenopterys* spp. are considered erroneous, not confirmed; they require verification (Jendek & Grebennikov, 2011; Jendek & Poláková, 2014; Volkovitsh et al., 2020a; X.-Y. Wang, pers. comm., 2022). Consequently, in this PRA, these plants were not considered hosts. Similarly, *Emmenopterys henryi* (Yang & Chen, 1956; Li & Zhang, 2017) was not considered a host.
- There are reports of willows (*Salix* spp.; Salicaceae) and golden rain trees (*Koelreuteria paniculata*; Sapindaceae) as hosts of *A. mali*, but it is likely that another beetle species was meant (Li & Zhang, 2017).
- *Conioselinum anthriscoides* is reported as host (as *Ligusticum chuanxiong*; Apiaceae) in Li & Zhang (2017), but it is a herb and is not likely to be a host for larval development.
- *Kaempferia galanga* (Zingiberaceae) has been reported in the literature as a host of *A. mali*, but it is a herbaceous plant and therefore not likely to be a host for larval development (Li & Zhang, 2017).

Notes on *Malus* in China

When cultivated apple or orchards are mentioned in Chinese publications, these are assumed to refer mostly to *M. domestica* (or *M. pumila* var. *domestica*, the dominant apple cultivated for fruit in the EPPO region).

Luo et al. (2014) indicate that, since the second half of the 20th century, apples cultivated in China are mainly varieties introduced from western countries (i.e. *M. domestica*).

It is worth noting, however, that there are other cultivated/domesticated apples in China (and the Chinese literature, especially very old references, may not only refer to *M. domestica* when referring to cultivated apples – see especially Section 12). At least two other 'cultivated apples', *M.* × *domestica* subsp. *chinensis*[3] and *M. asiatica*, have been cultivated for fruit in China, and several others as rootstocks or ornamentals (Zhang et al., 1993; Luo, 2014; Gao et al., 2021; Chen et al., 2022; Li et al., 2022 citing Jin et al., 2019).

Regarding *M. domestica*, no information is available on whether *A. mali* attacks differ on *M. domestica* subsp. *chinensis*, and in this PRA the subspecies and species are considered equally susceptible.

There are 21 wild *Malus* species in China. *Malus baccata* is a genetic resource for apple breeding programmes in China (especially as a rootstock; Chen et al., 2022), and its distribution widely matches the range of *A. mali*. Wild apple *M. sieversii* is widely distributed in Central Asia (see Section 9). In China, *M. sieversii* forms wild apple forests from which fruit is collected, but it is not planted in orchards. It is recognized as an important source of germplasm (Volk et al., 2013; Cornille et al., 2014; Cui et al., 2019). *Malus sieversii* is likely a progenitor species of the domesticated apple, *M. domestica* (Velasco et al., 2010).

8. Pathways for entry

Bark- and wood-infesting insects, including some *Agrilus* species, can be transported in plants for planting as well as wood products such as round wood, wood packaging material, sawn wood, bark, and wood chips (Meurisse et al., 2018).

It is important to note that the main hosts of *A. mali* are not forest wood trees (i.e. wood pathways are incidental). Consequently, compared to other *Agrilus* species, the likelihood of entry with wood is very low (because of a very limited volume of trade of *Malus* wood) and wood commodities are likely to be more important pathways at the local/regional scale (e.g. from China into Central Asian countries close by) than internationally to the rest of the EPPO region.

In addition, *M. sieversii* (confirmed host) appears to be a 'Grade II protected species' (i.e. endangered and precious tree species) in China, which may influence how this species can be used/traded (Xu et al., 2022).

Some definitions related to pathways are provided in Annex 5.

The following pathways for entry of *A. mali* are discussed in detail in this PRA in Section 8.1:

- **Host plants for planting (except seeds, tissue culture, pollen) (Table 8.1),**
- **Round wood and sawn wood of hosts (with or without bark) (Table 8.2),**
- **Deciduous wood chips, hogwood, processing wood residues (except sawdust and shavings) (Table 8.3).**

The following pathways are discussed in Section 8.1, but not considered in detail:

- **Natural spread from countries where *A. mali* occurs to EPPO countries where it does not occur,**
- **Cut branches of hosts,**
- **Hitchhiking on other commodities or vehicles.**

The following pathways are considered unlikely and are discussed in Section 8.2:

- **Wood packaging material (including dunnage),**
- **Bark of hosts,**

[3] *M.* ×*domestica* subsp. *chinensis* is a landrace that is believed to be over 2000 years old and is more similar to the wild species than are most of the *M.* ×*domestica* cultivars (Gao et al., 2015)

- **Furniture and other objects made of wood of host plants,**
- **Sawdust and shavings, processed wood material, post-consumer scrap wood,**
- **Seeds, fruits, bulbs and tubers, grain, pollen, stored plant products, soil and growing medium,**
- **Movement of individuals, shipping of live insects, e.g. traded by collectors.**

8.1 Pathways studied

Examples of prohibition and inspection are given for some EPPO countries (in this express PRA the regulations of all EPPO countries were not analysed). Similarly, the current phytosanitary requirements in place in EPPO countries for the different pathways are not detailed in this PRA (although some were taken into account when looking at management options). EPPO countries would have to check whether their current requirements are appropriate to help to prevent the introduction of the pest.

Pathways are considered for all hosts (confirmed and unconfirmed) from areas where the pest is present.

Table 8.1. Host plants for planting (except seeds, tissue culture, pollen).

Pathway	**Host plants for planting (except seeds, tissue culture, pollen)**
Coverage	• Plants for planting in pots or similar (including bonsais), plants with bare roots, cuttings, scions. • This pathway covers commercial trade and internet trade by private persons (although there are no specific data on the latter). • Seeds, tissue culture, pollen are excluded because the pest is not associated with these pathways. This pathway also includes travellers carrying in their luggage plants for planting from areas where the pest occurs. For example, apple scion material may also be brought in by private collectors (T. Wöhner, pers. comm., 2023). However, little data are available for travellers' luggage, which is therefore not assessed separately.
Pathway prohibited in the PRA area?	Yes, partly, in some EPPO countries. In the EU: - It is prohibited to introduce plants for planting of *Malus*, *Cydonia*, *Prunus*, and *Pyrus* and their hybrids, other than seeds from China, Koreas, Mongolia, Russian Far East and Eastern Siberia (Commission implementing regulation (EU) 2019/2072; EU, 2019); - *Sorbus* is listed in the provisional list of '*high risk plants*' in the EU. Therefore, in the EU, import of plants for planting of these genera is prohibited pending a risk assessment (Commission Implementing Regulation (EU) 2018/2019; EU, 2018); - Temporary derogations for research and similar purposes exist (Commission delegated regulation (EU) 2019/829; EU, 2019); however, the material will go through post-entry quarantine. In the UK, import of *Malus, Cydonia, Prunus, Pyrus, Sorbus* is prohibited from third countries (pending risk assessment) (https://www.gov.uk/government/publications/plant-species-by-import-category/import-requirements-for-plants-plant-produce-and-products). In Norway, currently there are no prohibitions (B.A. Hatteland, pers. comm., 2023). The EWG was not able to check whether the import of host genera is prohibited in other EPPO countries, or whether import of host genera from China into EPPO countries, other than EU member states, the UK, and Norway, is possible in particular in neighbouring Central Asian countries.
Pathway subject to a plant health inspection at import?	Yes. Plant health regulations usually specify that plants for planting (with often exceptions for seeds, tissue culture and pollen) are regulated and should be imported with a Phytosanitary Certificate and are consequently subjected to import inspection. This is the case for EU countries and EAEU countries (Commission implementing Regulation (EU) 2019/2072; EU, 2019; Decisions of the Council of the Eurasian Economic Union # 157 and 158 of 30.11.2016; EEU, 2016; *A. mali* is on the A2 Quarantine List of Eurasian Economic Union).
Pest already intercepted?	No interceptions of *A. mali* reported for the EU on plants for planting, no known interceptions of *A. mali* for other countries.
Plants concerned	Hosts in Table 7.1 (Section 7). This pathway analysis covers confirmed and unconfirmed hosts.
Most likely stages that may be associated	Eggs, larvae, pupae and callow (pharate) adults may be associated with plants for planting. If plants are dormant, eggs will not be associated with them, because larvae hatch much earlier. Adults may be associated if they emerge during storage and transport.

Pathway	Host plants for planting (except seeds, tissue culture, pollen)
Important *factors for association with the pathway	- Diameter of infested branches can vary but the pest is reported to be mostly associated with branches of a diameter of 10–55 mm; infestations are possible in smaller (down to 4 mm) or larger (up to 100 mm) diameter branches (Section 2.6). Thus, plants for planting of different age/size/diameter can serve as a pathway. - On young trees, trunks (with thin bark) may be infested. - Scions for orchards are available locally and may be available online (e.g. from USA: https://www.etsy.com/ie/search?q=scions+of+malus+sieversii&ref=search_bar). A scion diameter is usually small (maximum 1.12 cm; Malasi et al., 2017), and may be infested (see sizes given above). Usually, scions are taken from the best (i.e. healthy and well managed) trees, and are less likely to be infested. Scions are prepared in autumn or spring and stored in moderately cool conditions, but this would not eliminate the pest, if it is present. - Several larvae can infest one branch/tree. - *A. mali* seems to prefer stressed trees rather than healthy trees and nursery plants for planting are usually well maintained. - The presence of signs and symptoms of infestations may allow detection of infested plants (especially red oil dots, D-shaped exit holes, etc.). They may not, however, be conspicuous at low levels of infestation in a consignment (see Section 2.7). Detection during inspection will depend on the intensity of inspection. - There is uncertainty about the pest prevalence in production areas in nurseries and orchards, especially on *M. domestica*, and whether control measures are applied that reduce the prevalence. In Xinjiang, there are some highly infested areas. - There is uncertainty about the risk of introduction with young plants. *Agrilus mali* is reported to attack young apple trees in orchards or nurseries (see Section 2.6). However, Li & Zhang (2017) indicate that 'there had not been a single report of trees and scions available in the trade/market carrying *A. mali*, thus the occurrence of *A. mali* in apple growing areas in China is likely to come from local wild or semi-domesticated hosts; the possibility that it is carried and spread by plants for plantings needs to be further explored'.
Survival during transport and storage	Eggs, larvae, pupae and callow (pharate) adults would have suitable conditions for survival within the host plant during transport. Adults can survive a few days without food (ca. 4–7 days reported in laboratory starvation experiments at 25 °C), and may be able to survive longer at lower temperatures (however, they need maturation feeding for reproduction). If host leaves are available, the lifespan will be longer (see Section 2.4).
Trade	Apple plants for planting are more likely to be moved as scions or as bare rooted plants in the dormant stage, than as potted trees. Wild apple species from the centers of origin in Central Asia or China are valuable sources of genetic material. Breeding material may be imported into collections/breeding programmes, in the form of seeds or budwood (e.g. *M. sieversii* and *M. orientalis* – Volk et al., 2013). France has a very active breeding programme for *Malus*, *Pyrus*, and *Prunus* and budwoods from China have been imported in the quarantine station (data from 2014–2017; Larguier et al., 2018). No details were found for other EPPO countries, but it cannot be excluded that similar material is imported in this form from China or collected in Central Asian countries (as described in Volk et al., 2010). Scions are mostly used as material for this purpose (T. Wöhner, pers. comm., 2023). Theoretically, genetic material may also be introduced into breeding programmes of some EPPO countries in the form of rooted plants, if allowed by national regulations.

Pathway	Host plants for planting (except seeds, tissue culture, pollen)
	Data for the period 2000–2010 (ISEFOR data regarding imports from non-EU countries into seven EU countries; Eschen et al., 2017) (Annex 6) show import of some host species or genera. These data are incomplete and there is a high uncertainty concerning import volumes of host plants for planting into the EPPO region. The origin of such trade may also change. Thus: • few *Malus* plants were imported from China, in 2001; • data relating to some EPPO countries were added to illustrate possible trade within the region; • import was registered for some plants for planting of fruit species that are prohibited in the EU from such origins. It is supposed that such consignments were rejected or only allowed under derogation (e.g. in EU countries); • data is provided at a genus level, i.e. imports may have been other species than host species. Note that *Prunus avium* and *Prunus cerasus* were left in the table, but are not recorded hosts. There is no data on trade of host plants for planting from countries where the pest occurs to other parts of the EPPO region, such as Central Asian countries. It is not known if there is any movement of such material across the border between Kazakhstan and China. Remark: Internet trade of bonsais of *Malus* spp. from China and the Korea Rep. exist (e.g. https://bonsai.en.made-in-china.com/product/IdtAeFcbLVkD/China-Chinese-Bonsai-High-Quality-Malus-Spectabilis.html) and these may escape phytosanitary requirement. There is no information on whether host plants for planting are brought in by travellers, but they are likely to be in very small quantities.
Transfer to a host	Eggs, larvae, pupae would continue their development once at destination. If leaves are present, emerging adults would already be on a suitable host.
Likelihood of entry and uncertainty	Host plants for planting (except seeds, tissue culture, pollen): For countries where import of host plants for planting is not prohibited, the likelihood of entry is *moderate* (in China, it is thought to have spread with plants for planting; trade is presumably limited; low infestations are not likely to be detected; prevalence at origin on host plants for planting that are exported would be low) with a *high uncertainty* (lack of knowledge on hosts, including status of unconfirmed hosts, prevalence at origin, association with the production of plants for planting at origin, trade to non-EU EPPO countries). For countries where import of host plants for planting is prohibited and imported breeding material goes through post-entry quarantine (e.g. the EU), the likelihood of entry is *low* (not very low because of possible transport by passengers or internet trade) with a *low* uncertainty.

Table 8.2. Round wood and sawn wood of hosts (with or without bark).

Pathway	**Round wood and sawn wood of hosts (with or without bark)**
Coverage	This pathway covers all types of round wood and sawn wood, with or without bark. The hosts of *A. mali* are not trees normally used for wood production. Use of *Malus* for example is most likely limited to high quality parts of furniture or wooden items (see Trade). There is an internet trade of large chunks of *Malus* wood with or without bark, particularly for smoking. It can also not be excluded that the wood of hosts may be used and traded, especially between neighbouring countries as firewood. The understanding of sawn wood is as per definition in ISPM 5, i.e. wood sawn longitudinally, with or without its natural rounded surface with or without bark (FAO, 2018a). Round wood includes logs, but also other types of material. Whole trees including branches, twigs, possibly stumps, may be harvested (e.g. as fuel wood / 'firewood'). In addition, part of the commodity described in the EPPO Study on wood commodities other than round wood, sawn wood and manufactured items (EPPO, 2015) as '*harvesting residues*' is a type of round wood (when in the form of tops of trees, branches, twigs etc.). - *composition*: Consignments of round wood (as logs) and sawn wood would generally be of one species. Harvesting residues (in the form of round wood) arise from the harvest of logs and may initially be from one tree species, but it is not known if they would be grouped with other tree species from other origins when traded (e.g. as fuel wood). Round wood intended for other purposes (e.g. fuel wood, production of chips) may contain a mixture of species. - *presence of bark*: Round wood (as logs) and sawn wood may be traded with or without bark. Other types of round wood may also have bark attached. - *size*: Logs would normally be of a large size. For harvesting residues (in the form of round wood) and any material sold as fuel wood/firewood, the material may be of variable size (including branches, tops of trees, branches, twigs etc.). Sawn wood of less than 6 mm of thickness is considered to pose a minimal risk because larvae and pupae will be damaged during the processing. - *intended use*: Such wood commodities may generally be used for construction, furniture, long poles, energy purposes or processed (such as chips, pulp, fibreboard, etc.).
Pathway prohibited in the PRA area?	No.
Pathway subject to a plant health inspection at import?	Yes, at least in some EPPO countries. In the EU, round wood (with or without bark) and sawn wood of hosts from China, Koreas, Mongolia, Russian Far East and Eastern Siberia should be accompanied by a phytosanitary certificate and should be subject of phytosanitary inspection (Commission Implementing Regulation (EU) 2019/2072; EU, 2019). There are also specific requirements for wood of certain hosts from countries where *A. mali* occurs, and host wood would be inspected. In the phytosanitary legislation of the Eurasian Economic Union (Armenia, Belarus, Kazakhstan, Kyrgyzstan, and Russian Federation) there are no specific restrictions to round wood (with or without bark) and sawn wood of *Malus* spp., but all imported wood material should be free of *A. mali* (Decisions of the Council of the Eurasian Economic Union # 157 and 158 of 30.11.2016; EEU, 2016).

Pathway	**Round wood and sawn wood of hosts (with or without bark)**
Pest already intercepted?	No interceptions of *A. mali* reported for the EU in round wood or sawn wood, no known interceptions of *A. mali* for other countries.
Plants concerned	Hosts in Table 7.1 (Section 7). This pathway analysis covers confirmed and unconfirmed hosts.
Most likely stages that may be associated	The presence of eggs and early larval instars on this pathway is restricted to wood with bark. Final instar larvae and pupae may be associated with wood with or without bark. Adults would be associated with consignments of wood only if they are still in their pupal cells or emerge during transport or storage.
Important factors for association with the pathway	- *A. mali* is mostly associated with branches, and seldom with trunks and then mostly on young trees. It is mostly associated with branches of a diameter of 10–55 mm, but infestations are possible in smaller (down to 4 mm) or larger (up to 100 mm) diameter branches (Section 2.6). - It is assumed that there may be many larvae or pupae in one branch. - Debarking will destroy or remove eggs and some feeding larvae, but final instar larvae are recorded to reach the xylem. - The presence of bark on the wood would favour survival of larvae, pupae, and adults. - Low levels of infestation may not be detected. The pest would probably be more easily detected in sawn wood as galleries may be seen after sawing (in relation to short galleries when the insect enters to molt and pupae), or in round wood without bark because larval galleries can be seen directly on the sapwood surface. - As for *A. planipennis* and *A. bilineatus*, date of cutting may greatly influence the number of viable larvae present in the wood (Haack & Benjamin, 1980; Petrice & Haack, 2007). - The concentration is expected to be higher in wood for bio-energy use/firewood/wood chunks, as wood of poor quality is usually used for this purpose and no treatment is applied afterwards. - Careful visual examination of round wood and sawn wood for presence of symptoms may enable the detection of the pest but would be difficult. The presence of exit holes may be the result of attack by other insects, and they may not be conspicuous at low levels of infestation in a consignment. - The trade of wood including firewood has been important for the international movement of *A. planipennis* (EPPO, 2013a)
Survival during transport and storage	Larvae of later instars may survive during transport (transit), and during subsequent storage if they have enough phloem, bark and wood at their disposal, and that the wood remains suitable for feeding/boring galleries. This is considered possible as there are reports of live larvae of other *Agrilus* species having survived on dying or dead trees in dunnage (although it may be more difficult on small diameter wood; Haack et al., 2014). Stark (1955) reported the larval diapause of xylophagous insects, including some *Agrilus*, in cut trees under moisture deficiency. In cut firewood stored outdoors, Petrice & Haack (2007) recorded successful adult emergence of *A. planipennis* 1 year after infested trees were cut, which was 2 years after they were initially infested. Many buprestid larvae can remain alive during many years within a dry substrate (M. Volkovitsh, pers. comm., 2023). If this is the case for *A. mali*, late larval instars may survive very long transportation and storage. There is an uncertainty as to the ability of early instar larvae to complete development, especially in small diameter material. Pupae and callow (pharate) adults would survive. If adults emerge during transport, their survival would be more limited. The survival of emerged adults of *A. mali* in the absence of host leaves to feed on is limited. Under experimental starvation conditions at 25 °C, adults were shown to survive on average 4.7 days (males) or 6.5 days (females), perhaps, longer under lower temperatures. The transport time from China to Europe on railway freight routes (how the commodity would likely be transported) is currently 18–30 days while maritime transport may take over 40 days (Ziegler, 2022).

Pathway	Round wood and sawn wood of hosts (with or without bark)
Trade	There is an uncertainty on the quantity of the internet trade of large chunks of *Malus* wood, but some material is available for sale on the internet from China (e.g. https://www.alibaba.com/product-detail/Apple-BBQ-Smoking-Wood-Chunks-Chips_60776352400.html?spm=a2700.galleryofferlist.normal_offer.d_image.7ecd7758548QSE). There is an internet trade of apple wood sticks for handicrafts or pets' chewing sticks from China (e.g. https://www.alibaba.com/product-detail/Dried-natural-apple-tree-s-wood_1600360327363.html?spm=a2700.galleryofferlist.normal_offer.d_image.754628e6Q8Oh3s). It is possible that infested host wood of low quality may be traded as firewood at a local scale, e.g. between neighbouring areas, especially Kazakhstan and China. The list of commercial timber species by Mark et al. (2014) mentions *M. domestica* (*M. pumila*), *M. sylvestris*, several *Prunus* spp., *Pyrus communis*, and *Sorbus* spp. The wood database (Meier, 2022) mentions that apple (referring to '*Malus domestica*, *M. sieversii*, *M. sylvestris* etc.') is 'seldom available as lumber, and is usually seen only in very small sizes when available. Likely to be rather expensive, and is usually meant for only small projects and specialized applications'. The use of fruit trees for timber is likely to be limited. The Useful Temperate Plants Database (2016) notes that the wood of *M. sieversii* is 'generally of too small size for commercial exploitation but, where larger sizes are attained the wood has been used for making a wide range of items'. No data were available on the import of wood from host genera into the EU (the only data available is for broad categories and is therefore of limited interest for the PRA). Trade of wood from Russia into many EPPO countries is currently (2023) prohibited, but it is likely that some of EPPO countries still allow import of Russian wood (though it is unlikely that wood of *Malus* is actively traded).
Transfer to a host	Wood is often stored outdoors. If final instar larvae or pupae are present in the wood, adults could emerge later. Emerging adults would need to find a suitable host tree species with foliage within approx. 4 to 7 days (Table 7.1, Section 7). The possibility for escape from chunks of wood would vary depending on the type of packaging. The pest is considered rather poor flyer. The survival of larvae would depend on their developmental stage and the availability of suitable quantity of phloem and wood in suitable state. However, the conditions in drying wood are unlikely to allow their full development for more than 1 year (see above). This also assumes that the wood is not used/processed before it becomes unsuitable to support the developments of the pest.
Likelihood of entry and uncertainty	*Low likelihood:* - life stages are more associated with branches than with trunks, and not trunks of large trees, - *Malus* is not a major wood species; however, there is an internet trade of small diameter material with bark from China that may not be sufficiently controlled, - volumes are probably limited; *High uncertainty:* - lack information on trade, on size of the material, on the origin of *Malus* chunks, how they are packaged and processed, - whether larvae are able to complete development and emerge from such material, lack information on trade, packaging and processing.

Table 8.3. Deciduous wood chips, hogwood, processing wood residues (except sawdust and shavings).

Pathway	Deciduous wood chips, hogwood, processing wood residues (except sawdust and shavings)
Coverage	Wood chips, hogwood, processing wood residues (except sawdust and shavings) that contain wood of hosts. The hosts of *A. mali* are not major forest/wood trees. Low quality or damaged trees might be used for chips' production, etc., most likely in a mixture with trees of other species (e.g. when orchards are cleaned or cut). However, it is likely that the wood products will be limited amount and mostly consumed locally. In addition, there is an internet trade of wood chips made of host plants (in particular *Malus* spp.) available for international private purchase for barbecue or smoking food. Sawdust and shavings are excluded because the pest is not associated with these pathways. Note '(except sawdust and shavings)' is not repeated below to simplify but is intended throughout this pathway. Where harvesting residues are in another form than round wood (e.g. residues from squaring), the EPPO Study on wood commodities other than round wood, sawn wood and manufactured items (EPPO, 2015) considers that they would either be left on-site or be transformed on-site, in which case they become another commodity (e.g. wood chips, hogwood). All these commodities may be used for different purposes, such as pulp, fibreboard production, energy purposes, mulch. - *composition:* Depending on the intended use, wood chips are produced from one or a mixture of tree species. This is not known for the other commodities but would presumably be the same. - *presence of bark:* Wood chips or hogwood may be produced from different types of initial material (e.g. wood with or without bark, post-consumer scrap wood, etc.). Processing wood residues are residues from round and sawn wood, e.g. made from off-cuts, and may have bark attached. As a consequence, at least part of these commodities may include some bark. - *size:* Wood chips are produced through a shredder using a round-hole sieve that defines the dimension of chips (e.g. <2.5 cm) on two sides (not the third). The European Standard on solid fuel (Alakangas, 2010; CEN, 2010) identifies four classes of wood chips according to size; in the class with the largest wood chips, 75% of wood chips should be comprised in the range 16–100 mm, and 6% can measure 200–350 mm. Hogwood or processing wood residues have no size requirement. As a consequence, both wood chips and hogwood can be quite large. - *intended use*: Use of the wood commodities as mulch presents the highest risk (as facilitating transfer of pests to nearby trees), but this is a minor use of such commodities.
Pathway prohibited in the PRA area?	No.
Pathway subject to a plant health inspection at import?	Yes, partly, at least in some EPPO countries: In the EU, requirements are in place for this pathway from different origins (including areas where the pest is present) and a Phytosanitary Certificate should be issued and inspection can be performed at import. In the phytosanitary legislation of the Eurasian Economic Union (Armenia, Belarus, Kazakhstan, Kyrgyzstan, and Russian Federation), there are no specific restrictions to wood chips, hogwood, processing wood residues of *Malus* spp., but all imported wood material should be free of

Pathway	Deciduous wood chips, hogwood, processing wood residues (except sawdust and shavings)
	A. mali (Decisions of the Council of the Eurasian Economic Union # 157 and 158 of 30.11.2016; EEU, 2016). Inspection can be performed at import.
Pest already intercepted?	No interceptions of *A. mali* reported for the EU in wood chips, hogwood, processing wood residues of host plants, no known interceptions of *A. mali* for other countries.
Plants concerned	Hosts in Table 7.1 (Section 7). This pathway analysis covers confirmed and unconfirmed hosts.
Most likely stages that may be associated	Eggs, larvae, pupae, and adults in pupal chambers.
Important factors for association with the pathway	- Consignments of wood chips may be a mix of hardwood species, and may contain very limited quantities of host wood (because these are not major timber species). Heavily infested trees from orchards or wild apple forests that cannot be used for other purposes may be processed into, e.g. wood chips. - *A. mali* is mostly associated with branches, and seldomly with trunks. It is mostly associated with branches of a diameter of 10–55 mm, but infestations are possible in smaller (down to 4 mm) or larger (up to 10 cm) diameter branches (Section 2.6). Thus, wood chips, hogwood, processing wood residues originated from branches of different age/size/diameter can serve as a pathway. - For chips, existing requirements (e.g. in the EU) based on size, i.e. that chips should be below 2.5 cm in two dimensions, would make it very unlikely that final instar larvae, pupae and adults in pupal chambers would survive the process. However, the third dimension can be of any size. - The higher risk of introduction would arise from the presence of final instar larvae, pupae or adults in pupal chambers (see other considerations below).
Survival during transport and storage	Survival is considered to be less likely than on wood. Chipping of infested wood greatly reduces survival of *Agrilus* species such as *A. bilineatus* (Dunbar & Stephens, 1974), *A. auroguttatus* (Jones et al., 2013), and *A. planipennis* (McCullough et al., 2007). Processes for chipping or hogwood production would cause high larval mortality. This was demonstrated for *A. planipennis* prepupae using a horizontal grinder with a 2.5 cm x 2.5 cm screen: no evidence of survival was observed (McCullough et al., 2007). Chipping 2.5 cm x 2.5 cm or smaller is considered effective against *A. planipennis* [and therefore against *A. mali* which has a similar size] (McCullough et al., 2007). However, Økland et al. (2012) considered that surviving prepupae could have been found if a larger volume of wood chips would have been used in the experiment. Further, mortality of any insects that would survive chipping is presumed to be high since the chips are usually dry and because of all other treatments (Dunbar & Stephens, 1974). Young larvae would not be able to survive and complete their development since the amount of phloem would not be enough and of suitable quality. Final instar larvae, pupae and callow (pharate) adults can survive in pieces of wood in which they have survived the chipping processing. Such commodities may be stored in big piles. The temperature in the core of the bulk for wood chips may become high (e.g. 60° C) due to composting effect, which will likely be detrimental to the pest. Temperatures in the periphery of the pile are expected to be much lower and seldom lethal. Thus, only part of the consignment/pile is likely to present conditions that would allow survival of larvae and pupae.

Pathway	Deciduous wood chips, hogwood, processing wood residues (except sawdust and shavings)
	If adults at the periphery of consignments emerge during transport, they would not find foliage to feed if the consignment is enclosed in a way which would prevent escapes in transits. They are less likely to survive (as they would need to feed on leaves).
Trade	Wood chips made of host plants (in particular *Malus* spp.) are available for international private purchase from China via online shops, e.g.: https://www.alibaba.com/product-detail/China-Factory-Supply-wood-chips-prices_1600386011512.html?spm=a2700.7724857.0.0.13751c60Xl3WF4 and https://www.alibaba.com/product-detail/Subtle-Sweet-flavor-Smoking-Apple-Wood_60767789340.html?spm=a2700.7724857.0.0.13751c60Xl3WF4 but the scale must be very limited. Trade data is available in Eurostat (i.e. into the EU) for 'deciduous wood chips', and for 'wood waste and scrap (whether or not agglomerated in logs, briquettes or similar forms (excl. sawdust and pellets)'. Data extracted for 2013–2017 in the EPPO PRA for *A. fleischeri* (EPPO, 2019) showed: *Wood chips* Major imports from Russia (260,000–343,000 t) in 2013–2017, mostly to Finland, but also to Estonia and Denmark, and more recently to Sweden. Minor and irregular imports from other countries: *China: 23–5,457 t in 2013–2017 (highest value for 2016), *Korea Rep.: 3–123 t per year in 2013–2017. *Wood waste and scrap* Major imports from Russia in 2013–2017 (163,650–222,202 t depending on years), in 2017 mostly to Belgium and Finland. Minor and irregular imports from other countries in 2013–2017: *China: 89–154 t per year, * Korea Rep.: 0.4 t in 2014 and 7 t in 2015.
Transfer to a host	Transfer would be similar as for wood. Transfer is facilited when the commodity is stored outdoors for enough time prior to processing, allowing emergence. In addition, transfer may be limited by the intended use of the commodity (e.g. chips for energy, or apple wood chips used to smoke meat in barbeque, etc.) or facilitated if the commodities are used outdoors (e.g. ground cover, mulch). However, products for ground cover (mulch) likely constitute a small part of imports. Adults would need to find a suitable host tree species. The possibility for escape from wood chips for barbecue or smoking food would vary depending on the type of packaging.
Likelihood of entry and uncertainty	*Very low likelihood* - survival related to the size of pieces and processes, - processes would kill a large proportion of individuals, and survival during storage and transport is less likely in wood chips than other wood (material would dry out faster), - presumably very small proportion of *Malus* in wood chips consignments, except for *Malus* wood chips for barbeque and smoking, which are traded on the internet; *Moderate uncertainty*

Pathway	Deciduous wood chips, hogwood, processing wood residues (except sawdust and shavings)
	- whether larvae are able to complete development and emerge from such material, - lack information on trade, packaging and processing.

- **Natural spread from countries where *A. mali* occurs to EPPO countries where it does not occur**

Agrilus mali is present in Xinjiang, which has a border with Kazakhstan, Kyrgyzstan, and Tajikistan. Xinjiang is considered in numerous Chinese publications to be part of the pest's invasive range, but recent genetic analysis of Sun et al. (2022) questions the recent arrival of the pest to the province, i.e. it may have had longer time to spread naturally to neighbouring countries. The closest localities to the border of Kazakhstan where the pest was collected (Sun et al., 2022) are located ca. 30 and 60 km from the border (in Zhaosu county, 43°9′20″N, 81°7′57″E; in Hainuke town 43°43′41″N; 81°22′34″E; 2019 and 2020) and ca. 85 km from the border to Kazakhstan (43.2035°N, 81.8449°E; 2013; location # 88; Lu et al., 2022, Supplementary Material 1). Adults of *Agrilus* spp. can fly considerable distances, even though they rarely do so (Section 2.4). In the case of *A. mali*, even though the flight capacity of this species is low, it would allow natural spread locally to a neighbouring country, especially where the border lies in the forest with *M. sieversii* present.

Kazakhstan is considered the most likely country where the pest could enter through natural spread. The pest is present in Xinjiang, very close to the border of Kazakhstan, and there are wild apple forests and apple orchards in Kazakhstan close to the border. The EWG considered that it is a matter of time before the pest reaches Kazakhstan.

Likelihood of entry: Very high to Kazakhstan.

Uncertainty: Low.

- **Cut branches of hosts**

This pathway covers cut branches of hosts (confirmed and unconfirmed), used for decoration or other ornamental purposes. It is not known whether cut branches of any host are used, nor if they are traded internationally (including between neighbouring countries). This is consequently a hypothetical pathway.

Cut branches for ornamental purposes are expected to be high value and consequently of good quality, and therefore infested material is likely to be discarded at origin.

Given its biology, *A. mali* can be associated with branches (larvae in galleries under the bark, pupae or callow (pharate) adults in pupal chambers). Cut branches may be small and below or at the lower margin of diameters of branches that are most often infested (10–55 mm; see Section 2.6) however branches with a diameter of 4–6 mm have been reported to be infested. Cut branches are likely to be unsuitable for the completion of larval development as they dry out, especially for earlier larval instars. Mature (likely the final instar) larvae, pupae and callow (pharate) adults may be able to complete development. Emerging adults would need to find a host, bouquets are usually discarded in wastes.

If cut branches are discarded by industry or private buyers outdoors or on private compost piles (e.g. dumping of waste or binning/composting, depending on the processing of the waste), the pest may be able to escape. In EPPO countries where waste is subject to composting or incineration / anaerobic digestion, the possibility of escape would be lower. It is difficult to estimate this probability.

In the EU, cut branches of host genera require phytosanitary certificates (Commission Implementation Regulation (EU) 2019/2072, EU, 2019). In the phytosanitary legislation of the Eurasian Economic Union (Armenia, Belarus, Kazakhstan, Kyrgyzstan, and Russian Federation) there are no specific restrictions for cut branches of *Malus* spp., but all imported woody material should be free of *A. mali* (Decisions of the Council of the Eurasian Economic Union # 157 and 158 of 30.11.2016; EEU, 2016).

Likelihood of entry: Low (trade is probably very limited, cut branches for ornamental purposes would be of good quality).

Uncertainty: High (lack of information on the trade, size of branches, disposal processes).

- **Hitchhiking on other commodities or in vehicles**

Hitchhiking on vehicles was considered as a pathway for *A. planipennis* (PRA on *A. planipennis*, EPPO, 2013a; Selikhovkin et al., 2022) adults to spread over relatively short distances (i.e. neighbouring countries). *Agrilus mali* adults may become associated with non-host commodities, containers or vehicles (road, train). However, as explained in Section 2.3, adults of *A. mali* have a relatively short lifespan without host leaves and would not survive for more than 4–7 days. Although hitchhiking cannot be excluded, it would be limited to countries that are relatively close to an infestation, especially Kazakhstan and possibly Kyrgyzstan and Tajikistan (the latter, not an EPPO member yet).

Hitchhiking was the probable pathway for *A. planipennis* from Moscow in Russia into St Petersburg, because its host plants (*Fraxinus excelsior and F. pennsylvanica*) is widely used as a road tree. There is no evidence that *A. mali* has moved along transportation routes to new areas, including not between eastern and western Siberia.

The movement of commodities across the border from China is probably limited.

Likelihood of entry: Low.

Uncertainty: Moderate (how it moved within China, volume of movement across the China-Kazakhstan border).

The overall rating of the likelihood of entry is based on the rating of the pathway with the highest rating:

The highest rating is entry by natural spread into **Kazakhstan** (very high likelihood with a low uncertainty). The overall rating of the likelihood of entry indicated below is given for **Kazakhstan**:

Rating of the likelihood of entry (into Kazakhstan)	Very low ☐	Low ☐	Moderate ☐	High ☐	Very high X
Rating of uncertainty			Low X	Moderate ☐	High ☐

For EPPO countries other than Kazakhstan, the overall likelihood of entry is moderate with a moderate uncertainty (for the countries that do not prohibit *Malus* plants for planting) and low with a moderate uncertainty (for the countries that prohibit *Malus* plants for planting).

8.2 Unlikely pathways: very low likelihood of entry

- **Wood packaging material (including dunnage)**

The main hosts of *A. mali* are not forest wood/trees and wood of e.g. *Malus* is a high value wood which is unlikely to be used when manufacturing, e.g. pallets.

Requirements for wood packaging material in ISPM 15 (FAO, 2018b) cover all species of wood. Consequently, if compliance with ISPM 15 is ensured by the exporting country the risk of entry with this pathway is very low with low uncertainty.

Uncertainty: Low.

- **Bark of hosts**

This covers bark traded on its own, with the understanding that in bark consignments, pieces of cambium or wood may be attached to the bark (EPPO, 2015). There is no information that the bark of hosts is used, nor on the trade of bark of hosts into the EPPO region. The EWG believes that the amount of host bark traded is very limited, if it exists at all.

Eggs of *A. mali* could be present on the bark for a short time before harvest, and larvae can be associated to thick bark. Mature larvae and pupae are in the outer xylem and are unlikely to be associated with bark consignments. Early life stages would not complete their development in the absence of a sufficient quantity of wood, and because the material would dry and degrade.

Uncertainty: Low.

- **Furniture and other objects made of wood of host plants**

The wood database (Meier, 2022) mentions that wood of apple is usually available only in very small sizes (see also round wood, Table 8.3), and that common uses are 'fine furniture, tool handles, carving, mallet heads, turned items, and other small specialty wood objects'. In addition, the Useful Temperate Plants Database (2016) mentions that the wood of *M. sieversii* is 'generally of too small a size for commercial exploitation but, where larger sizes are attained the wood has been used for making a wide range of items, including furniture, mallet heads, umbrella handles, cog wheels, pianos, tools etc, and also for turnery (citing several sources).

Some minor uses of objects made of wood of *Malus* spp. are known such as furniture, decorations or souvenirs. For most of these objects, any holes and galleries would be seen as a defect. Insects would very likely have been killed during the manufacturing process.

The size of some wooden objects may not be sufficient to allow the presence or the complete development of the insect. As the wood dries, the wood will also become unsuitable for larval development and, if pupae or callow (pharate) adults are present in the wood, it is not known if adults would be able to emerge from very dry wood, although a few similar cases concerning other buprestid species are known in literature (e.g. Bílý, 2002; Hawkeswood, 2006). Some traded wood objects are known to allow the movement of insects: the longhorn beetles *Monochamus alternatus* (vectoring *Bursaphelenchus xylophilus*), *Trichoferus holosericeus* have been found in dining chairs, *Trichoferus campestris* in a wooden cutlery tray, *Leptura quadrifasciata*, in a railway sleeper, and the buprestid *Coomaniella purpurascens* was found in souvenir pencils (size: 25 x 5 cm) made from unknown host (Ostojá-Starzewski, 2014; Bílý & Volkovitsh, 2015; Hodgetts et al., 2016).

Uncertainty: Low.

- **Sawdust and shavings, processed wood material, post-consumer scrap wood (see definitions in ANNEX 5 and EPPO [2015])**

EPPO Study on wood commodities other than round wood, sawn wood and manufactured items (EPPO, 2015) assesses the risk as being low for all pests. Such wood material is processed to a level that would not allow survival of the pest. Any eggs, larvae or pupae present in the initial material would die or not be able to continue development.

Uncertainty: Low.

- **Seeds, fruits, bulbs and tubers, grain, pollen, stored plant products, soil and growing medium**

No life stages are associated with these.

Uncertainty: Low.

- **Movement of individuals, shipping of live Buprestidae, e.g. traded by collectors**

The insect will most likely be moved or shipped dead, but not always; insects are sometimes in pieces of wood[4]. This pathway is also difficult to regulate.

Uncertainty: Low.

9. Likelihood of establishment outdoors in the PRA area

9.1. Climatic suitability

Lu et al. (2022) analyzed the current and potential future distribution of *A. mali* using a CLIMEX model (see main parameters in Section 2.3). The model considers the area where 450 degree-days are accumulated within a year (what corresponds to the univoltine life cycle of the pest) and it does not take into account that the pest can accumulate 450 degree-days during the 2nd year of its development. Some parameters used in the model were estimations based on another species (*A. planipennis*), which limits reliability and predictive quality of the model. The model also uses the temperature averages for 1961–1990, whereas the current temperatures are higher (e.g. https://www.cbs.nl/en-gb/society/nature-and-environment/green-growth/environmental-quality-

[4] Frequently Asked Questions' on a webpage for collectors: 'Do I need a permit to ship live insects…' http://www.insectnet.com/faq.htm#usda

of-life/average-temperature). In addition, although the model was found to reasonably reflect the current known distribution of the pest in China, some areas where the pest is known to occur in Xinjiang (where outbreaks occur on wild apple), East Siberia and Mongolia were classed as ‘marginally suitable’ or ‘not suitable’. The EWG considers that this model underestimates the potential distribution because it does not consider the regions where 450 degree-days are accumulated only during the 2nd year of the pest’s cycle, and acknowledges there is considerable uncertainty around the parameter values used in the model. This model and its output are nevertheless included in this PRA because it still provides some information about the potential distribution of *A. mali* worldwide. The EWG also considers that the model underestimates the potential area of establishment of the pest in the EPPO region. Nevertheless, it suggests that a large part of the EPPO region may be at least marginally suitable for a univoltine development of the pest (Fig. 9.1).

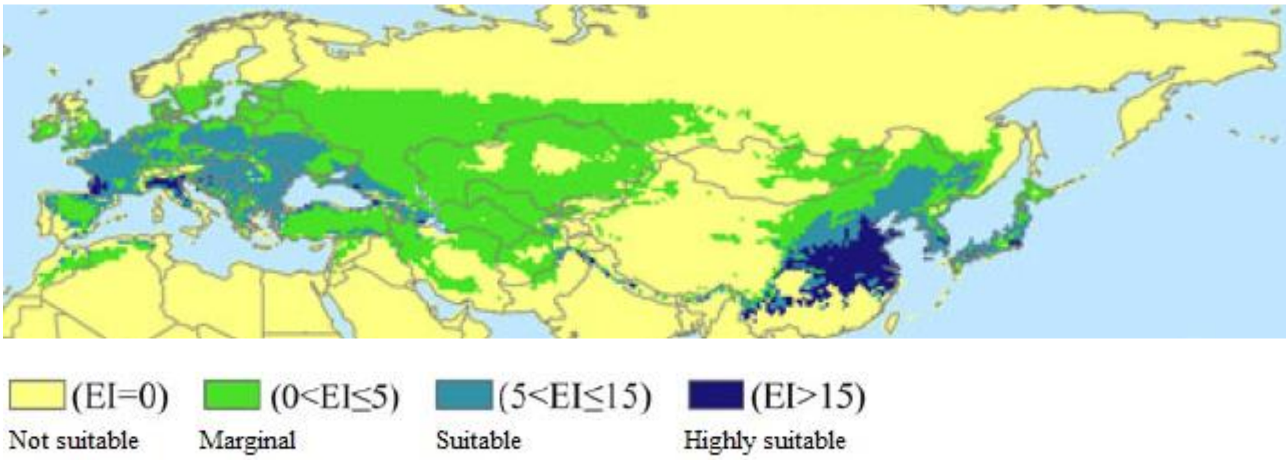

Figure 9.1. Potential distribution of *Agrilus mali* in the EPPO region and China under current climate (map and legends are extracted from Lu et al., 2022). Note that in Lu et al. (2022) both the labels ‘suitable’ and ‘low suitability’ is used for the category 5<EI<15. The plotted potential distribution is based on the assumption that the pest can establish only in the area where 450 degree-days are accumulated within a year, and therefore the EWG group assess it as likely that the potential distribution of the pest should also include cooler areas. In addition, temperature averages of the period 1961–1990 has been used, whereas the global temperatures have increased significantly since then.

Under a climate change scenario[5], Lu et al. (2022) predict that the potential distribution of *A. mali* (understood as an area where 450 degree-days are accumulated within a year) will shift by 2100 northwards and to higher altitudes. In the EPPO region, Scotland, as well as a part of Scandinavia, Russia and Central Asia would become marginally suitable (0<EI<5).

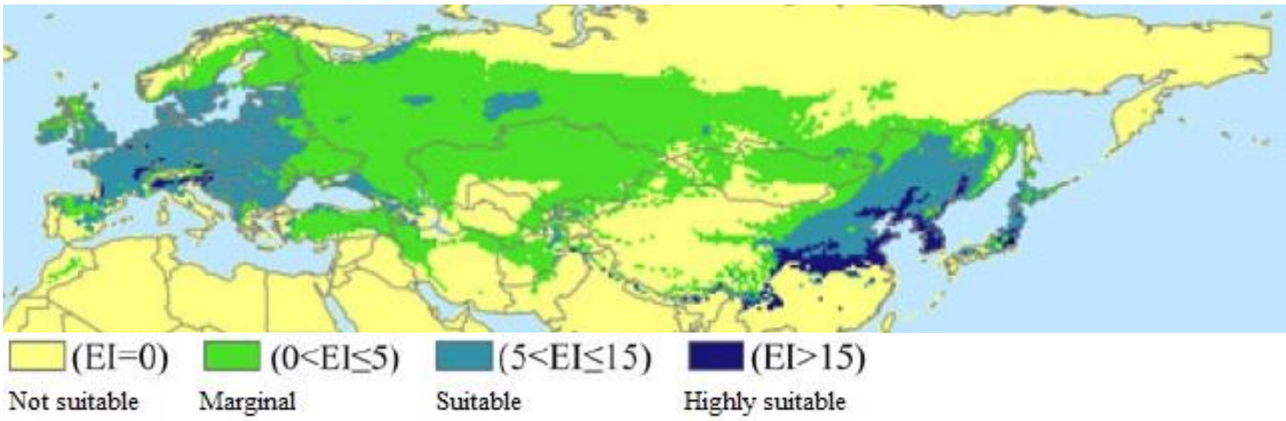

Figure 9.2. Potential distribution of *Agrilus mali* in the EPPO region and China in 2100 under future climate scenario (map and legends are extracted from Lu et al., 2022). See Fig. 9.1 for details.

[5] A1B greenhouse gas emissions scenario which describes a world with a balanced use of fossil and renewable resources resulting in an estimated temperature rise of 2.8 °C (compared to 1980–1999; https://archive.ipcc.ch/publications_and_data/ar4/wg1/en/spmsspm-projections-of.html) (range from 1.7 to 4.4 °C) (Nakicenovic et al., 2000).

Comparisons of areas where *A. mali* occurs and the EPPO region

The EWG used several methods to compare areas where *A. mali* occurs and the EPPO region:

- ***Similarity of the biogeographical zones***

Within the Palaearctic region, a native range of *A. mali* in general matches the Stenopean nemoral region (Manchurian – North Chinese – North Japanese) and intermediate territories; its western analogue is the European nemoral region covering Europe without North and Mediterranean region (Emeljanov, 1974; Krivokhatsky & Emeljanov, 2000).

- ***Degree-day accumulation***

The maps of degree-day accumulation for Europe / the Mediterranean area and Asia in ANNEX 47 (Annex: Fig. A7.1) show similarities between a large part of the PRA area and areas where *A. mali* occurs, considering a degree-day threshold (above 10 °C) of 450 degree-days in 1 year (used by Lu et al., 2022). However, lower degree-day accumulations may also be suitable as *A. mali* can extend its life cycle into a 2^{nd} year.

A set of 146 observation records of *A. mali* within its current range (from Lu et al., 2022 and Volkovitsh et al., 2020a) were matched to the number of degree-days above the 10°C base. All records were ranked according to their accumulated degree-days and classified into five percentile bands (0–10% [<556 degree-days], 10–25% [556–881 degree-days], 25–75% [881–1529 degree-days], 75–90% [1529–2022 degree-days], and 90–100% [2022–3055 degree-days]; Fig. A7.2A). More than 93% of all observation records (136) of *A. mali* corresponded the conditions with more than 450 degree-days per year. However, 10 remaining records corresponded to lower degree-day accumulation. If the geographic records for these observations are correct, then this might reflect the situation when some pixels for the degree-day data (20 km × 20 km) include, for example, both small warm valleys and high cold mountains or represent occasional catches and not stable populations. Thus, cooler areas with heat accumulation below 450 degree-days per year are likely to be less suitable for *A. mali*. In terms of the degree-days data above the 10°C base it corresponds to the most part of the EPPO region except the northern areas (Fig. A7.2B) (D. Eyre, pers. comm., 2023).

- ***Plant hardiness***

Agrilus mali occurs in areas ranging from hardiness zones 1 to 9 (out of a total 13 zones with zone 1 representing the harshest conditions; see Annex 7, Fig. A7.3) suggesting that it can tolerate very cold winter temperatures. These zones encompass the majority of the EPPO region, excluding only the southern part of Morocco.

- ***Köppen-Geiger classification of climate zones***

A set of 95 observation records of *A. mali* listed by Lu et al. (2022) and 26 observation records of *A. mali* outside of China listed by Volkovitsh et al. (2020a) were cross-referenced with the Köppen-Geiger data from 1980–2016 at a spatial resolution of 0.0083° (approximately 1 km at the equator) plotted on a map (Beck et al., 2018). The 121 observations of *A. mali* were categorized within the following Köppen-Geiger types: BWk (15 locations), BSk (22), Cwa (3), Cfa (3), Dwa (39), Dwb (28), Dwc (7), Dfb (1), and ET (3) (J. Tuomola, pers. comm., 2023).

Based on these data and analysis of distribution data (Section 6) and maps (Annex 7: Fig. A7.4 and 7.5), EWG considers that *A. mali* is present in a wide range of climatic zones that are also present in the EPPO region, and is widely distributed in:
- **cold semi-arid steppe climate (Bsk – dry, steppe/semi-arid),**
- **monsoon-influenced subarctic climate (Dwc – continental, dry winter, cold summer).**

Climate types under which its presence cannot be ruled out:
- humid subtropical climate (Cfa – warm temperate, fully humid, hot summer) is present in the Chinese provinces but is at the southern limit of *A. mali* distribution (e.g. Figure 6.2 – in Hubei);
- continental climates with warm or cold summer (Dfb, Dfc), because these climate types are present in very limited areas in Xinjiang, and otherwise in Khabarovskiy Krai in Russia, further north from known locations of *A. mali* and at higher latitudes than the rest of its known distribution;

- warm temperate oceanic climate, fully humid with warm summer (Cfb), which occurs in the Korea Rep.; it is not known if the pest is present in such areas.

EWG assumes that *A. mali* does not occur (or occurs rarely) under two climate types occurring in parts of territories where it is present: cold arid desert climate type (Bwk – < 5 mm rainfall per year) and polar tundra climate (ET) (which occurs at high latitude and altitudes, and is present for example in Tibet, Xinjiang, Qinghai, Sichuan) because of the absence of hosts.

Finally, *A. mali* appears to occur under some climate types that are not present in the EPPO region: subtropical climates with dry winters (Cwa – monsoon-influenced, humid, with hot summers; Cwb – highland or oceanic climate with warm summers); and monsoon-influenced continental climates with dry winter (Dwa – hot summer). *Agrilus mali* also occurs under the climate monsoon-influenced continental climates with dry winter with warm summer (Dwb), which in EPPO is present only in the Far East.

Mediterranean climates (Csa, Csb – warm temperate, with hot and warm dry summer) do not occur in the current distribution of the pest. In such areas, apple is likely grown under irrigation.

Cold winter temperatures and duration of the cold winter period in the EPPO region are not considered to be major limiting factors for the survival of larvae, which overwinter within trees, nor for the completion of the life cycle. *Agrilus mali* is present and widely distributed under climates with cold winter temperatures and long winters, such as in Xinjiang (cold semi-arid steppe climate – Bsk in the Köppen-Geiger classification) or areas in Far East of Russia and Northeast China (monsoon-influenced subarctic climate – Dwc – continental, dry winter, cold summer).

Low relative humidity and low rainfall are similarly not considered a major limiting factor. *Agrilus mali* is present under dry climates, such as in Xinjiang. Consequently, the EWG considers that the pest could establish under dry climates that do not exist in its current distribution, such as in the Mediterranean area.

In areas where the sum of effective temperatures needed to fulfil the lifecycle cannot be accumulated in 1 year, the life cycle could extend over 2 years. However, summer temperatures would need to be sufficient to allow pupation, adult emergence, reproduction and egg development and hatch (thermal requirements not known). In its current distribution, *A. mali* is present in climates in which summer temperatures are probably higher than in parts of the EPPO region. Summer temperatures may not be sufficient in parts of the EPPO region, such as in the cooler humid northern Atlantic climates. However, it is not possible to define the northern limit of the potential establishment.

The EWG took note that, while several *Agrilus* species are widespread in England, there are no *Agrilus* species in Ireland and Scotland, which may be in part due to the climatic conditions.

9.2. Host plants

***Malus* hosts are widespread throughout the PRA area. Lu et al. (2022) note that the potential distribution of *A. mali* overlaps with the range of cultivated and wild apple species *M. sieversii* (Central Asia), *M. baccata* (Siberia), *M. sylvestris* (Europe – not known host) and *M. orientalis* (Caucasus, Türkiye – not known host).**

Cultivated apple (*M. domestica*) is grown commercially throughout the EPPO region (Fig. 9.3). It is mostly grown in temperate areas, but also under less-suitable climates (e.g. semi-arid with irrigation) (OECD, 2022). *Malus domestica* is widely present in private gardens and orchards and as an ornamental tree and has escaped into the natural environment. It is also present in abandoned orchards. In terms of apple production, EU countries contribute about 13% in volume (12 million tonnes) and 10% in area (0.5 million ha) to the world harvest of apples (FAOSTAT, 2022). In the EPPO region, Poland, Türkiye, Italy, and France (listed in the order of the amounts produced) are the top four apple producers (data for 1994–2021; FAOSTAT, 2022).

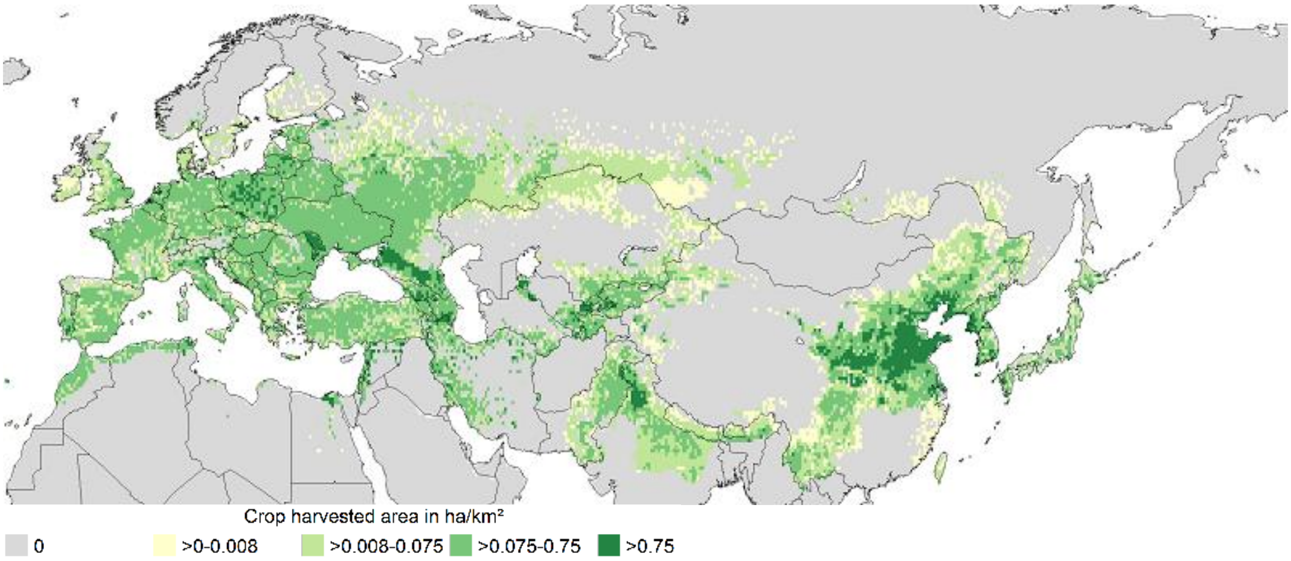

Figure. 9.3. Harvested area of apple (Monfreda et al., 2008).

Malus sieversii is found only in the mountains of Central Asia, including southern Kazakhstan, eastern Uzbekistan, Kyrgyzstan, Tajikistan, Turkmenistan, and Xinjiang (China) (Fig 9.4; Volk et al., 2013). In Central Asia, wild apple and other wild fruit trees together form ancient forests (Tian et al., 2022). *Malus sieversii* is categorized as vulnerable on the IUCN Red List (Wilson & Stephan, 2018).

Malus baccata is native to the Asian part of Russia (Fig. 9.4; Cornille et al., 2014).

The unconfirmed hosts are also widely distributed in the EPPO region. Apricot (*Prunus armeniaca*), peach (*P. persica*), and pear (*Pyrus communis*) are widely cultivated commercially, as are to a lesser extent quince (*Cydonia oblonga*) and Japanese plum (*Prunus salicina*). All are also present in private orchards or gardens, and most also in the wild.

It is possible that the pest could switch to new taxonomically related host species, not widely present in its native range in Asia (as has happened, for example, with *A. planipennis*; EPPO, 2013a; Musolin et al., 2022). Other species in the genera *Malus* and *Prunus* are also widely distributed in the EPPO region.

- The wild apple species *M. sylvestris*, *M. orientalis*, and *M. trilobata* are native to the EPPO region. *M. sylvestris* and *M. orientalis* have a wide distribution (Fig. 9.4). *Malus sylvestris* is native to most countries in Europe and occurs in scattered distribution patterns as single individuals or in small groups (EUFORGEN, 2009). It is also used as an ornamental tree. *M. orientalis* is present in the Caucasus and eastern Black Sea area in mixed forests as single trees or small groups (Höfer et al., 2013). *Malus trilobata* is native to Bulgaria, Greece, Israel, Syria, and Türkiye. Its populations are severely fragmented and subject to a continuous decline; it is categorized as near threatened on the IUCN Red List (Wilson & Stephan, 2018). Other native wild *Malus* are also present (such as *M. crescimmanoi* – OECD, 2022).
- Many other *Prunus* spp. are widely distributed in the EPPO region for fruit production (commercial or private), as ornamentals and in nature (such as *Prunus avium*, *P. cerasifera*, *P. domestica*, and *P. amygdalus*).

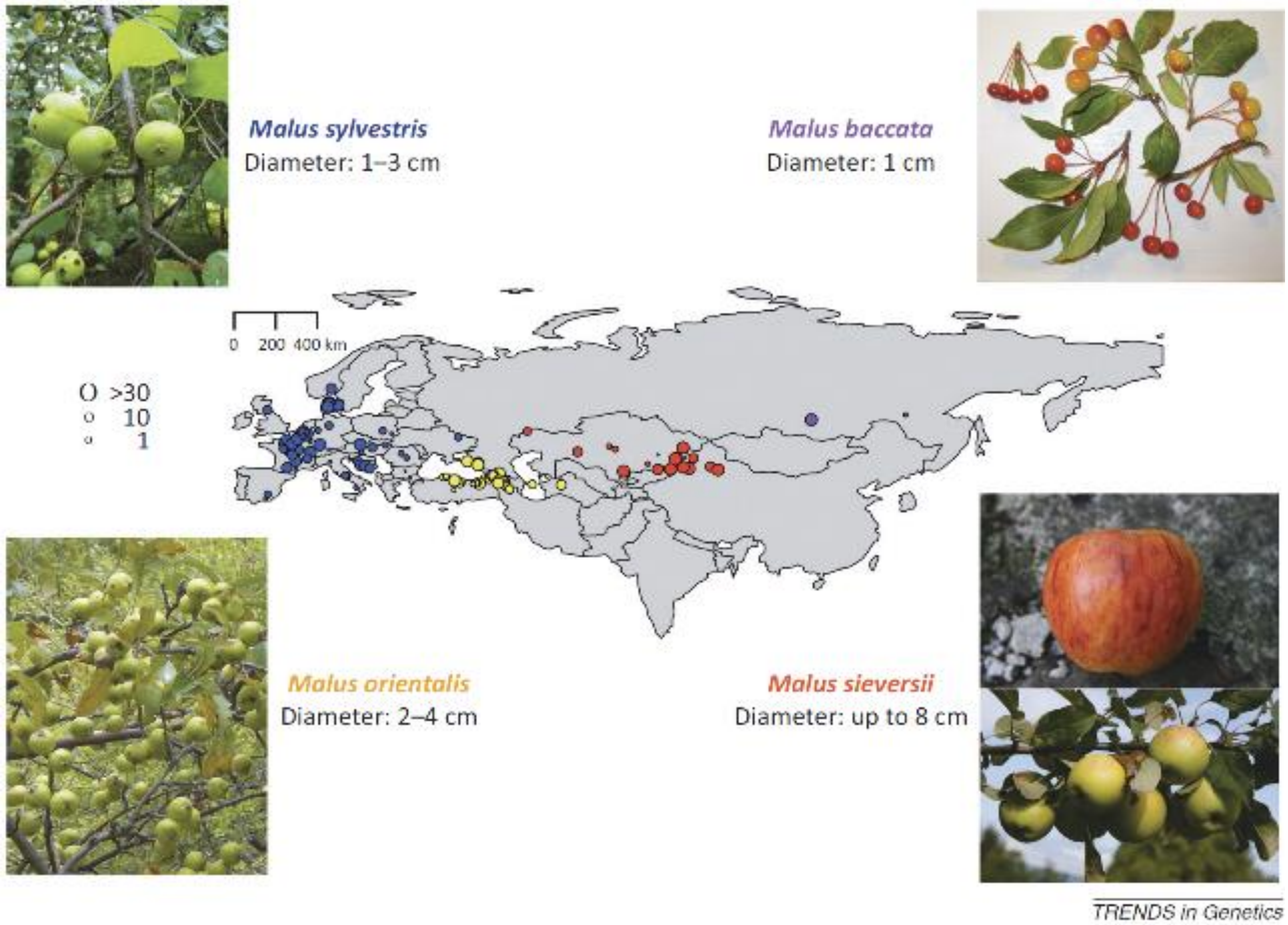

Figure 9.4. Indicative distribution of wild apple species (from: Cornille et al., 2014). Disk locations represent collection of material and areas are proportional to a number of accessions, rather than representing the whole distribution of the species (see the paper for details).

9.3. Other factors

- For the establishment of a population, individuals of both sexes or a single mated female must be present.
- Emerging adults would need to find fresh foliage for maturation feeding.
- The lifespan of the adults can be up to 60 days and the egg-laying period is about 10–20 days, and adults have a limited dispersal ability (Section 2.2). There would therefore be a limited time period during which females would need to find a mate (if individuals are isolated), maturation feed, and find a host for feeding and oviposition.
- A female may lay 60–70 eggs on average (Section 2.2). Reproduction of a few individuals may result in the establishment of a population.
- Practices such as applications of plant protection products (e.g. pyrethroids) against this or other pests may have a negative effect on establishment if they are applied regularly at a time when adults of *A. mali* are present (by killing adults and preventing oviposition).
- Abandoned *M. domestica* orchards may be favourable to establishment.
- The effect of natural enemies on the establishment is unknown, although the braconid parasitoid *Atanycolus denigrator* (Hymenoptera), known to control *A. mali* in China (Cui et al., 2019), is present in the EPPO region (https://fauna-eu.org/cdm_dataportal/taxon/6193b067-ed0b-4f5e-9cc2-3492db2ff72f).
- *Agrilus mali* has already proved that it is able to establish in new areas (Lu et al., 2022; Fig. 1).
- In the EPPO region, *M. domestica* is a host of the native species *Agrilus macroderus*, *A. roscidus*, and *A. sinuatus*, and several unconfirmed hosts in the genera *Prunus*, *Pyrus*, and *Sorbus* are also hosts of native *Agrilus* species (see Annex 4). There is, however, no information indicating that establishment of *A. mali* could be prevented by competition with existing *Agrilus* species in the PRA area.

9.4. Conclusion

The EWG considered that climatic conditions in the EPPO region where hosts are present would not be a major limiting factor for the establishment of the pest, and that it may be able to establish in almost all areas where *Malus* hosts are present. *Malus* species are widely grown throughout much of the EPPO region, especially in temperate areas.

The northern limit of the potential area of establishment cannot be defined precisely. The critical parameters would be the presence of hosts and whether summer temperatures would allow emergence and reproduction of adults (threshold not known), for example in the cooler Atlantic climates. It is unlikely that cold temperatures will restrict the distribution of *A. mali* because it is present in areas that experience cold winter temperatures, it overwinters as larvae in trees and is somewhat protected from the extreme cold, and it has an extended 2-year life cycle in part of its range (see Section 2.2).

Rating of the likelihood of establishment outdoors	Very low ☐	Low ☐	Moderate ☐	High ☐	Very high X
Rating of uncertainty			Low X	Moderate ☐	High ☐

10. Likelihood of establishment in protected conditions in the PRA area

Agrilus mali is a pest of woody plants, which are normally not grown under protected conditions in the PRA area. However, bonsais, ornamental or collection plants and, perhaps, plants for breeding purposes may be grown under protected conditions, e.g. in nurseries or botanical gardens. Establishment would require that *A. mali* be able to complete its life cycle on plants that are small in size. No information was found indicating that *A. mali* have ever established in protected conditions.

Temperatures in protected conditions may be even more favourable for the pest than in open field conditions. The pest would be easier to detect and eliminate under protected conditions compared to within orchards or forests.

Hosts for planting are usually grown for a limited period under protected conditions (if at all) and are often planted in open air. Establishment in bonsai collections, botanical gardens, collections of genetic material, etc. might be higher because *A. mali* can develop in branches and small trunks. The EWG considered that the risk of establishment under protected conditions is lower if compared to open field conditions.

Rating of the likelihood of establishment in protected conditions	Very low ☐	Low ☐	Moderate ☐	High X	Very high ☐
Rating of uncertainty			Low ☐	Moderate X	High ☐

11. Spread in the PRA area

Agrilus mali is considered to be able to disperse up to several kilometres a year, depending on distribution and density of host plants (Section 2.4). However, in most situations, natural spread would be less because some host plants, e.g. *M. domestica* are widely grown and should be easily accessible. Abandoned orchards may also play a role in natural spread due to an expected increase in tree susceptibility. The rate of spread will probably be affected by the pest's ability to locate suitable hosts, and whether it will be capable of infesting *Malus* spp. (e.g. *M. sylvestris* or *M. orientalis*) or widespread woody plants of other genera (in particular in the natural environment) that are currently not known as hosts (Section 9.2). In areas with warm summers (like in Central Asia), the pest could complete its development in one year, and spread more rapidly via natural dispersal. The EWG concluded that the magnitude of natural spread would be moderate.

Several references from China report comparatively fast spread of the pest in different regions of the country, which might have been enhanced by human activity (transport of infested plant material, hitchhiking with transport, etc.; Section 12). In the EPPO region, many (if not all) countries breed and grow hosts for fruit production (Section 9.2). Therefore, *A. mali* could spread by longer 'jumps' over longer distances via transportation in plants for planting, potentially leading to multiple establishments. However, *Malus* plants for planting are likely to be young plants, which can be infested, but may originate from nurseries where management is applied, reducing the likelihood of infestation. In the EU, such plants would be subject to phytosanitary controls, e.g. for the issuance of plant passports. Additionally, in the eastern part of the EPPO region around the area of current distribution, in particular, movement of round wood, especially firewood, may also increase the spread of the beetle. Hitchhiking may also play a role locally, as may movement of pruning material. The EWG therefore considered that the magnitude of human-assisted spread is moderate.

In conclusion, if *A. mali* behaves like *A. planipennis*, speed of natural spread will depend on the situation (host plant availability in orchards and forests and their distribution in the landscape) and may be increased by hitchhiking or movement of poorly checked plant material (first of all plants for planting) or round wood, that would lead to multiple outbreaks and increase spreading within the EPPO region. The magnitude of spread is estimated to be generally between 1 to 10 km per year corresponding to a 'moderate' rating according to the rating guidance of the PRA-scheme (https://www.eppo.int/RESOURCES/eppo_standards/pm5_pra). The magnitude of spread may be higher in case of human assisted spread but in those cases spread may lead to new populations but it is unlikely that that the front of an existing population moves more than 10 km within a year.

Rating of the magnitude of spread	Very low ☐	Low ☐	Moderate X	High ☐	Very high ☐
Rating of uncertainty			Low ☐	Moderate X	High ☐

Uncertainty: discrepancy between spread in China and in Russia, susceptibility of other *Malus* spp. such as *M. sylvestris*, ability to detect the early stages of infestation, difference of susceptibility of *M. domestica* varieties, effectiveness of management measures applied in nurseries.

12. Impact in the current area of distribution

Despite the distribution extent of *A. mali* in Asia (Section 6 and Figs 6.1 and 6.2), significant impact has only been reported in provinces of China and only on *M. domestica* and *M. sieversii*.

For the purpose of this section, 'cultivated/domesticated apples' and 'orchards' in Chinese publications are understood to refer mostly to *M. domestica*. Wild apple in Xinjiang refers to *M. sieversii* forests (see a note on *Malus* in China in Section 7).

In a description of *A. mali* from Korea, Matsumura (1924) mentions that heavy damage on apple trees by this pest had occurred in the southern district of Liaoning Province of China since ancient times (i.e. likely not the western *M. domestica* at that time, see a note in Section 7).

According to Lu et al. (2022), around the 1950s, the pest became widespread in Northeastern China, and until the 1990s continued to spread westwards and southwards, and was then found in the 1990s in Xianjiang (Fig. 6.2).

In Xinjiang, in Northwestern China, *A. mali* is now widespread in wild apple forests in the Tian Shan Mountains in Xinjiang (Lu et al., 2022 citing others). Since 1995, within 10 years, it has spread from Xinyuan County to Gongliu, Nilek, and Turks counties, and has escaped from the cultivated orchard to the wild apple forest infesting a total area of 5 000 ha, of which 4 867 ha of wild apple forest accounting for about 60% of the wild apple forest area (Ji et al., 2004; Cui et al., 2015). Sun et al. (2022) noted that recent outbreaks in Xinjiang might be the result of climatic and environmental factors and poor management in apple orchards.

Apart from causing serious economic impact to apple fruit production, both in orchards and for wild apple (affecting yield and, in extreme cases, killing trees), the pest is affecting regeneration of wild apple trees in the natural environment, and threatening the existence of unique natural gene bank (Tianshan wild fruit forest) of economical fruit resources in China (Ji et al., 2004). *Malus sieversii* is listed as 'Vulnerable' on the IUCN Red List of Threatened Species and subject to a continuous decline in its area current of distribution (IUCN, 2023).

Attacks by *A. mali* have been recorded in wild apple forests, on individual wild apple trees, in big industrial orchards, in nurseries, and in small private (individual) orchards (Linyi Agro-Forestry Bureau, 1973; Chen & Yao, 19977). Damage might be especially severe in orchards located in mountainous areas and in young orchards with poor management (Feng et al., 2013; Guli & Wang, 2013). In apple orchards with intensive appropriate management, the infestation level was much lower than in poorly managed ones (Cui et al., 2018; Lu et al., 2022). Currently, *A. mali* is considered a secondary pest in *M. domestica* orchards, as most apple orchards are managed carefully (X.-Y. Wang, pers. comm., 2022).

Social impact is not reported in the literature.

Estimates of damage in different provinces of China in the literature as follows (prepared by X.-Y. Wang; number in brackets refer to the number of provinces in Fig. 6.2). It should be noted that there are no recent publications on damage to *M. domestica*.

- Xinjiang [1] (where both cultivated apple orchards and wild apple forests of *M. sieversii* occur): *A. mali* has caused reduction of the yield of wild apples, from 90 to 10 kg/plant on average, seriously affecting the regeneration of seedlings (Zhang et al., 2021). It has led to the death of wild apple trees in large areas (Cui et al., 2018). Wang (2013) specified that after nearly 20 years of spread, 40% of the Xinjiang wild apple forest (i.e. over 3 866 ha stand) were damaged and another approximately 7% (i.e. appr. 666 ha stand) were killed. In cultivated apple orchards, damage is less important in actively and well-managed orchards (where pruning and burning of infested branches, and sprays of plant protection products against adults are performed), than in inappropriately managed and abundant orchards (fruit growers abandon management and populations of the pest develop, leading to absence of fruit) (Cui et al., 2018).
  In Xinjiang, both *A. mali* and the fungus *Cytospora mali* (=*Valsa mali*) cause damage to *M. sieversii*. Several authors make the hypothesis that attacks by *A. mali* may increase the vulnerability of trees to *V. mali*, which in turn might accelerate tree mortality (Liu et al., 2014a; Bozorov et al., 2019 citing Wang et al., 2011, 2014a, 2014b). However, evidence for this hypothesis is lacking (X.-Y. Wang, pers. comm., 2022).
- Gansu [3]: The damage rate in Baofeng Village, Liuhu Township, Pingliang City was as high as 86% in trees infested in 1991, and some orchards had been destroyed by 1996. According to the field survey on the campus of Pingliang Agricultural School, the infestation rate was 16% in 1993 and 100% in 1997 (Xue, 2004); Chen & Yao (1997) recorded that hundreds of hectares of orchards were destroyed in Minhe County.
- Hebei [9]: 225,000 kg of dead branches were cut in a village in Huailai County, Hebei Province in 1951; In some orchards, most of the main branches were cut off due to the infestations. The injury rate of apple trees in South Wujiazi Township of Pingquan, Hebei Province was 80% (Yang & Chen, 1956).
- Heilongjiang [6]: The percentage of fruit trees infestation was 100% in Shuangcheng Fruit Tree Farm (Plant Protection Research, 1977).
- Hubei [16]: 68% of early maturing apple trees in Yichang were damaged (Xiang, 1997).
- Liaoning [8]: Taizigou Hanfu Apple Professional Cooperative in Liqianhu Town, Tieling County transplanted 150 large Hanfu apple trees from Shenyang in 2013. In 2014, it was found that some apple trees were damaged by *A. mali*. In 2015, nearly 2,000 trees in the orchards (1/3) were infested (Wang et al., 2020). In an infestation by *A. mali* detected in an orchard (Shishan Town, Jinzhou) in 1988, and although management was attempted, 520 apple trees (out of over 7,300) died in 1990. In the following 2 years spraying (trichlorfon) against larvae in early spring allowed to control the pest (Yang & Song, 1994).
- Qinghai [2]: The tree mortality rate reached 9% in Jianzha and Guide Counties in 1998, in the most severely damaged orchard it reached 20% (Li, 1998). In 1996–1999, more than 20,000 apple trees were felled in Guide County (Wang, 2000).
- Shandong [13]: In 1967, 25 villages in Yedian, Mengyin County, suffered from *A. mali*, which affected more than 4,000 trees (about 20% of the apple trees). In Zhangzhuang township of Yiyuan County, more than 70% of apple trees were injured (Linyi Agro-Forestry Bureau, 1973).
- Shanxi [11]: In Shuozhou area, the incidence of the pest in some orchards was up to about 30% (Zhang, 2008).
- Shaanxi [12]: In 1974–1975, an average infestation rate was 34% in Fengxian County (Sun et al., 1979).

Very limited information about economic impact is available from **Russia**. *Agrilus mali* is mentioned in Russian identification keys of orchards pests (Keys to Agricultural Pests, 1976) and as a pest of apple in a books of agricultural (Gurjeva, 1974) and forest pests (Arnoldi, 1955). Nikritin & Shutova (1985) and Nikritin (1994) briefly describe biology and damage, but lack of numerous publications suggests that the pest has a limited impact in the Russian Far East, where apple production is limited in scale.

No information was found for Republic of Korea (except a brief mention of 'damage' in Matsumura, 1924), Democratic People's Republic of Korea, and Mongolia. Lack of numerous publications suggests that the pest has a limited impact.

Existing control measures

Agrilus mali is regulated as a quarantine pest in some provinces and regions of China and has been included in the list of dangerous pests in forestry of China since 2013 (State Forestry Administration of China, 2013). Risk management measures are applied on this pest in its current area of distribution. *Agrilus mali* has been controlled in orchards using a combination of sanitation measures and application of insecticides (e.g. Xiang, 1997; Cui et al., 2018). The pest is in the Quarantine list of the Eurasian Economic Union (pests with limited distribution; EAEU, 2016), but currently no measures are being taken (O. Kulinich, pers. comm., 2023).

Sanitation and physical control

In apple orchards, it is usually recommended to cut off infested branches and dispose them safely. This sanitation pruning is the most effective and widely used control method (X.-Y. Wang, pers. comm., 2022; Zhang et al., 2024). The wounds are healed and disinfected with commercially available tree wound dressing (spread/plaster) for pruning and grafting (e.g. Tree wound dressing promoting healing suitable for bonsai shaping; Fruugo ID: 180281231-385120980; EAN: 3119916369273; https://tinyurl.com/yc746b73) to avoid infestation by fungal diseases. The cut branches are burned or caged (fine wire netting) in order to eliminate the pest (Chen & Yao, 1997; Xiang, 1997; Chen & Zhan, 2007; Guo & Ma, 2010; Guli & Wang, 2013; Cui et al., 2018; EPPO, 2023 [=Datasheet for *A. mali*]).

Cultural practices

As the pest prefers weakened trees, orchard/forest management should be strengthened, with application of fertilizers and appropriate irrigation; the trees should be carefully pruned (Agro-Forestry Bureau, 1973; Chen & Yao, 2007).

Chemical control

Chemical control has been used in the past in China using different active substances, such as: dichlorvos* (Duan, 1994; Chen & Yao, 1997; Ji et al., 2004; Feng et al., 2013), dimethoate* (Chen & Zhan, 2007), fenitrothion* and isofenphos-methyl* (Duan, 1994; Guo & Ma, 2010), fenitrothion* and isofenphos-methyl* (Duan, 1995), imidacloprid*, emamectin benzoate** and imidacloprid* (Guli & Wang, 2013), imidacloprid*, abamectin, omethoate* (Huang, 2004), omethoate* in combination with fenvalerate* (Qu et al., 1998), hexachlorocyclohexane* (South China Agricultural University, 1981), ioxynil* and monocrotophos* (Jia et al., 2003), trichlorfon* (Yang & Song, 1994), or thiacloprid* (Zhang et al., 2021). Chemical control is currently considered less effective as a stand-alone measure compared with sanitation by pruning infested branches (X.-Y. Wang, pers. comm., 2023).
** currently not registered in the EU (EC, 2023).*
*** as emamectin.*

For chemical control with the above listed compounds, both spraying and injections used to be applied (Guli & Wang, 2013).

Aerial spraying of ultra-low volume of thiacloprid (systemic neonicotinoid insecticide) has been attempted in Xinjiang over 3 sites measuring 100 to 2,000 ha during 3 consecutive years (3 applications per year), with the aim to kill adults while they are feeding on leaves, but effects on *A. mali* infestation where not conclusive (Zhang et al., 2021). This was in contrast with studies in Xinyun region (citing Liu et al., 2016 – 1,600 ha), where the same compound was used, but the larval density of *A. mali* declined by 65% in the 2nd season (Zhang et al., 2021).

Fumigation of insect-bearing seedlings and scions using 16 g of sodium cyanide per cubic meter for 1 h at 25–26 °C was also considered effective and suggested for application (Chen & Zhan, 2007), as well as application of pyrethrins (Li, 2019).

Biological control

Sclerodermus parasitoids (Hymenoptera: Bethylidae) such as *S. pupariae* and *S. guani* are used to control larvae of *A. mali* and are available on the market in China (X.-Y. Wang, pers. comm., 2023). In the production practice, the augmentative biological control method can be used to quickly control the pest population in the area where the *A. mali* is an important pest. For areas with less pronounced damage, *Sclerodermus* wasps can be released in a ratio of wasp to pest of 2:1 to 4:1 (Wang et al., 2014c; EPPO, 2023). Wang et al. (2014c) reported that more than 5 million parasitoid wasps have been released since 2009. Their efficacy in controlling *A. mali* is still being evaluated, but internal unpublished results demonstrate that population of *A. mali* decreased by more than 90% (X.-Y. Wang, pers. comm., 2023).

Pyemotes moseri (Acriformis: Pyemotidae) has been used to control various insects, including larvae and pupae of *A. mali* and is available on the market in China. In laboratory studies, this predatory mite showed excellent efficacy (Cui et al., 2019; Zhang et al., 2020; Tang et al., 2022). Because of they are easy to rear, low cost of production, small size, and ability to spread by wind, they can be used as an augmentative release in orchards and forests. The mites can be released from late April to early May each year to feed upon larvae and pupae of *A. mali* (Wang, 2013; Cui et al., 2019).

Some other native natural enemies were identified, e.g. *Atanycolus denigrator* (Hymenoptera: Braconidae) (Liu et al., 2010; Wang et al., 2014c; Cao et al., 2019; Cui et al., 2019) and *Tetrastichus* sp. (Hymenoptera: Eulophidae) (Sun et al., 1979), but these parasitoids have not been mass produced and used in practice.

The native natural enemies *A. denigrator* and *P. moseri* and fungal entomopathogens were responsible for mortality rates of *A. mali* larvae ranging 20–80% during the summers and autumns 2016–2017 in four sites within wild apple forests. The most abundant and important natural enemy was *A. denigrator*, which was responsible for up to 15% mortality of *A. mali* larvae (Cui et al., 2019). *Atanycolus denigrator* is present in the EPPO region (https://fauna-eu.org/cdm_dataportal/taxon/6193b067-ed0b-4f5e-9cc2-3492db2ff72f).

Additionally, setting of artificial birdhouses for woodpeckers and creation of suitable habitats for woodpeckers is suggested (Sun et al., 1979; Chen & Zhan, 2007).

Integrated pest management

Integrated pest management measures used for the control of *A. mali* include cutting infested branches, releasing of biological control agents, limiting grazing by animals (to protect natural biodiversity in order to provide resources and shelter for natural enemies, and facilitate natural regeneration of wild apple), and providing honey sources and overwintering shelters for natural enemies in wild forests. In orchards, IPM also includes chemical control (X.-Y. Wang, pers. comm., 2023).

Conclusion

The EWG decided to separately rate the impact on *M. sieversii* in wild forests (i.e. in Xinjiang only) and *M. domestica* orchards (i.e. in the whole distribution of the pest). Note that there is no information on impact on other *Malus* hosts.

Malus sieversii wild forests. Impact is higher than for *M. domestica* orchards, with some mortality reported. *Malus sieversii* is a valuable genetic resource. Currently, management is applied, but efficiency is not known.

Uncertainty: Lack of information, non-target impact of control measures, environmental impact (including ecosystem services).

Rating of the magnitude of impact in the current area of distribution (*Malus sieversii* in Xinjiang, China)	Very low ☐	Low ☐	Moderate ☐	High **X**	Very high ☐
Rating of uncertainty			Low **X**	Moderate ☐	High ☐

Malus domestica orchards. Impact is currently low but costly management measures are applied to control the pest which increase the overall impact rating to moderate.

Uncertainty: Impact in areas other than in China, current impact within China.

Rating of the magnitude of impact in the current area of distribution (*Malus domestica*)	Very low ☐	Low ☐	Moderate **X**	High ☐	Very high ☐
Rating of uncertainty			Low ☐	Moderate **X**	High ☐

13. Potential impact in the PRA area

Will impacts be largely the same as in the current area of distribution? Yes, as in China on the same host plants, but with more uncertainty in the case of *M. domestica* and *Malus* species in the EPPO region that are currently not known to be hosts /~~No~~

Impact will probably be similar in the EPPO region with the impact reported from China, on the same host plants:

- As observed in Xinjiang (China), a possible high impact may be expected on (wild) *M. sieversii*. Even though *M. sieversii* has limited distribution at the scale of the EPPO region (see Table 7.1), it is widely distributed in Central Asia. Wild *M. sieversii* forests in central Asia have high ecological importance (Jashenko & Tanabekova, 2019; Tanabekova, 2021).
- Assuming that most of the apple cultivated orchards in China are made up of *M. domestica*, similar impact as observed in China is expected for cultivated orchards in the EPPO region. Impact in orchards will greatly depend on how apple production (such as orchard size, management, concentration and varieties) is conducted and whether plants are stressed (Zhang et al., 2020): e.g. modern (high density) orchards with drip irrigation and fertigation are expected to be less impacted than more traditional orchards lacking these systems. Most insecticides mentioned in Section 12 are not authorized at least in the EU (e.g. in the EU, abamectin is only approved as an insecticide for greenhouse use; https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32023R0515). However, some cover treatments applied during the flight period of *A. mali* may be possible in some settings (see Section 16.2). It is unclear if there are differences in the patterns of apple production in the EPPO region and in China. In the EPPO region there is a diversity of apple production regarding cultural practices, intensity and variety of phytosanitary treatments and water supply. This diversity includes intensively managed orchards, with or without irrigation, IPM orchards, organic orchard and meadow orchards pruned but not treated with plant protection products, and also abandoned orchards. *Malus domestica* is also widely used in private gardens/orchards for domestic consumption.
- The EWG expected that *M. domestica* varieties in the EPPO region are susceptible to the pest, as they share the same genetic background.
- The pest has been reported to be trophically associated with a few other Rosaceae species (Table 7.1). Considering that no impact has been reported on such plant species in the area of origin, it is considered that potential impact on these species will most probably also remain limited in the EPPO region.
- In addition, the pest could expand its trophic niche in the EPPO region and switch to other *Malus* species. The species *M. sylvestris*, *M. orientalis*, and *M. trilobata* are present in the natural environment (see Section 9.2). If such species are hosts, potential impact on forest environments could then be similar to the impact observed in China with *M. sieversii*. However, these species have a more scattered distribution in the EPPO region than *M. sieversii* in China and are not the primary components of forests. If such wild species prove to be good hosts, they could serve, together with abandoned orchards, as reservoirs of pest populations for

reinfestation of commercial orchards. *Agrilus mali* could further contribute to the decline of the threatened species *M. sieversii* and *M. trilobata* (see Section 9.2).

- *Malus* species are also often used in urban gardens and parks (e.g. https://kb.jniplants.com/tangy-green-urban-columnar-apple-malus-domestica-ak98/; Ariluoma et al., 2021) as well as a street tree, such as *M. baccata*, *M. floribunda*, and *M. toringo*. Such ornamental trees might be weakened by stressful environmental conditions, thus become more susceptible to the pest. Impact on *Malus* species not yet recorded as hosts remains uncertain.
- Considering that, together with temperature, the frequency and duration of severe droughts is expected to increase in upcoming years because of climate change, the impacts of many pests of woody plants in the natural environment may become more significant in the future (Sallé et al., 2014; IPPC Secretariat, 2021).
- It should be noted that, with the exception of *A. sinuatus* re-emerging in Europe on pear (see Annex 4 and Section 16.2), other species of genus *Agrilus* in the EPPO region (e.g. *A. roscidus*, *A. macroderus*, *A. malicola*, *A. mendax*) do not seem to significantly impact the host plants (including unconfirmed) of *A. mali* (*Malus* and others) in the EPPO region (Bílý, 2002; de Jong et al., 2014; Jendek & Poláková, 2014; M. Volkovitsh, pers. comm., 2023). These species are not considered serious pests of orchards (M. Volkovitsh, pers. comm., 2023). Consequently, at present, control measures against *Agrilus* in apple orchards are often not necessary. If introduced, *A. mali* could cause additional impact to commercial apple production and wild apples in the EPPO region.
- Existing predators and parasitoids of native buprestids in the EPPO region may contribute to the control of *A. mali*. This was the case for *A. planipennis* in Russia where the local polyphagous parasitoid *S. polonicus* switched to this new abundant host a few years after the beginning of the infestation and contributed to the reduction of *A. planipennis* populations (Musolin et al., 2017; Baranchikov et al., 2018); as well as in North America where predation by woodpeckers appears to be the most important source of mortality in *A. planipennis* populations, causing 9–95% of the mortality rates (Cappaert et al., 2005).
- The biological control agents *Sclerodermus* spp. and *Pyemotes moseri* are not listed in the EPPO Standard PM 6/3(5) biological control agents safely used in the EPPO region. These species are not currently available for use in case of outbreak.

For *M. sieversii*, the magnitude of potential impact and the uncertainty are the same as in China.

Rating of the magnitude of impact in the current area of distribution (*Malus sieversii*)	Very low ☐	Low ☐	Moderate ☐	High X	Very high ☐
Rating of uncertainty			Low X	Moderate ☐	High ☐

For other *Malus* hosts (including *M. domestica*), the magnitude of potential impact is the same as in China, but there is a higher uncertainty.

Rating of the magnitude of potential impact (other *Malus* hosts)	Very low ☐	Low ☐	Moderate X	High ☐	Very high ☐
Rating of uncertainty			Low ☐	Moderate ☐	High X

Uncertainty: It is not known how effectively and how quickly outbreaks of the pest can be controlled under the different settings of apple cultivation in the EPPO region, susceptibility of wild apples that are not known as hosts (*M. sylvestris*, *M. orientalis*, and *M. triloba*), whether natural enemies will have an effect.

14. Identification of the endangered area

In the EPPO region, the pest may be able to establish wherever *M. domestica* and *M. sieversii* are present. However, the northern limit of the potential area of establishment cannot be defined precisely (see Section 9.4). Within the potential area of establishment, it is expected that the largest impact would occur in *M. sieversii* wild apple forests in Central Asia. In addition, impact is expected in the rest of the potential area of establishment, but it would likely be lower in areas close to the northern limit of establishment.

15. Overall assessment of risk

Summary of ratings:

	Likelihood	**Uncertainty**
Entry (overall) for Kazakhstan	Very high	Low
Entry (overall) for countries that do not prohibit *Malus* plants for planting	Moderate	Moderate
Entry (overall) for countries that prohibit *Malus* plants for planting	Low	High
Host plants for planting (except seeds, tissue culture, pollen) For countries where import of host plants for planting is prohibited and imported breeding material goes through post-entry quarantine (e.g. the EU), the likelihood of entry is *low* (not very low because of possible transport by passengers) with a *low* uncertainty	Moderate	High
Round wood and sawn wood of hosts (with or without bark)	Low	High
Deciduous wood chips, hogwood, processing wood residues (except sawdust and shavings)	Very low	Moderate
Natural spread from countries where *A. mali* occurs to EPPO countries where it does not occur (to Kazakhstan); natural spread to other EPPO countries is not rated	Very high	Low
Cut branches of hosts	Low	High
Hitchhiking on other commodities or in vehicles	Low	Moderate
Establishment outdoors	Very high	Low
Establishment in protected conditions	High	Moderate
Magnitude of spread	Moderate	Moderate
Magnitude of impact in the current area of distribution *M. sieversii* (in Xinjiang, China) *M. domestica*	 High Moderate	 Low Moderate
Magnitude of potential impact in the PRA area *M. sieversii* other *Malus* hosts (including *M. domestica*)	 High Moderate	 Low High

The likelihood of entry into Kazakhstan through natural spread is considered very high (low uncertainty), because of the very close proximity and continuous presence of *M. sieversii* between places in northern Xinjiang (Yili Valley, China), where *A. mali* is present, and Kazakhstan. For the rest of the EPPO region, natural spread is not considered as a significant pathway for entry. Entry into Kazakhstan via hitchhiking on other commodities or in vehicles has a low likelihood with moderate uncertainty.

For all EPPO countries, the most likely commodity pathways for entry are: host plants for planting (except seeds, tissue cultures, pollen); round wood and sawn wood of hosts (with or without bark); and cut branches. Long distance dispersal via vehicles is not expected to be a likely entry pathway.

For EPPO countries other than Kazakhstan, the likelihood of entry was overall moderate with a moderate uncertainty (for countries where import of *Malus* plants for planting is not prohibited) and low with high uncertainty (for countries where import of *Malus* plant for planting is prohibited; corresponding to the rating for cut branches), and linked to commodity pathways only.

The likelihood of establishment of *A. mali* outdoors in the EPPO region is considered very high with low uncertainty. *Malus domestica* is widely distributed in the EPPO region and *M. sieversii* is widely present in Central Asia and the climatic conditions are not considered to be a major limiting factor for the establishment of the pest where *Malus* hosts are present. The pest has a life cycle which can be completed within 1 or 2 years depending on climatic conditions. The northern limit of the potential area of establishment cannot be defined precisely. The critical parameters would, however, be the presence of hosts and whether cool summer temperatures allow emergence and reproduction of adults (thermal requirements are not known).

The magnitude of spread was rated as moderate with a moderate uncertainty. The pest has limited natural dispersal capacity but there may be longer 'jumps' through human-assisted means (traded commodities or vehicles), that could lead to multiple outbreaks and increase the magnitude of spread. *Malus* plants for planting in trade are likely to be young plants, which can be infested, but the likelihood of spread is expected to be reduced due to management at the nurseries.

The impact (economic, environmental and social) in the pest's native range in China was rated for *M. sieversii* as high with a low uncertainty and for *M. domestica* moderate with moderate uncertainty. Limited or no data were found on the situation and/or impact on other hosts, or in other areas where the pest occurs (Mongolia, Russia, Democratic People's Republic of Korea, Republic of Korea). The magnitude of potential impact in the EPPO region was rated for *M. sieversii* as high with low uncertainty and for other *Malus* hosts (including *M. domestica*) as moderate with high uncertainty. The potential impact was rated especially high for *M. sieversii* forests in Kazakhstan because this species is a valuable genetic resource.

In China, sanitation pruning and chemical insecticide applications are the most efficient control measures in orchards. Sanitation pruning could also be applied in the EPPO region. If *A. mali* is introduced again into the EPPO region, available insecticides are very limited, and biological control agents are not yet available.

Because of the high damage recorded in China and of the importance and widespread distribution of hosts in the EPPO region, the EWG recommended that phytosanitary measures may be considered.

In the context of climate change, the area of potential establishment of *A. mali* might extend northwards and to higher altitudes. Increased temperature, frequency and duration of severe droughts might increase the negative impact of the pest.

Stage 3. Pest risk management

16. Phytosanitary measures

16.1. Measures on individual pathways

The EWG identified management options for all pathways for which the likelihood of entry was low or higher.

Measures for plants for planting were reviewed in detail (Annex 1). The EWG recommended that they should be applied to the genus *Malus* (Section 7). If more scientific publications confirming new host status become available, the same measures should be recommended for these additional hosts.

With the currently available information, some countries may decide to regulate unconfirmed hosts to achieve a higher level of protection (Table 7.1).

Measures for cut branches were adapted from those for plants for planting.

For round wood and sawn wood of *Malus* (with or without bark), the measures were adapted from those for *A. fleischeri* and were not reviewed in detail. A number of apple wood commodities from China are available on the Internet for the purpose of barbecue and smoking, and the EWG recommended that such Internet trade should be placed under scrutiny.

The EWG recommended that official surveillance be conducted in Central Asian countries close to Xinjiang (China) on *Malus* hosts particularly on *M. sieversii* and *M. domestica*, especially in Kazakhstan and Kyrgyzstan. Surveys in Tajikistan (not a member of EPPO yet) would also be useful.

Table 16.1. Recommended measures.

Possible pathways (in order of importance)	Measures identified (see Annex 1 for details)
Malus plants for planting (except seeds, tissue culture, pollen)*	PFA (Pest-free area; ISPM 4 [FAO, 2017a], ISPM 29 [FAO, 2017b]; see requirements below) or Pest-free site of production under physical isolation (PM 5/8 *Guidelines on the phytosanitary measure* 'Plants grown under physical isolation') **AND** Plants packed in conditions preventing infestation during transport or Plants moved outside the period when adults are present
Malus round wood and sawn wood (with or without bark)*	PFA (ISPM 4 [FAO, 2017a], ISPM 29 [FAO, 2017b]; see requirements below) or Heat treatment (minimum temperature of 56 °C for a minimum duration of 30 continuous minutes throughout the entire profile of the wood [including its core]) or Irradiation (EPPO Standard PM 10/8(1) Disinfestation of wood with ionizing radiation) or Fumigation with sulfuryl fluoride (only for debarked wood below 20 cm in cross-section) (ISPM 28 PT 22 or PT 23 [FAO, 2017c, 2017d]) or Removal of bark and 2.5 cm of outer xylem
Cut branches of *Malus**	PFA (ISPM 4 [FAO, 2017a], ISPM 29 [FAO, 2017a]; see requirements below)

* Countries may decide to regulate unconfirmed hosts to achieve a higher level of protection.

Requirements for establishing a PFA:
Measures are based on the requirements proposed for *A. planipennis* (EPPO, 2013b):

- A minimum distance of 10 km between the PFA and the closest known area where the pest is known to be present. The minimum distance recommended for *A. planipennis* (100 km) seemed to be too high for *A. mali*. Based on dispersal data and estimations for *A. mali* (2–3 km; Section 2.4) and those for *A. planipennis* (EFSA, 2019b,c; summarised in Section 2.4), existence of trapping for surveillance and the time required to establish a PFA, a distance of 10 km seemed to provide a minimum buffer. However, if hosts are not available or sparse in the region, adults of *A. mali* might fly over longer distances.
- To establish and maintain the PFA, detailed surveys and monitoring (using trapping and other methods) should be conducted in the area in the three years prior to establishment of the PFA and continued every year. Specific surveys should also be carried out in the zone between the PFA and known infestation to demonstrate pest freedom. The surveys should be targeted for the pest and should be based on appropriate combination of trapping, branch sampling and visual examination of host trees.
- Surveys should include high risk locations, such as places where potentially infested material may have been imported.

There should be restrictions on the movement of host material (originating from areas where the pest is known to be present) into the PFA, and into the area surrounding the PFA, especially the area between the PFA and the closest area of known infestation. Hitchhiking risk should be taken into account.

16.2. Eradication and containment

The pest can fly (although for comparatively short distances) and early detection and control of an infestation are difficult. Therefore, *A. mali* would be difficult to eradicate (see Section 11). However, in the case of early detection, and limited natural spread, eradication may be feasible, in certain settings such as well-managed orchards or nurseries (using sanitation pruning) (Zhang et al., 2024). Monitoring methods are available (sticky traps with pheromone, see Section 2.7)

The EPPO Standard PM 9/14 on *A. planipennis* (EPPO, 2013b) provides procedures for official control with the aim of containing and eradicating the pest. Some measures in this standard are likely to be relevant for *A. mali*.

Remark: Emamectin benzoate, a systemic insecticide administered by trunk injection, has demonstrated three years of control against both *A. planipennis* larvae and its leaf-eating adults (Herms et al., 2014; McCullough et al., 2011; Smitley et al., 2010). Using emamectin benzoate, it is reported that girdling *Fraxinus* trees 2–3 weeks after insecticide injection, created lethal trap trees that were attractive to *A. planipennis* adults (McCullough et al., 2016). However, no similar reported experience has been found for *A. mali* and it will be difficult to justify such approach. This active substance is authorized for other uses in Europe under the name 'emamectin' (e.g. in the EU by injection of palm trees for *Rynchophorus ferrugineus*; ANSES, 2018).

Other systemic insecticides used as trunk injections (azadirachtin, imidacloprid*) or applied as soil injections or drenches (imidacloprid*, dinotefuran*), may also be effective against *A. mali* as they have shown to be effective against *A. planipennis* (EPPO, 2013b).
** currently not registered in the EU (EC, 2023).*

Thiacloprid (currently not registered in the EU; EC, 2023) and lambda-cyhalothrin were shown to be very effective against *A. sinuatus* (pear tree borer) as cover treatments applied to trunk, branches and foliage of young pear trees, in insecticide trials conducted in 2008–2009 by the Walloon Agricultural Research Centre (EPPO, 2011 citing C. Fassotte, pers. comm., 2010).

Research would be needed regarding safety of consumption of fruit from trees treated with systemic plant protection products as well as the effect of these products on native *Agrilus* species.

17. Uncertainty

Main sources of uncertainty within the risk assessment are linked to the following issues. They are divided into two categories:

Key uncertainties*	**Other main uncertainties**[#]
• impact of *A. mali* in its current area of distribution and why impact has been recorded only in China; • susceptibility of unconfirmed host genera; • life cycle, biological parameters, flight capacity and thermal requirements, e.g. to improve predictive modelling of the potential distribution	• effective management apart from pruning; • trade of *Malus* commodities, including internet trade; • hitchhiking capacity; • actual mechanisms of spread within China; • precise distribution within its native and introduced range

* **Key uncertainties:** likely to significantly affect the overall conclusions (including overall risk and overall uncertainty) of the PRA (i.e. the determination of whether the pest has the characteristics of a quarantine pest, and the pathways that should be managed);
[#] **Other main uncertainties**: not likely to affect the overall conclusions of the PRA but likely to significantly impact conclusions of individual part(s) of the risk assessment or risk management.

18. Remarks

Possible topics for research:

- molecular and morphological identification methods;
- biological parameters of the life cycle so that potential distribution modelling can be conducted;
- push-pull agricultural pest management strategies using non-toxic repellents (Cook et al., 2007);
- a survey targeting *A. mali* on all *Malus* species and taxonomically related non-*Malus* unconfirmed hosts present within the native range would be useful to determine their susceptibility;
- susceptibility of *Malus* species in other parts of the EPPO region not known as hosts, especially *M. sylvestris*, *M. triloba* and *M. orientalis*;
- attractants that can be used for trapping;
- clarifying the pest's impact in some parts of its native range (e.g. Democratic People's Republic of Korea, Republic of Korea);

- pre-emptively assess the suitability of biological control agents, and the efficacy of chemical treatments, particularly for fruit trees;
- planting sentinel trees (European/EPPO species, including the planted elite *Malus* genotypes) in infested areas would be useful;
- evaluating under which conditions apparently healthy trees are colonized.

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ANNEX 1. Consideration of pest risk management options

Table A1.1 summarizes the consideration of possible measures for the pathways 'Host plants for planting (except seeds, tissue culture, pollen)'.

For measures, all *Malus* are considered as potential host plants.

When a measure is considered appropriate, it is noted 'Yes', or 'Yes, in combination' if it should be combined with other measures in a systems approach. 'No' indicate that a measure is not considered appropriate. A short justification is included. Elements that are common to several pathways are in bold.

Table A1.1. Possible measures for the pathways 'Host plants for planting (except seeds, tissue culture, pollen)'.

Option	**Host plants for planting (except seeds, tissue culture, pollen)**
Existing measures in EPPO countries	Partly, see Section 8.
Visual inspection at place of production	Yes, in combination* (for measures marked with *, see after the table). Detection by visual inspection is unlikely to be completely effective and needs to be used within a systems approach. Infestation is difficult to detect without destructive sampling (signs and symptoms may be restricted to exit holes and galleries under the bark. Larvae may not produce signs externally visible). Plants should be free from signs and symptoms of infestation.
Testing at place of production	Not available for *A. mali*.
Treatment of crop	Yes, in combination* Insecticide treatments can be applied to kill adults and prevent oviposition (see Section 12). However, this measure may not be entirely effective on its own. For *A. planipennis*, a range of systemic insecticides have been used to provide protection of mature trees (for example soil drench with imidacloprid, or stem injection with emamectin benzoate or azadirachtin). Such products are likely to provide protection for nursery material, but it still has to be proven. It is currently not considered as an option in nurseries in the USA and Canada (EPPO, 2013b).
Resistant cultivars	Not available.
Growing the crop in glasshouses/ screenhouses	Yes. Plants for planting could be grown under protected conditions with sufficient measures to exclude the pest (following EPPO Standard PM5/8(1) Guidelines on the phytosanitary measure 'Plants grown under physical isolation' (EPPO, 2016)). However, this is not common practice for nurseries of orchard/forest/ornamental trees and would be realistic only for small scale production of high value material.
Specified age of plant, growth stage or time of year of harvest	<u>Size of plant</u>: No. It is not clear what the minimum diameter of such material should be. <u>Growth stage/time of the year</u>: No. Larvae may be present in branches and trunks throughout the year. In particular, dormant plants may contain overwintering larvae.
Produced in a certification scheme	Not relevant.
Pest free production site	Yes, grown under physical isolation (see Growing the crop in glasshouses/screenhouses).

Option	Host plants for planting (except seeds, tissue culture, pollen)
	No, outdoors. The data available does not support that *A. mali* is a strong flier. Nevertheless, maximum flight distances in 24 h in a flight mill reached several hundred meters and data is lacking on dispersal in natural conditions. The data available is not sufficient to determine the size of the buffer zone. As for other *Agrilus*, pest free production site was not considered a possible option
Pest free place of production	Yes, grown under physical isolation. No, outdoors. See pest free production site.
Pest free area	Yes. PFA is considered applicable in the native range of the pest. Measures are similar to the requirements proposed for *A. planipennis* (EPPO, 2013b): • A minimum distance of 10 km between the PFA and the closest known area where the pest is known to be present. The minimum distance recommended for *A. planipennis* (100 km) seemed to be too high for *A. mali*. Based on dispersal data and estimations for *A. mali* (2–3 km; Section 2.4) and those for *A. planipennis* (EFSA, 2019b,c; summarised in Section 2.4), existence of trapping for surveillance and the time required to establish a PFA, a distance of 10 km seemed to provide a minimum buffer. However, if hosts are not available or sparse in the region, adults of *A. mali* might fly over longer distances. • To establish and maintain the PFA, detailed surveys and monitoring (using trapping and other methods) should be conducted in the area in the three years prior to establishment of the PFA and continued every year. Specific surveys should also be carried out in the zone between the PFA and known infestation to demonstrate pest freedom. The surveys should be targeted for the pest and should be based on appropriate combination of trapping, branch sampling and visual examination of host trees. • Surveys should include high risk locations, such as places where potentially infested material may have been imported. • There should be restrictions on the movement of host material (originating from areas where the pest is known to be present) into the PFA, and into the area surrounding the PFA, especially the area between the PFA and the closest area of known infestation. Hitchhiking risk should be taken into account.
Visual inspection of consignment	Yes, in combination*. Visual inspection may detect some infested trees. However, it would be difficult to detect the pest in large consignments or at early stages of infestation. Plants are generally traded during the dormant season, when the larvae would be overwintering inside the tree. Destructive sampling could be used.
Testing of commodity	No. There is no information about the practical use of a scanner or sniffing dogs for this pest.
Treatment of the consignment	No.
Pest only on certain parts of plant/plant product, which can be removed	No. Life stages are on or in branches or trunk.

Option	Host plants for planting (except seeds, tissue culture, pollen)
Prevention of infestation by packing/handling method	Yes, associated with certain measures. Plants should be packed in conditions preventing infestation during transport and storage.
Post-entry quarantine	No, except in the framework of a bilateral agreement. The EWG suggested that plants may be kept in post-entry quarantine for a sufficient time to detect the symptoms of larval activity or adult emergence (2 years to ensure that the pest is detected but under certain circumstances 1 year may be enough – Section 2.2). This measure is likely to be applicable only for small scale imports of high value plants, but it may pose practical difficulties for large trees. The Panel on Phytosanitary Measures considered that this measure should only be proposed in the framework of a bilateral agreement.
Limited distribution of consignments in time and/or space or limited use	No. Plants for planting are destined to be planted, and if adults emerged, they could fly and may find hosts in the vicinity. Limiting the distribution to areas where the pest is not likely to establish is not feasible (and this area cannot be precisely defined).
Only surveillance and eradication in the importing country	No Detection is difficult, and the pest may be detected only years after establishment. Moreover, signs and symptoms are already caused on the same host plants by other *Agrilus* species in the EPPO region, such as *A. sinuatus, A. macroderus, A. roscidus*. Adults may be confused with adults of other *Agrilus* spp. Surveillance and eradication are difficult.

*The EWG considered whether the measures identified above as ‘Yes, in combination’ (listed below) could be combined to achieve a suitable level of protection.

- Visual inspection at place of production,
- Treatment of crop,
- Visual inspection of the consignment.

No combination provides a sufficient level of protection. This was not possible. Therefore, the measures noted as ‘Yes, in combination’ in the above table are not relevant. Regarding treatment of the crop, data is missing on which treatments would be effective, and treatment should be applied over a period of three months, which would not be cost-effective.

For the pathway ‘*Malus* round wood and sawn wood of hosts (with or without bark)’, EWG discussed the need of debarking before heat treatment (with minimum temperature of 56 °C for a minimum duration of 30 continuous minutes throughout the entire profile of the wood [including its core]) as it was suggested in the PRA for A. *fleischeri* (EPPO, 2019). However, the EWG considered that debarking is not necessary for *Malus* wood for the efficiency of the treatment because *A. mali* is mainly infesting branches and twigs and because thin bark will not influence temperature regime inside. And also there would not be a possibility of reinfestation by this species. P PM agreed (2023-10).

ANNEX 2. Morphology of *Agrilus mali* (detailed description)

Adult (from Volkovitsh et al., 2020a). Body (Fig. A2.1A): length 6.1–8.7 mm; unicolor, metallic, coppery-red, underside also copper; elytra with three pairs of white tomentose spots. Head (Fig. A2.1B,C): frons and vertex with longitudinal medial impression, vertex slightly depressed or flat as seen from above, wide, slightly wider than frons above antennal fossae, frons with almost regularly arcuate sides, very densely punctate. Pronotum (Fig. A2.1C,D): widest at mid-length, sides arcuately converging toward anterior angles and base, slightly emarginated basally, posterior angles nearly rectangular; disc without distinct medial impressions; marginal and submarginal carinae (Fig. A2.1D: mc, sc) almost touching each other or even merging posteriorly; prehumeri (Fig. A2.1C,D: ph) well-marked, strongly elevated, arcuate from above but subparallel to common part of marginal carinae in lateral view, extending to approximately mid-length of pronotum. Elytra (Fig. A2.1A): coppery-red, matt, with three pairs of white tomentose spots (Fig. A2.1A: ts) of setiform scales located in humeral depressions and along the suture in anterior and posterior thirds, two anterior pairs frequently missing or poorly marked, posterior sutural pair always well-marked, cuneiform; apices arcuate or slightly angulate, with very finely denticulate margins. Pygidium: rounded, without apical process. Abdominal ventrites without tomentose spots. Aedeagus (Fig. A2.1E): tegmen widest in apical half, parameres apically with wide membranous marginal area; penis nearly subparallel with apex strongly acute.

Comparison. The most important diagnostic characteristics of *A. mali* to distinguish it from other members of subgenus *Sinuatiagrilus* (*sinuatus* species-group) are the presence of two-three pairs of tomentose spots on elytra and an aedeagus structure. Additionally, it differs from *A. sinuatus* (Olivier) (Fig. A2,1F-J), which bears a single pair of poorly marked tomentose spots in the posterior third of elytra, better developed and numerous elytral spots and an aedeagus structure (in *A. sinuatus* apical membranous areas on parameres nearly lacking and penis blunted apically). Compared with *A. sachalinensis* Obenberger, it differs based on its smaller size and the presence of white tomentose spots on elytra. Compared with *A. zhelochovtsevi* Alexeev, it differs based on the presence of tomentose spots on elytra and an absolutely different aedeagus structure (Volkovitsh et al., 2020a).

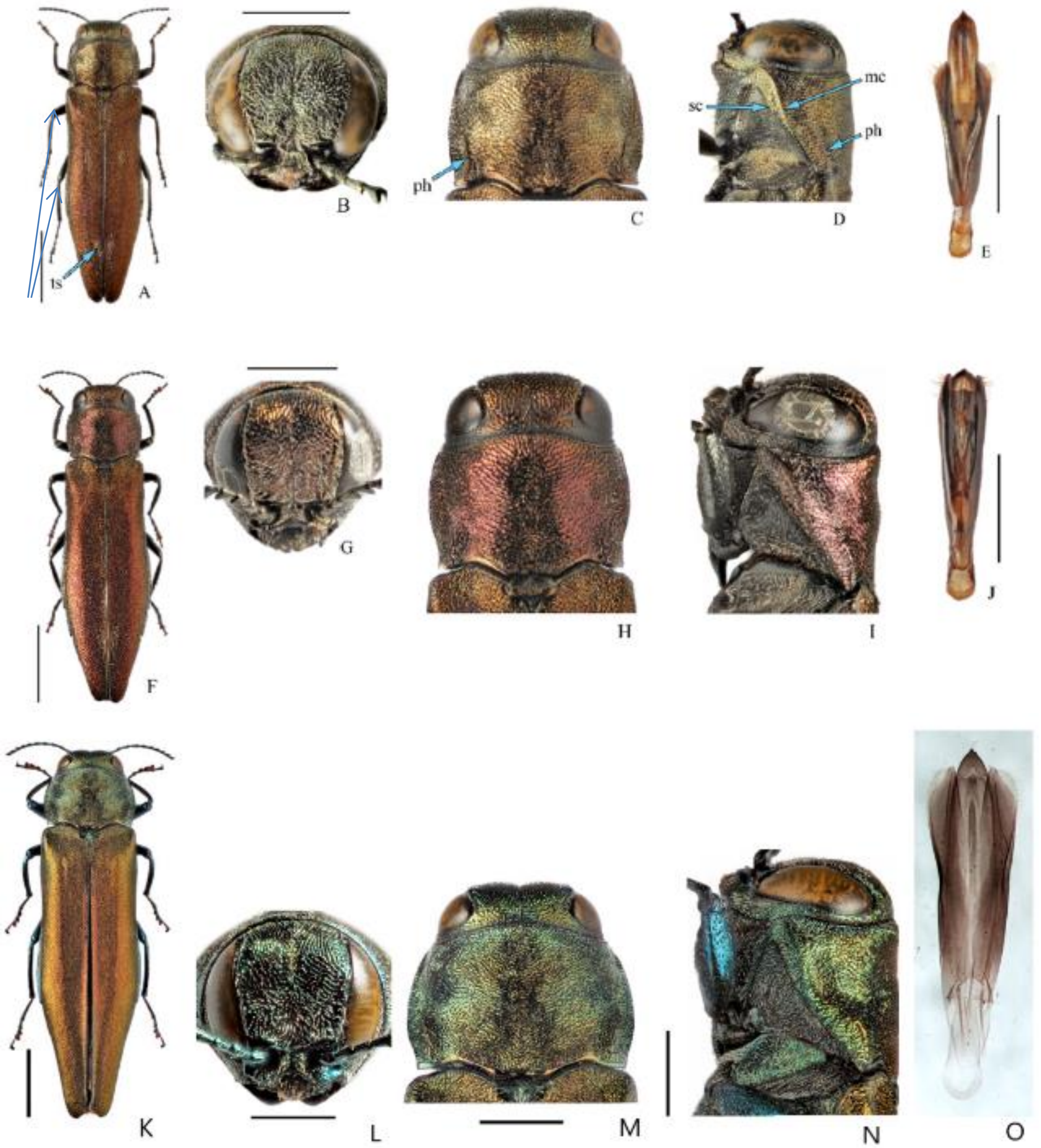

Figure A2.1. *Agrilus mali* Matsumura, 1924, *Agrilus sinuatus* (Olivier, 1790), and *Agrilus mendax* Mannerheim, 1837.
(A–E) *Agrilus mali* Matsumura, 1924, male. (A) Habitus; (B) head; (C) pronotum, dorsal view; (D) same, lateral view; (E) aedeagus, dorsal view.
(F–J) *Agrilus sinuatus* (Olivier, 1790), male. (F) Habitus; (G) head; (H) pronotum, dorsal view; (I) same, lateral view; (J) aedeagus, dorsal view.
(K–O) *Agrilus mendax* Mannerheim, 1837. (K) Habitus, female; (L) head; (M) pronotum, dorsal view; (N) same, lateral view; (O) aedeagus, dorsal view.
Scale bars for (A, F, K) = 2.0 mm; for (B–D, G–I, L–N) = 1.0 mm; for (E, J) = 0.5 mm; no scale available for (O). Photo by A.V. Kovalev (from: A–J – Volkovitsh et al., 2020a; K–N – Volkovitsh et al., 2020b; O – courtesy of M. Volkovitsh).

Additional pictures can be viewed in EPPO Global Database (https://gd.eppo.int/taxon/AGRLMA/photos).

Eggs (Fig. A2.2) oval, oblong or ellipsoid in shape, ca. 1.0–1.5 mm long, ca. 0.7–1.0 mm wide, laid milky white, then yellowish brown after a few days (Clausen, 1931; Han, 2002; Ji et al., 2004; Guo & Ma, 2010; Feng et al., 2013; Guli & Wang, 2013; Bozorov et al., 2019; Li, 2019).

Figure A2.2. Eggs of *Agrilus mali* (photo courtesy of Y.-L. Zhang, Ecology and Nature Conservation Institute, Chinese Academy of Forestry, China).

Larvae (Fig. A2.3) are elongated, flattened, slender, milky white, yellowish or brown and with 13 segments (3 thoracic and 10 abdominal) (Linyi Agro-Forestry Bureau, 1973). Head is small and brown, almost completely retracted into prothorax, transparent; external brown part is a peristome (consisting of articulated epistome, hypostome and pleurostomes) bearing small and brown mouth parts. There is a pair of black brown terminal processes with small serrations at the end of anal segment. The body length of final instar larvae is 16–22 mm (Linyi Agro-Forestry Bureau, 1973). Based on the width of the peristoma and length of the urogomphus, the larvae can be divided into 5 instars (early papers mentioned 6 instars; there is an opinion that actually there are only 4 instars – see Table 2.1), and the corresponding body length of 1^{st}–5^{th} instar is 2.25–2.99 mm, 2.61–3.6 mm, 3.33–6.11 mm, 5.4–9.99 mm, 9.18–19.25 mm, respectively (Wang et al., 2013). Segments are wider after the 4^{th} one, the 7^{th} abdominal segment is the widest (1.7–2.5 mm) and the last three segments become narrower. The end of body is nearly triangular, with a pair of toothed brown tail irons at the end (Linyi Agro-Forestry Bureau, 1973).

Figure A2.3. Larva of *Agrilus mali* (photo courtesy of Y.-L. Zhang, Ecology and Nature Conservation Institute, Chinese Academy of Forestry, China).

Pupae (Fig. A2.4) are exarate, spindle or fusiform shaped, around 6.0–10.0 mm long and 2.0–4.0 mm wide. It is milky or creamy white at the initial stage, gradually deepened in the later stage of the pupa, and turns blackish brown before emergence of an adult.

Figure A2.4. Pupa of *Agrilus mali* (photo courtesy of Y.-L. Zhang, Ecology and Nature Conservation Institute, Chinese Academy of Forestry, China).

ANNEX 3. Signs and symptoms of infestation

Fig. A3.1. Infestation symptom of *Agrilus mali.* (A) secretion (gum) of red sap; (B) sunken and cracked bark; (C) withered branches; (D) entire dead tree (photos courtesy of Y.-L. Zhang, Ecology and Nature Conservation Institute, Chinese Academy of Forestry, China).

ANNEX 4. *Agrilus* species on hosts of *Agrilus mali* in the EPPO region

The table below lists *Agrilus* spp. reported from *Malus* ssp. and unconfirmed hosts in the EPPO region.

Table A4.1. *Agrilus* spp. reported from *Malus* ssp. and unconfirmed hosts in the EPPO region.

Species	**Hosts**	**Distribution**	**Comments**
Agrilus sinuatus	*Malus domestica* and other Rosaceae (including *Crataegus*, *Mespilus*, *Prunus*, *Pyrus*, and *Sorbus*) (Bílý, 2002; Jendek & Poláková, 2014)	European Russia to Western Europe (Jendek, 2016a; Bílý, 2002)	Heavily infested pear (*Pyrus*) orchards were reported in the Netherlands in 1948 (Bílý, 2002 citing Leefmans, 1950). *Agrilus sinuatus* has been re-emerging in Europe (for example in Belgium, the Netherlands, France and Germany) since the 1990s and control measures have been developed and applied. Occasional pest of pear orchards in Belgium, and causes severe damage to mature orchards and young plantations in southern France (Bylemans & Thirry, 1998; Fassotte, 1999; Fassotte et al., 2004; Bangels, 2008; EPPO, 2011 citing others; Ondet, 2016). Also damaging to *Crataegus* (Bílý, 2002).
Agrilus malicola	*Malus* (Jendek & Poláková, 2014); *Pyrus malus* (Jendek, 2016b)	Morocco (Jendek, 2016a,b; Jendek & Poláková, 2014)	Described in Morocco as a pest of *Malus* (Jendek & Poláková, 2014 citing Rungs & Schaefer, 1948). Biology and damage are described in Balachowsky et al. (1962). No recent information was found.
Agrilus macroderus	*Prunus* (*armeniaca*, *avium*, *domestica*, *spinosa*) (Bílý, 2002), also *Malus domestica*, *Prunus persica*, *Pyrus* (Jendek & Poláková, 2014)	Southeastern Europe (Austria to Ukraine), southern Russia, Transcaucasia, Türkiye, Iraq (Bílý, 2002; Jendek, 2016b).	It was reported to damage fruit trees in former Yugoslavia (Bílý, 2002 citing Lekić, 1956).
Agrilus roscidus	*Malus domestica*, *M. sylvestris* and many rosaceous fruit trees (Bílý, 2002, Jendek & Poláková, 2014)	Mediterranean Basin to Türkiye and Russia; rather common in Southern Europe (Bílý, 2002)	Perhaps a complex of a few cryptic species.
Agrilus mendax	*Sorbus* (Bílý, 2002; Jendek & Poláková, 2014)	Sweden and Finland south to Czech Republic and east to Russia (Bílý, 2002; Jendek, 2016a)	Possibly this species spreads up to Japan and E. China, if *A. sachalinensis* is subspecies of *A. mendax* (Volkovitsh et al., 2020b; M. Volkovitsh, pers. comm., 2023).

ANNEX 5. Definitions related to pathways

As in the Guidance document for the drafting of a PRA according to the Express PRA scheme (EPPO PM 5/5(1) Decision-Support Scheme for an Express Pest Risk Analysis) (EPPO, 2022).

Table A5.1. Definitions related to pathways (EPPO, 2022).

Term	**Definition**
Bark	On its own, i.e. isolated bark as a commodity. Note: deleted from ISPM 5 (FAO, 2018a). PM 8/2(3): 'bark separated from wood (ISPM 5). Bark may contain pieces of wood with it.'
Hitchhiking	Defined as 'contaminating pest' in ISPM 5 (FAO, 2018a). Measures listed under this category only if hitchhiking is not related to other categories above (e.g. hitchhiking on fruit will be covered under 'fruit').
Hogwood	Wood with or without bark in the form of pieces of varying particle size and shape, produced by crushing with blunt tools such as rollers, hammers or flails.
Natural spread	Pest moving by itself or aided by, e.g. wind, water, wild animals.
Plants for planting	Note: all types of plants for planting are covered in the subcategories. The category 'other' is not needed. -ISPM 5. Plants intended to remain planted, to be planted or replanted. - note that pollen intended for pollination is included in this category.
Processing wood residues	Parts of wood and bark that are left after the process of transforming round wood into sawn wood and further transformation of sawn wood.
Round wood	Wood not sawn longitudinally, carrying its natural rounded surface, with or without bark.
Sawn wood	Wood sawn longitudinally, with or without its natural rounded surface with or without bark.
Wood chips	Wood with or without bark in the form of pieces with a definable particle size produced by mechanical treatment with sharp tools.
Wood packaging material	Wood or wood products (excluding paper products) used in supporting, protecting or carrying a commodity (includes dunnage).

ANNEX 6. ISEFOR data regarding import of plants for planting in host genera

In number of plants, from non-EU countries into seven EU countries for the period 2000–2010 (Eschen et al., 2017).

Table A6.1. Import of plants for planting in host genera (in number of plants) from non-EU countries into seven EU countries for the period 2000–2010 (Eschen et al., 2017).

Genus/species	**Number of plants, by years**						
	2001	2002	2003	2004	2008	2009	2010
Cydonia							
China						1,500	
Malus							
China	43*						
Uzbekistan[@]					3,180		
Prunus avium[#]							
China							9,000*
Prunus cerasus[#]							
Russian Federation							1*
Prunus persica							
China							18,000*
Prunus							
China				250*	100	10	20
Uzbekistan					9,080		
Pyrus							
China		8,100	8				
Republic of Korea	17*		30*				

* – the product class is indicated as nursery plants, nursery trees, fruit plants for end users, nursery and flower plants. For others, the product class is not indicated.
[@] – imports from Central Asian countries also included.
[#] – not recorded as hosts.

ANNEX 7. Basic comparison of climate between the area where the pest is present and the EPPO region

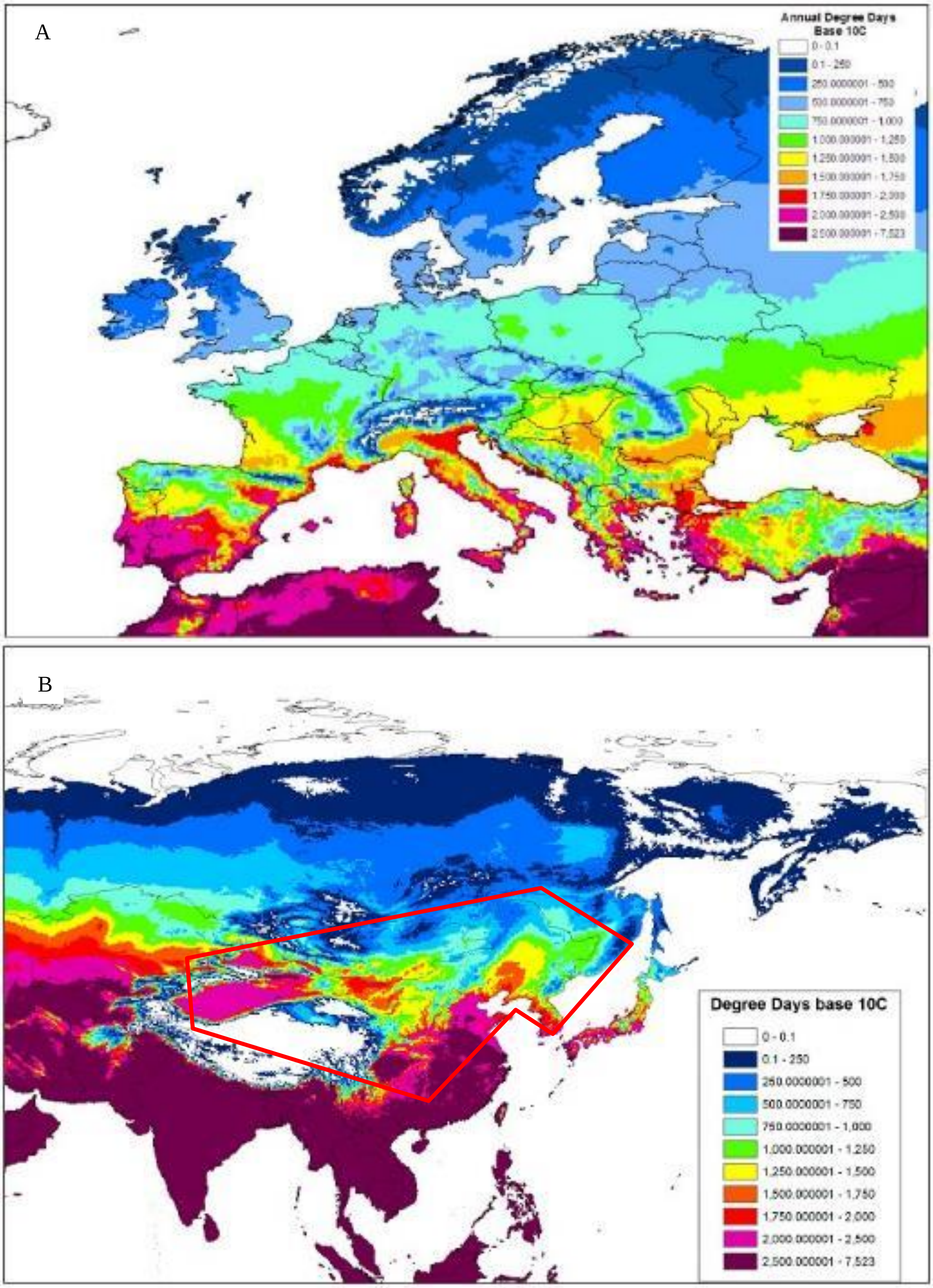

Figure A7.1. Maps of average annual temperature accumulation (degree days) based on a threshold of 10°C using 1961–1990 monthly average maximum and minimum temperatures taken from the 10-minute latitude and longitude Climatic Research Unit database (New et al., 2002). A, Europe; B, Asia; red outline roughly covers the current ranger of *Agrilus mali* (see Section 6 and Fig. A7.2).

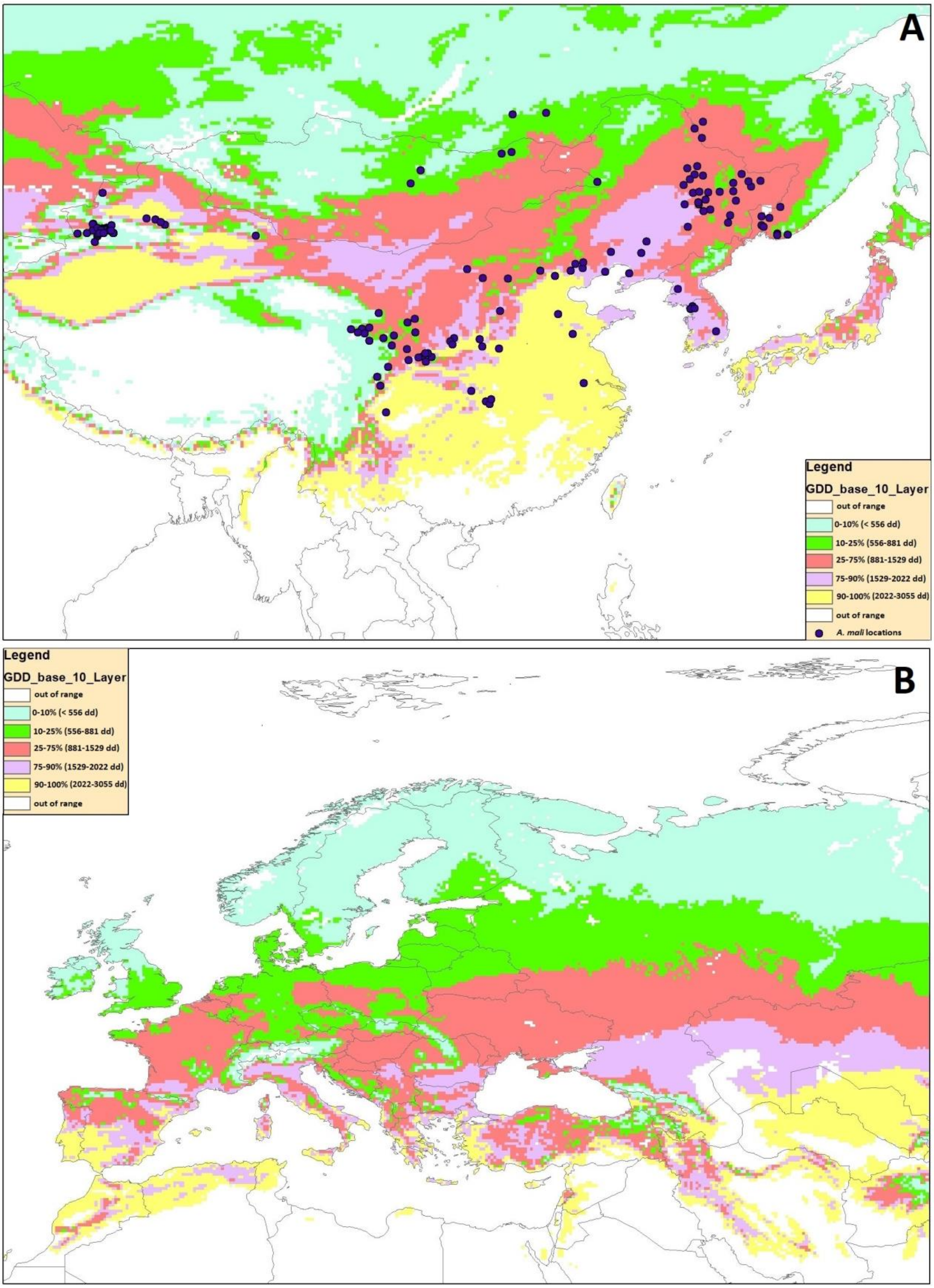

Figure A7.2. A: Records within the current range of *A. mali* (from Lu et al., 2022 and Volkovitsh et al., 2020a) matched to the number of degree-days above the 10°C base. The degree-day data are means for 1970–2019 (Mistry, 2019). All records are divided into five percentile bands for degree days (0–10% [<556 degree-days], 10–25% [556–881 degree-days], 25–75% [881–1529 degree-days], 75–90% [1529–2022 degree-days], and 90–100% [2022–3055 degree-days]). B: A part of the EPPO region within the degree-day percentile bands derived from the records of *A. mali* withing its current range. Both maps are produced in ArcGIS 10.7.1 (ArcGIS, 2023) by D. Eyre (2023).

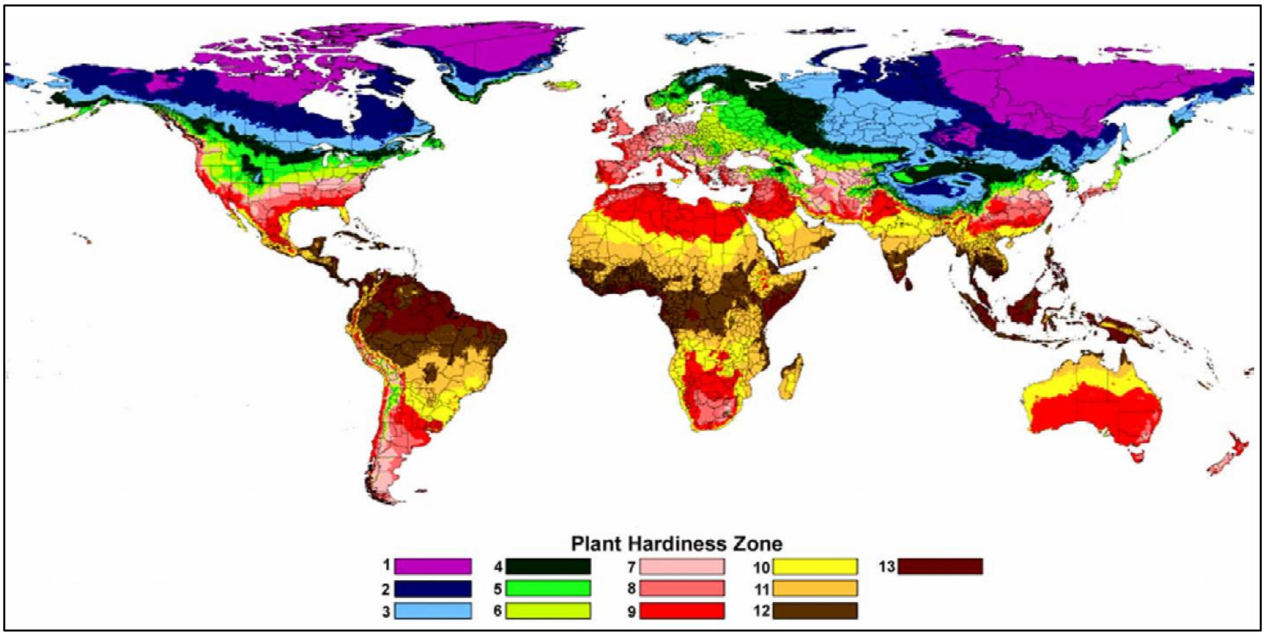

Figure A7.3. Comparison of plant hardiness zones: 30-year global plant hardiness zone map for the period 1978–2007. European and American Hardiness Zones updated by Magarey et al. (2008) (map extract).

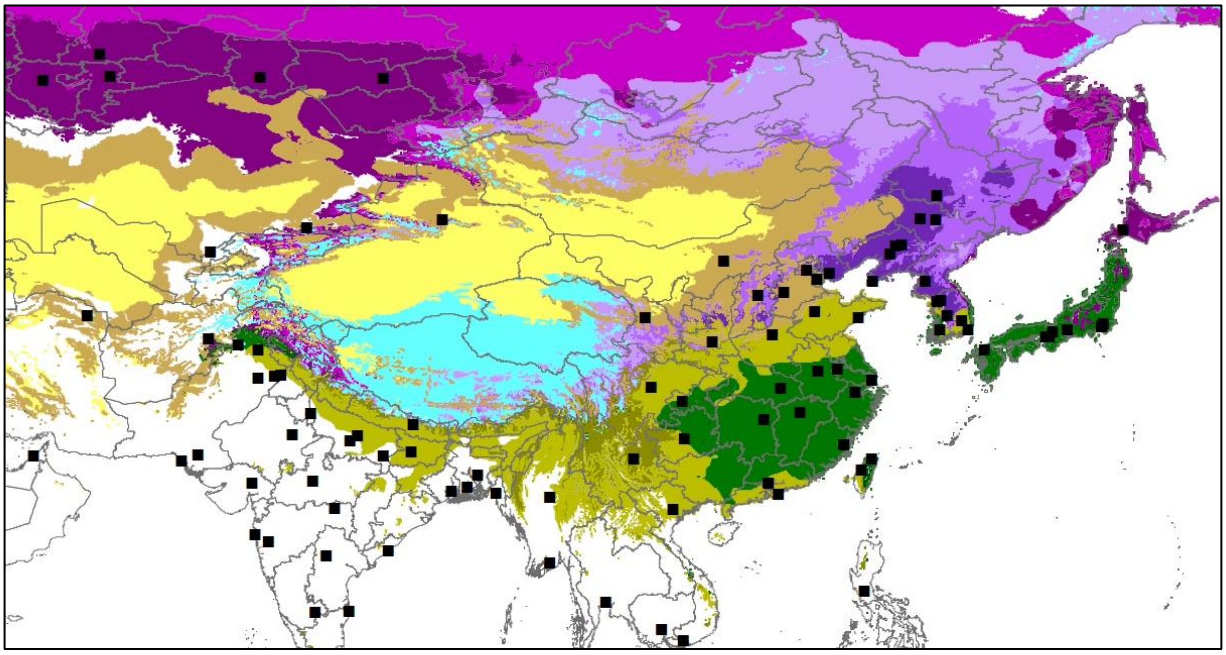

Figure A7.4. Köppen-Geiger climate zones in the area of natural distribution of *Agrilus mali* in Asia (MacLeod & Korycinska, 2019). Black squares are major cities.

Common for the current range and the EPPO region: – Bsk; – Cfa; – Cfb; – Dfb; – Dfc; – Dwc. Unique for the current range and not present in the EPPO region: – Cwa; – Cwb; – Dwa; – Dwb. Note: EWG assumes that *A. mali* does not occur (or occurs rarely) under two climate types occurring in parts of territories where it is present: cold arid desert climate type (Bwk – –< 5 mm rainfall per year) and polar tundra climate (ET –) (occurs at high latitude and altitudes in Tibet, Xinjiang, Qinghai, Sichuan) because of the absence of hosts.

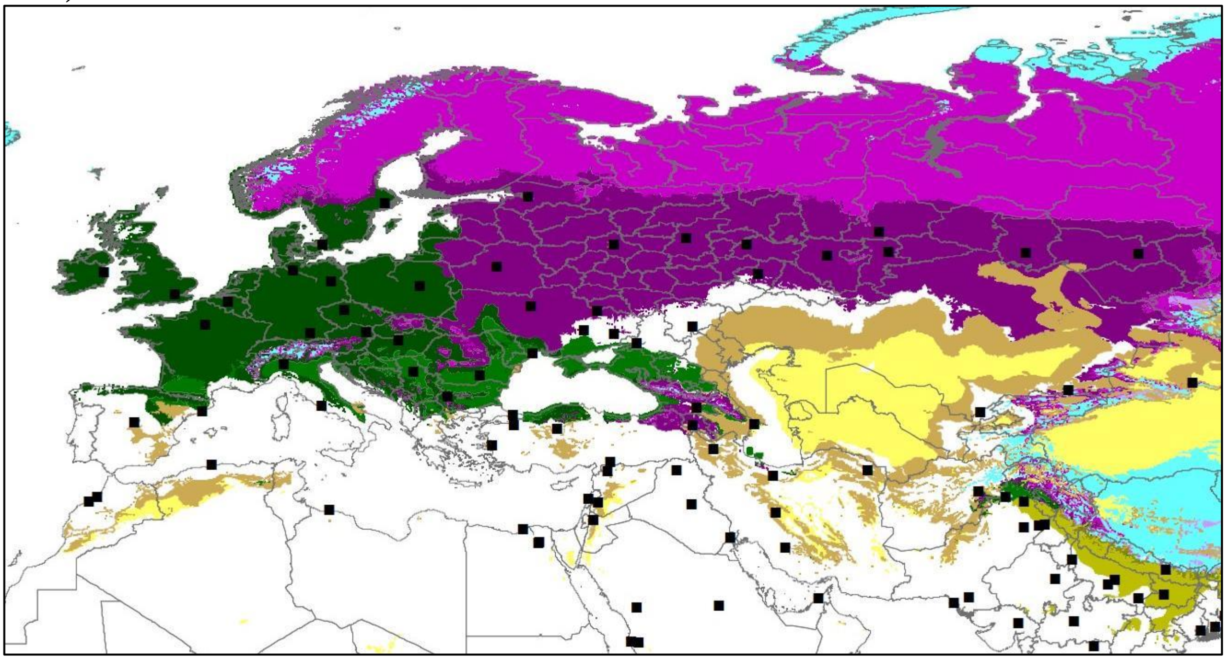

Figure A7.5. Köppen-Geiger climate zones in the EPPO region; only zones that are present in the natural distribution of *Agrilus mali* in Asia are shown (MacLeod & Korycinska, 2019). Black squares are major cities.

Zones: – Bsk; – Cfa; – Cfb; – Dfb; – Dfc; – Dwc. Note: EWG assumes that *A. mali* does not occur (or occurs rarely) under two climate types occurring in parts of territories where it is present: cold arid desert climate type (Bwk – –< 5 mm rainfall per year) and polar tundra climate (ET –) (occurs at high latitude and altitudes in Tibet, Xinjiang, Qinghai, Sichuan) because of the absence of hosts.