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SCIENTIFIC OPINION

Pest categorisation of *Dendrolimus punctatus*

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Abstract

The EFSA Panel on Plant Health performed a pest categorisation of *Dendrolimus punctatus* (Lepidoptera: Lasiocampidae), following a commodity risk assessment of bonsai *Pinus parviflora* grafted onto *P. thunbergii* from China, in which *D. punctatus* was identified as a pest of possible concern to the European Union (EU). *D. punctatus*, also known as the Masson pine caterpillar, is present in China, Taiwan, Vietnam, India and has recently spread to Japanese islands close to Taiwan. Larval feeding on the needles of *Pinus elliottii*, *P. luchuensis*, *P. massoniana*, *P. merkusii* and *P. tabulaeformis* causes important damage. *D. punctatus* larvae can also feed on *P. armandii*, *P. echinata*, *P. latteri*, *P. parviflora*, *P. sylvestris* var. *mongolica*, *P. taeda*, *P. taiwanensis* and *P. thunbergii*, but full development on these hosts is uncertain. The pest has three to five generations per year; winter is spent as larvae on branch tips, on tree trunks and in the soil. The females lay egg clusters on pine needles. Pupation occurs in cocoons attached to branches or needles. *D. punctatus* could enter the EU either as eggs, larvae or pupae in the foliage of plants for planting or cut branches, as larvae on wood with bark or as overwintering larvae in branches, crevices in the bark or in the litter of potted plants. However, Annex VI of 2019/2072 prohibits the introduction of *D. punctatus* hosts (*Pinus* spp.) from countries and areas where the pest occurs. There are climate zones where the pest occurs in Asia that also occur in the EU, though they are limited, which constitutes an uncertainty regarding establishment. The pest's main hosts are not grown in the EU. However, the fact that it attacks the North American *Pinus echinata*, *P. elliottii* and *P. taeda* in its Asian native area suggests a potential capacity to shift to pine species occurring in the EU territory. *D. punctatus* satisfies all the criteria that are within the remit of EFSA to assess for it to be regarded as a potential Union quarantine pest. Whether the *Pinus* commonly found in Europe could act as hosts is unknown but is fundamental, affecting the criteria of establishment and magnitude of impact.

KEYWORDS

forest entomology, Lasiocampidae, Masson pine caterpillar, pest risk, *Pinus*, plant health, plant pest

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1 | INTRODUCTION

1.1 | Background and Terms of Reference as provided by the requestor

1.1.1 | Background

The new Plant Health Regulation (EU) 2016/2031, on the protective measures against pests of plants, is applying from 14 December 2019. Conditions are laid down in this legislation in order for pests to qualify for listing as Union quarantine pests, protected zone quarantine pests or Union regulated non-quarantine pests. The lists of the EU regulated pests together with the associated import or internal movement requirements of commodities are included in Commission Implementing Regulation (EU) 2019/2072. Additionally, as stipulated in the Commission Implementing Regulation 2018/2019, certain commodities are provisionally prohibited to enter in the EU (high risk plants, HRP). EFSA is performing the risk assessment of the dossiers submitted by exporting to the EU countries of the HRP commodities, as stipulated in Commission Implementing Regulation 2018/2018. Furthermore, EFSA has evaluated a number of requests from exporting to the EU countries for derogations from specific EU import requirements.

In line with the principles of the new plant health law, the European Commission with the Member States are discussing monthly the reports of the interceptions and the outbreaks of pests notified by the Member States. Notifications of an imminent danger from pests that may fulfil the conditions for inclusion in the list of the Union quarantine pest are included. Furthermore, EFSA has been performing horizon scanning of media and literature.

As a follow-up of the above-mentioned activities (reporting of interceptions and outbreaks, HRP, derogation requests and horizon scanning), a number of pests of concern have been identified. EFSA is requested to provide scientific opinions for these pests, in view of their potential inclusion by the risk manager in the lists of Commission Implementing Regulation (EU) 2019/2072 and the inclusion of specific import requirements for relevant host commodities, when deemed necessary by the risk manager.

1.1.2 | Terms of Reference

EFSA is requested, pursuant to Article 29(1) of Regulation (EC) No 178/2002, to provide scientific opinions in the field of plant health.

EFSA is requested to deliver 53 pest categorisations for the pests listed in Annex 1A, 1B, 1D and 1E (for more details see mandate M-2021-00027 on the Open.EFSA portal). Additionally, EFSA is requested to perform pest categorisations for the pests so far not regulated in the EU, identified as pests potentially associated with a commodity in the commodity risk assessments of the HRP dossiers (Annex 1C; for more details see mandate M-2021-00027 on the Open.EFSA portal). Such pest categorisations are needed in the case where there are not available risk assessments for the EU.

When the pests of Annex 1A are qualifying as potential Union quarantine pests, EFSA should proceed to phase 2 risk assessment. The opinions should address entry pathways, spread, establishment, impact and include a risk reduction options analysis.

Additionally, EFSA is requested to develop further the quantitative methodology currently followed for risk assessment, in order to have the possibility to deliver an express risk assessment methodology. Such methodological development should take into account the EFSA Plant Health Panel Guidance on quantitative pest risk assessment and the experience obtained during its implementation for the Union candidate priority pests and for the likelihood of pest freedom at entry for the commodity risk assessment of High Risk Plants.

1.2 | Interpretation of the Terms of Reference

Dendrolimus punctatus is one of a number of pests listed in Annex 1C to the Terms of Reference (ToR) to be subject to pest categorisation to determine whether it fulfils the criteria of a potential Union quarantine pest for the area of the EU excluding Ceuta, Melilla and the outermost regions of Member States referred to in Article 355(1) of the Treaty on the Functioning of the European Union (TFEU), other than Madeira and the Azores, and so inform European Commission decision-making as to its appropriateness for potential inclusion in the lists of pests of Commission Implementing Regulation (EU) 2019/2072. If a pest fulfils the criteria to be potentially listed as a Union quarantine pest, risk reduction options will be identified.

1.3 | Additional information

This pest categorisation was initiated after *D. punctatus* was identified as a pest of *Pinus thunbergii* and *P. parviflora* in a commodity risk assessment of bonsai plants from China consisting of *P. parviflora* grafted on *P. thunbergii* (EFSA PLH Panel, 2022).

D. punctatus is also included in a list of pests of concern in relation to naturally or artificially dwarfed *P. parviflora* and *P. thunbergii* plants for planting from Japan in Commission Implementing Regulation (EU) 2020/1217. The regulation provides for a derogation from Article 7 and point 1 of Annex VI of Implementing Regulation (EU) 2019/2072 if the plants comply with the conditions set out in Commission Implementing Regulation (EU) 2020/1217.

2 | DATA AND METHODOLOGIES

2.1 | Data

2.1.1 | Literature search

A literature search on *D. punctatus* was conducted at the beginning of the categorisation in the ISI Web of Science bibliographic database, using the scientific name of the pest as search term. Papers relevant for the pest categorisation were reviewed, and further references and information were obtained from experts, as well as from citations within the references and grey literature.

2.1.2 | Database search

Pest information, on host(s) and distribution, was retrieved from the CABI Compendium and scientific literature databases, as referred above in Section 2.1.1.

The Europhyt and TRACES databases were consulted for pest-specific notifications on interceptions and outbreaks. Europhyt is a web-based network run by the Directorate General for Health and Food Safety (DG SANTÉ) of the European Commission as a subproject of PHYSAN (Phytosanitary Controls) specifically concerned with plant health information. TRACES is the European Commission's multilingual online platform for sanitary and phytosanitary certification required for the importation of animals, animal products, food and feed of non-animal origin and plants into the European Union, as well as the intra-EU trade and EU exports of animals and certain animal products. Up until May 2020, the Europhyt database managed notifications of interceptions of plants or plant products that do not comply with EU legislation, as well as notifications of plant pests detected in the territory of the Member States and the phytosanitary measures taken to eradicate or avoid their spread. The recording of interceptions switched from Europhyt to TRACES in May 2020.

GenBank was searched to determine whether it contained any nucleotide sequences for *D. punctatus* that could be used as reference material for molecular diagnosis. GenBank® (www.ncbi.nlm.nih.gov/genbank/) is a comprehensive publicly available database that, as of August 2019 (release version 227), contained over 6.25 trillion base pairs from over 1.6 billion nucleotide sequences for 450,000 formally described species (Sayers et al., 2020).

2.2 | Methodologies

The Panel performed the pest categorisation for *D. punctatus*, following guiding principles and steps presented in the EFSA guidance on quantitative pest risk assessment (EFSA PLH Panel, 2018a), the EFSA guidance on the use of the weight of evidence approach in scientific assessments (EFSA Scientific Committee et al., 2017) and the International Standards for Phytosanitary Measures No. 11 (FAO, 2013).

The criteria to be considered when categorising a pest as a potential Union quarantine pest (QP) are given in Regulation (EU) 2016/2031 Article 3 and Annex I, Section 1 of the Regulation. Table 1 presents the Regulation (EU) 2016/2031 pest categorisation criteria on which the Panel bases its conclusions. In judging whether a criterion is met, the Panel uses its best professional judgement (EFSA Scientific Committee et al., 2017) by integrating a range of evidence from a variety of sources (as presented above in Section 2.1) to reach an informed conclusion as to whether or not a criterion is satisfied.

The Panel's conclusions are formulated respecting its remit and particularly with regard to the principle of separation between risk assessment and risk management (EFSA founding regulation (EU) No 178/2002); therefore, instead of determining whether the pest is likely to have an unacceptable impact, deemed to be a risk management decision, the Panel will present a summary of the observed impacts in the areas where the pest occurs, and make a judgement about potential likely impacts in the EU. While the Panel may quote impacts reported from areas where the pest occurs in monetary terms, the Panel will seek to express potential EU impacts in terms of yield and quality losses and not in monetary terms, in agreement with the EFSA guidance on quantitative pest risk assessment (EFSA PLH Panel, 2018a). Article 3 (d) of Regulation (EU) 2016/2031 refers to unacceptable social impact as a criterion for quarantine pest status. Assessing social impact is outside the remit of the Panel.

TABLE 1 Pest categorisation criteria under evaluation, as derived from Regulation (EU) 2016/2031 on protective measures against pests of plants (the number of the relevant sections of the pest categorisation is shown in brackets in the first column).

Criterion of pest categorisation	Criterion in regulation (EU) 2016/2031 regarding union quarantine pest (article 3)
Identity of the pest (Section 3.1)	Is the identity of the pest clearly defined, or has it been shown to produce consistent symptoms and to be transmissible?
Absence/ presence of the pest in the EU territory (Section 3.2)	Is the pest present in the EU territory? If present, is the pest in a limited part of the EU or is it scarce, irregular, isolated or present infrequently? If so, the pest is considered to be not widely distributed.
Pest potential for entry, establishment and spread in the EU territory (Section 3.4)	Is the pest able to enter into, become established in, and spread within, the EU territory? If yes, briefly list the pathways for entry and spread.
Potential for consequences in the EU territory (Section 3.5)	Would the pests' introduction have an economic or environmental impact on the EU territory?
Available measures (Section 3.6)	Are there measures available to prevent pest entry, establishment, spread or impacts?
Conclusion of pest categorisation (Section 4)	A statement as to whether (1) all criteria assessed by EFSA above for consideration as a potential quarantine pest were met and (2) if not, which one(s) were not met.

3 | PEST CATEGORISATION

3.1 | Identity and biology of the pest

3.1.1 | Identity and taxonomy

Is the identity of the pest clearly defined, or has it been shown to produce consistent symptoms and/or to be transmissible?

Yes, the identity of the species is established, and ***Dendrolimus punctatus*** (Walker) is the accepted scientific name and authority.

Dendrolimus punctatus (Walker, 1855) is an insect within the order Lepidoptera and family Lasiocampidae. It is commonly known as the Masson pine caterpillar (CABI, online; Cai & Liu, 1962). It was sometimes referred to as *Dendrolimus punctata* in the older literature (Cai & Liu, 1962). This species had also been referred to as *Oeona punctata* Walker, 1855; *Lebeda hebes* Walker, 1855; *Lasiocampa innotata* Walker, 1855; *Lasiocampa remota* Walker, 1855; *Lasiocampa consimilis* Walker, 1865; *Odonestis abstersa* Walker, 1865; *Odonestis sodalis* Walker, 1865; *Lebeda inconclusa* Walker, 1865; and *Dendrolimus tabulaeformis* Tsai & Liu, 1962 (see Section 3.1.4 'intraspecific diversity').

The European and Mediterranean Plant Protection Organization (EPPO) code[1] (EPPO, 2019; Griessinger & Roy, 2015) for this species is: DENDPU (EPPO, online). EPPO also has a code for the subspecies *D. punctatus tabulaeformis*: DENDTA, a taxon originally described as a separate species (*Dendrolimus tabulaeformis* Tsai & Liu) (Tsai & Liu, 1962) but soon afterwards considered as a synonym of *D. punctatus* based on morphological features (de Lajonquière, 1973). This was later confirmed by hybridisation experiments and molecular identification methods (Dai et al., 2012; Kononov et al., 2016; Qin et al., 2019; Zhao et al., 1992).

3.1.2 | Biology of the pest

The biology of *D. punctatus* has been described by Cai and Liu (1962) in China, and by Bassus (1974) and Billings (1991) in Vietnam and is summarised in CABI (online). The pest has three to five generations per year. Winter is spent as larvae in branch tips, on tree trunks and in the soil. The females lay clusters of 100–400 eggs on pine needles. There are six larval instars, and pupation occurs in cocoons attached to branches or needles. This is an oligophagous species, as host plants belong exclusively to the genus *Pinus* (pines) (see Section 3.1.3). Larval winter diapause is induced above a night-length threshold of about 10 h 40 min at 25°C (Huang et al., 2005).

The active components of the female sex pheromone of *D. punctatus* were identified as Z5,E7-12:OH, (5Z,7E)-5,7-dodecadien-1-yl acetate (Z5,E7-12:OAc) and (5Z,7E)-5,7-dodecadien-1-yl propionate (Z5,E7-12:OPr). Two additional

[1]An EPPO code, formerly known as a Bayer code, is a unique identifier linked to the name of a plant or plant pest important in agriculture and plant protection. Codes are based on genus and species names. However, if a scientific name is changed, the EPPO code remains the same. This provides a harmonised system to facilitate the management of plant and pest names in computerised databases, as well as data exchange between IT systems (EPPO, 2019; Griessinger & Roy, 2015).

components, (5Z)-5-dodecen-1-yl acetate (Z5-12:OAc) and (5Z)-5-dodecen-1-ol (Z5-12:OH), also found in the sex pheromone gland, increase the attractiveness of the former three compounds (reviewed by Zhang et al., 2022).

Natural enemies [tachinid flies, egg parasitic wasps (*Telenomus* spp., *Anastatus* spp., *Trichogramma* spp.) and bacterial, viral and fungal entomopathogens] are described as having a significant impact on the population dynamics of *D. punctatus* in China (Chang, 1991; Chen et al., 1997; Li, 2007; Lord, 2005; Tang & Tian, 2003), in Vietnam (Bassus, 1974) and in Taiwan (Ying, 1986).

In addition to natural enemies, population changes seem influenced by climatic factors. In China, Bao et al. (2020) report a positive influence of long-term drought on outbreaks.

3.1.3 | Host range/species affected

The larvae of *D. punctatus* feed on the needles of *Pinus elliottii*, *P. luchuensis*, *P. massoniana*, *P. merkusii* and *P. tabulaeformis*, causing important damage; they can also feed on *P. armandii*, *P. bungeana*, *P. densiflora*, *P. echinata*, *P. latteri*, *P. parviflora*, *P. taeda*, *P. taiwanensis*, *P. sylvestris* var. *mongolica* and *P. thunbergii*, although its full development on these hosts is uncertain. The full list of host plants is presented in Appendix A.

3.1.4 | Intraspecific diversity

According to the revision of the genus *Dendrolimus* performed by de Lajonquière (1973), the species *D. punctatus* includes four subspecies and six forms, which show morphological differences related to either (a) the generation they belong to or (b) the geographical area within the distribution range of this species. The four subspecies are the following:

- *D. punctatus punctatus* (Walker), which is the lectotype, described from a female specimen of the second generation captured in Hong Kong,
- *D. punctatus hebes* (Walker) (=*D. punctatus tabulaeformis* Tsai & Liu), which corresponds to specimens with lighter yellow, more contrasted wing colours captured in the north of the distribution range of *D. punctatus*,
- *D. punctatus tehchangensis* Tsai and Liu (1964), typical of western Sichuan (SW China) with darker brown wing colours,
- *D. punctatus wenchanensis* Tsai & Liu, typical of the province of Yunan (SW China), with a variable paler colour

3.1.5 | Detection and identification of the pest

Are detection and identification methods available for the pest?

Yes, the pest has been clearly described, and morphological identification is possible. Molecular methods based on the whole nuclear genome and the mitochondrial genome can be implemented. The sex pheromones have been identified and are used for monitoring.

Detection

Eggs, larvae and pupae can be detected visually, especially large numbers of egg masses or larvae. Late instar larvae are large (approximately 6 cm in length). At high population density, the host can be completely defoliated. Billings (1991) described a monitoring procedure used in Vietnam based on 100 m^2 permanent survey plots visited once per generation and on 1 m^2 excrement traps beneath sample trees for estimating larval population per tree.

The sex pheromones of *D. punctatus* have been identified (review in Zhang et al., 2022), and are being used for monitoring (Zhang et al., 2003).

Pest damage can be localised and quantified by applying random forest algorithms to remote sensing data (Xu et al., 2020).

Identification

A key for the identification of all stages (in Chinese) is available (Cai & Liu, 1962). It encompasses the following species of *Dendrolimus*: *D. sibiricus*, *D. spectabilis*, *D. punctatus*, *D. superans*, *D. latipennis*, *D. kikuchi*, *D. tabulaeformis* and *D. xichangensis*. According to Cai and Liu (1962), the male adults of *D. punctatus* have a body length of 20.2–28.7 mm and a wingspan of 36.1–48.5 mm; the female adults have a body length of 18.4–29.4 mm and a wingspan of 42.8–56.7 mm. They are greyish-white, greyish-brown, yellowish-brown or blackish-brown. The eggs are 1.39 mm long and 1.13 mm wide. They are pale green, pink and purplish, to pale yellow. The larvae are greyish-black and bear setae. At the third instar, they start growing urticating hairs on the thorax. They are 38–58 mm long at the last (sixth) instar.

The complete nuclear genome has been sequenced (Zhang et al., 2020) and is accessible on GenBank-NCBI (accession number: ASM1227379v1). A mitochondrial phylogeny of six *Dendrolimus* species, including *D. punctatus*, has been proposed by Qin et al. (2019). Mitochondrion sequence data are available at GenBank, for example under accession number KJ913813.1. Additional information in GenBank includes the transcriptome of *D. punctatus*, which has also been characterised (Yang et al., 2016), and the data are deposited under accession numbers SRX1330748, SRX1332929, SRX1332930, SRX1332932 and SRX1332933. However, no protocol for molecular identification has been implemented to the best of the Panel's knowledge.

3.2 | Pest distribution

3.2.1 | Pest distribution outside the EU

D. punctatus occurs in China (Eastern China, Hong Kong, Macau), Taiwan, Vietnam, India (Manipur) and has recently spread to Japanese islands (Ishigaki and Iriomote) close to Taiwan. Figure 1 shows the global distribution of *D. punctatus*. Appendix B provides details of the global distribution based on the CABI Compendium (CABI, online) and on literature data. According to CABI (online), the northern limit of the pest's distribution is between the 32nd and 33rd parallels north.

FIGURE 1 Global distribution of *Dendrolimus punctatus* (*Source*: CABI, online accessed on 27/07/23, and literature; for details see Appendix B). The circle in the East China Sea corresponds to the Japanese islands of Ishigakijima and Iriomotejima.

3.2.2 | Pest distribution in the EU

*Is the pest present in the EU territory? If present, is the pest in a limited part of the EU or is it scarce, irregular, isolated or present infrequently? If so, the pest is considered to be not widely distributed***.**

No, *D. punctatus* is not known to be present in the EU territory.

3.3 | Regulatory status

3.3.1 | Commission implementing regulation 2019/2072

D. punctatus was identified as a pest of *Pinus thunbergii* and *P. parviflora* in a commodity risk assessment of bonsai plants from China consisting of *P. parviflora* grafted on *P. thunbergii* (EFSA PLH Panel, 2022).

3.3.2 | Hosts or species affected that are prohibited from entering the union from third countries

The list of hosts affected by *D. punctatus* and prohibited from entering the EU is shown in Table 2.

TABLE 2 List of plants, plant products and other objects that are *Dendrolimus punctatus* hosts whose introduction into the Union from certain third countries is prohibited (*Source*: Commission Implementing Regulation (EU) 2019/2072, Annex VI).

List of plants, plant products and other objects whose introduction into the union from certain third countries is prohibited			
	Description	**CN code**	**Third country, group of third countries or specific area of third country**
1.	Plants of […] *Pinus* L., […] other than fruit and seeds	ex 0602 20 20 ex 0602 20 80 ex 0602 90 41 ex 0602 90 45 ex 0602 90 46 ex 0602 90 47 ex 0602 90 50 ex 0602 90 70 ex 0602 90 99 ex 0604 20 20 ex 0604 20 40	Third countries other than Albania, Andorra, Armenia, Azerbaijan, Belarus, Bosnia and Herzegovina, Canary Islands, Faeroe Islands, Georgia, Iceland, Liechtenstein, Moldova, Monaco, Montenegro, North Macedonia, Norway, Russia (only the following parts: Central Federal District (Tsentralny federalny okrug), Northwestern Federal District (Severo-Zapadny federalny okrug), Southern Federal District (Yuzhny federalny okrug), North Caucasian Federal District (Severo-Kavkazsky federalny okrug) and Volga Federal District (Privolzhsky federalny okrug)), San Marino, Serbia, Switzerland, Türkiye, Ukraine and the United Kingdom
19.	Soil as such consisting in part of solid organic substances	ex 2530 90 00 ex 3824 99 93	Third countries other than Switzerland
20.	Growing medium as such, other than soil, consisting in whole or in part of solid organic substances, other than that composed entirely of peat or fibre of *Cocos nucifera* L., previously not used for growing of plants or for any agricultural purposes	ex 2530 10 00 ex 2530 90 00 ex 2703 00 00 ex 3101 00 00 ex 3824 99 93	Third countries other than Switzerland

D. punctatus is included in a list of pests of concern in relation to naturally or artificially dwarfed *P. parviflora* and *P. thunbergii* plants for planting from Japan (EFSA PLH Panel, 2019) in Commission Implementing Regulation (EU) 2020/1217. The regulation provides for a derogation from Article 7, point 1 of Annex VI of Implementing Regulation (EU) 2019/2072 if the plants comply with the conditions set out in Commission Implementing Regulation (EU) 2020/1217.

3.4 | Entry, establishment and spread in the EU

3.4.1 | Entry

> *Is the pest able to enter into the EU territory? If yes, identify and list the pathways***.**
>
> **Yes**, the pest can enter the EU, either as eggs, larvae or pupae in the foliage of plants for planting or cut branches, as larvae on wood with bark or as overwintering larvae in the litter of potted plants.
>
> *Comment on plants for planting as a pathway.*
>
> Plants for planting could, in principle, provide a pathway.

Annex VI of 2019/2072 prohibits the introduction of *D. punctatus* hosts (*Pinus* spp.) from countries and areas where *D. punctatus* occurs (Table 3).

TABLE 3 Potential pathways for *Dendrolimus punctatus* into the EU.

Pathways	**Life stage**	**Relevant mitigations [e.g. prohibitions (Annex VI), special requirements (Annex VII) or phytosanitary certificates (Annex XI) within Implementing Regulation 2019/2072]**
Plants for planting of *Pinus* spp.	Eggs and larvae on needles and branches, larvae and pupae on bark and branches, larvae in the litter of potted plants	2019/2072 Annex VI prohibition
Cut branches of *Pinus* spp.	Eggs and larvae on needles and branches, larvae and pupae on bark and branches	2019/2072 Annex VI prohibition
Wood with bark of host plants	Larvae on bark	-
Isolated bark of host plants	Larvae on bark	-
Soil	Overwintering larvae	2019/2072 Annex VI prohibition

Notifications of interceptions of harmful organisms began to be compiled in Europhyt in May 1994 and in TRACES in May 2020. As of 24 August 2023, there were no records of interceptions of *D. punctatus*. The related species *D. spectabilis* was intercepted in April 2018 on dwarf *P. thunbergii* imported from Japan.

The EFSA Panel on Plant Health (2022) commodity risk assessment of artificially dwarfed plants from China consisting of *P. parviflora* grafted on *P. thunbergii* estimated pest freedom from *D. punctatus* for bonsai plants following evaluation of proposed risk mitigation measures as 'almost always pest free' with the 90% uncertainty range spanning from 'pest free with some exceptional cases' to 'almost always pest free'. An Expert Knowledge Elicitation indicated, with 95% certainty, that between 9983 and 10,000 plants per 10,000 would be free from *D. punctatus*. Currently, no derogation exists.

3.4.2 | Establishment

Is the pest able to become established in the EU territory?

Yes, there are climate zones where the pest occurs in Asia that also occur in the EU, though they are limited. ***Pinus*** spp. are widespread in the EU. Although ***D. punctatus*** is known to have switched onto North American ***Pinus*** species grown in Asia, there is a lack of information regarding whether the pest could switch to ***Pinus*** species commonly grown in the EU.

Climatic mapping is the principal method for identifying areas that could provide suitable conditions for the establishment of a pest, taking key abiotic factors into account (Baker, 2002). The availability of hosts is considered in Section 3.4.2.1. Climatic factors are considered in Section 3.4.2.2.

3.4.2.1 | *EU distribution of main host plants*

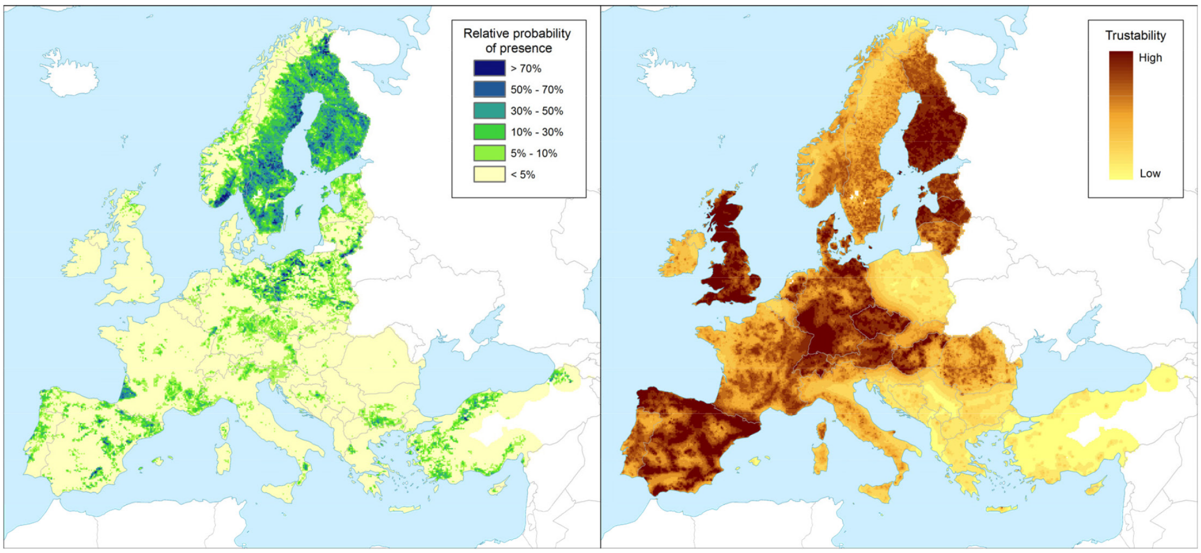

FIGURE 2 Left panel: Relative probability of the presence (RPP) of the genus *Pinus* in Europe, mapped at 100 km^2 resolution. The underlying data are from European-wide forest monitoring datasets and from national forestry inventories based on standard observation plots measuring in the order of 100 m^2. RPP represents the probability of finding at least one individual of the taxon in a standard plot placed randomly within the grid cell. For details, see Appendix C (courtesy of JRC, 2017). Right panel: Trustability of RPP. This metric expresses the strength of the underlying information in each grid cell and varies according to the spatial variability in forestry inventories. The colour scale of the trustability map is obtained by plotting the cumulative probabilities (0–1) of the underlying index (for details, see Appendix C).

The most common native hosts are *P. massoniana*, *P. merkusii*, *P. luchuensis and P. tabulaeformis*. However, in its native area, *D. punctatus* can develop on the North American pines *P. echinata*, *P. elliottii* and *P. taeda* (see Section 3.1.3). This suggests some host plasticity in the pest, possibly allowing a shift to local pine species in the EU territory, for example *P. sylvestris*, *P. nigra* and *P. maritima*. Figure 2 presents the relative probability of presence of *Pinus* species in the EU.

3.4.2.2 | *Climatic conditions affecting establishment*

The global Köppen–Geiger climate zones (Kottek et al., 2006) describe terrestrial climate in terms of average minimum winter temperatures and summer maxima, amount of precipitation and seasonality (rainfall pattern). Some climatic zones in which *D. punctatus* occurs (Dfb, Dfc, Cfa, Cfb and, marginally, BSk) are also found in the EU (Figure 3). However, only 0.5%

of the area of the 8 provinces of China where outbreaks regularly occur, corresponding to the dominant climate zone of the EU, Cfb.

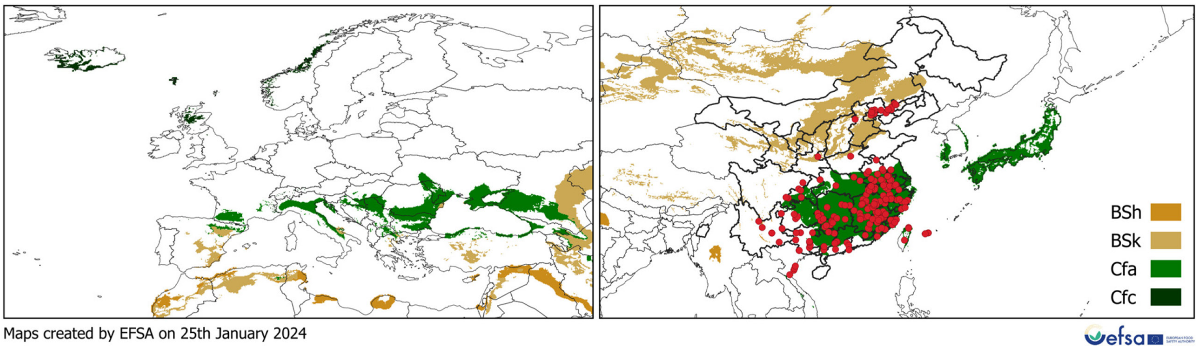

FIGURE 3 World distribution of Köppen–Geiger climate types that occur in the EU and which occur in sites where *Dendrolimus punctatus* has been reported. (Red dots represent specific coordinate locations.)

Based on data in MacLeod and Korycinska (2019), the climate types in the 11 Chinese provinces in which large annual outbreaks of *D. punctatus* occur are shown in Table 4. The provinces are Anhui, Fujian, Guangdong, Gansu, Guangxi, Heilongjiang, Hubei, Hunan, Inner Mongolia, Jiangxi and Zhejing. The climate type Cfa (humid sub-tropical) is most prevalent in provinces with large outbreaks (27.7% of the combined area of the 11 provinces). This climate type only occurs in 6.7% of the EU territory. The next most common climates in the Chinese provinces occupy over 50% of the provinces, but only 1.6% of the EU. The Cfb climate type (temperate oceanic) occurs in 0.2% of the 11 Chinese provinces, but it occupies the largest area of the EU (45.8%).

TABLE 4 Relative area (%) of climate types occurring in 11 Chinese Provinces where major outbreaks occur and the area of these climates in the EU.

Climate type	% occurrence of climate type in 11 Chinese provinces	% occurrence of climate type in EU 27
Cfa	27.7	6.7
Dwb	17.2	-
BSk	16.1	1.6
Bwk	16.1	-
Dwc	8.2	-
Cwa	7.8	-
Dwa	5.4	-
ET	0.6	1.1
Cwb	0.5	-
Cfb	0.2	45.8
Dfb	< 0.1	9.2
Aw	< 0.1	-
EF	< 0.1	-
Others	-	35.6
Sum	100	100

Because of the limited climate matching between the area of origin and the EU territory, there is some uncertainty regarding the capacity of the pest to establish in the EU.

Spread

Describe how the pest would be able to spread within the EU territory following establishment?

The pest would be able to spread either with plants for planting or by natural dispersal. Movement on pine wood with bark and contaminated soil could also facilitate spread.

Comment on plants for planting as a mechanism of spread.

Eggs, larvae or pupae could be transported with the needles of potted conifers or bare root plants, or cut branches, and overwintering larvae could travel with potted plants.

Flight

The literature provides no information regarding the flight capacity of the species. *Dendrolimus sibiricus* showed dispersal capacities of 15–50 km (EFSA PLH Panel, 2018b and references therein). However, the female wingspan of *D. sibiricus* is 64–88 mm, while the female wingspan of *D. punctatus* is smaller (43–57 mm, according to Cai & Liu, 1962), possibly permitting shorter dispersal distances by flight.

Plants for planting

If infested *Pinus* plants circulate within the EU, the pest's spread could be considerable.

3.5 | Impacts

Would the pests' introduction have an economic or environmental impact on the EU territory?

Yes, the pest would probably have an economic and environmental impact on the EU territory.

According to CABI, online, *D. punctatus* outbreaks occur in over 1 million ha each year in China (Anhui, Jiangxi, Hubei, Hunan, Zhejing, Fujian, Guangdong and Guangxi provinces). According to Bao et al. (2022), outbreaks result in substantial impacts on forest ecosystem structure, distribution and productivity. Outbreaks are also common in Vietnam (Billings, 1991). Defoliation by caterpillars may significantly reduce tree growth 1 year after defoliation (CABI, online). Ge et al. (1988) reported that volume growth was significantly reduced when the trees lost 70% of their needles. After nearly 100% defoliation, 25% of the trees died, and volume growth was reduced by 30%. *D. punctatus hebes* (=*tabulaeformis*) *is* considered a major pest for *P. tabulaeformis* in northern China, significantly reducing the growth of monocultural pine plantations during frequent outbreaks (Shao et al., 2018).

There is also considerable uncertainty over the potential impact of the pest in pine species in EU. In the native range, impact is reported only on four pine species out of the 11 species reported as hosts (see Section 3.1.3).

3.6 | Available measures and their limitations

Are there measures available to prevent pest entry, establishment, spread or impacts such that the risk becomes mitigated?

Yes, Annex VI of 2019/2072 prohibits the introduction of plants and plant products of ***Pinus*** spp. from many third countries, including countries and areas where ***D. punctatus*** occurs.

Annex VI of 2019/2072 prohibits the introduction of plants and plant products of *Pinus* spp. from many third countries, including countries and areas where *D. punctatus* occurs. EPPO (2018) suggests commodity-specific phytosanitary measures for Coniferae.

Insect parasitoids (tachinid flies, egg parasitic wasps) and viral and fungal diseases are described as exerting a strong impact on *D. punctatus* population dynamics (see Section 3.1.2). In China, several microorganisms have been successfully used against *D. punctatus*. Starting in the 1970s, the entomopathogenic fungus *Beauveria bassiana* was mass-produced, on bran or peat, in a large number of small production units throughout China (Li, 2007). The use of *B. bassiana* against *D. punctatus* constitutes a very successful biological control programme in China and has been implemented over one million ha of pine forests (Lord, 2005) A complete review is provided by Hajek and van Frankenhuyzen (2017). According to Ying (1986), a three-component mixture of locally isolated species of the fungus *Isaria farinosa*, the bacteria *Bacillus thuringiensis* and a cytoplasmic polyhedrosis virus (CPV) was used to control the pest in 1966–1971. In China in 1984–1994, 4282 ha of pine forest were treated with a CPV against *D. punctatus* with a 70%–93% control over the year (Chen et al., 1997).

3.6.1 | Identification of potential additional measures

Phytosanitary measures (prohibitions) are applied to the host genus (see Section 3.3.2). If these prohibitions stay in place, additional measures will not increase protection. Therefore, no additional measures have been identified.

3.6.1.1 | *Additional potential risk reduction options*

Given the existing prohibition, no additional risk reduction options are warranted. EPPO (2018) suggests commodity-specific phytosanitary measures for Coniferae. Trade of dwarfed plants of *Pinus* species from Japan is permitted through a derogation (Commission Implementing Regulation EU 2020/1217). Should trade of these plants from other countries be granted, the risk reduction measures that have been listed in the derogation for hosts from Japan could be considered.

3.6.1.2 | *Additional supporting measures*

Given the existing prohibition and requirements for the derogation from Japan, no additional supporting measures have been identified.

3.7 | Uncertainty

There is no information regarding whether *D. punctatus* could feed and develop on conifer species commonly occurring in the EU. Nevertheless, it expanded its host range to American species of pine grown in Asia. This is considered as a key uncertainty.

4 | CONCLUSIONS

Notwithstanding the uncertainties regarding establishment, *D. punctatus* satisfies all the criteria that are within the remit of EFSA to assess for it to be regarded as a potential Union quarantine pest (Table 5).

TABLE 5 The Panel's conclusions on the pest categorisation criteria defined in Regulation (EU) 2016/2031 on protective measures against pests of plants (the number of the relevant sections of the pest categorisation is shown in brackets in the first column).

Criterion of pest categorisation	Panel's conclusions against criterion in regulation (EU) 2016/2031 regarding union quarantine pest	Key uncertainties
Identity of the pest (Section 3.1)	The identity of the species is established and *Dendrolimus punctatus* (Walker) is the accepted scientific name and authority	
Absence/presence of the pest in the EU (Section 3.2)	*D. punctatus* is not known to be present in the EU territory	
Pest potential for entry, establishment and spread in the EU (Section 3.4)	*D. punctatus* could enter the EU on host plants for planting and plant products such as cut branches or wood with bark. However, Annex VI of 2019/2072 prohibits the introduction of *D. punctatus* hosts (*Pinus* spp.) from countries and areas where *D. punctatus* occurs. There are climate zones where the pest occurs in Asia that also occur in the EU, though they are limited. There is uncertainty regarding its ability to fully develop on *Pinus* species growing in the EU, as such there is uncertainty over its establishment The pest would be able to spread either with plants for planting or by natural dispersal	There is a lack of information regarding whether *D. punctatus* could feed and develop on *Pinus* species commonly grown in the EU. Nevertheless, it expanded its host range to American species of pine grown in Asia. This uncertainty affects establishment
Potential for consequences in the EU (Section 3.5)	*D. punctatus* is described as a pest of conifer forests in China, Taiwan, Vietnam and India. However, reports of damage are to *Pinus* species not commonly grown in EU forestry. Impacts in the EU would depend on whether *D. punctatus* could feed and develop on EU *Pinus* species	There is a lack of information regarding whether *D. punctatus* could feed and develop on *Pinus* species commonly grown in the EU
Available measures (Section 3.6)	Annex VI of 2019/2072 prohibits the introduction of plants and plant products of *D. punctatus* host genera from many third countries, including countries and areas where *D. punctatus* occurs	

TABLE 5 (Continued)

Criterion of pest categorisation	Panel's conclusions against criterion in regulation (EU) 2016/2031 regarding union quarantine pest	Key uncertainties
Conclusion (Section 4)	*D. punctatus* satisfies all the criteria that are within the remit of EFSA to assess for it to be regarded as a potential Union quarantine pest. Whether the *Pinus* in Europe could act as hosts is unknown but is fundamental, affecting the criteria of establishment and magnitude of impact	There is a lack of information regarding whether *D. punctatus* could feed and develop on *Pinus* species commonly grown in the EU
Aspects of assessment to focus on/ scenarios to address in future if appropriate	It would be useful to find out whether *D. punctatus* could feed, reproduce and cause impact on *Pinus* species either commonly used in EU forestry or naturally occurring in the EU. Such information would reduce the key uncertainty within this pest categorisation	

ABBREVIATIONS

EPPO European and Mediterranean Plant Protection Organization
FAO Food and Agriculture Organization
IPPC International Plant Protection Convention
ISPM International Standards for Phytosanitary Measures
MS Member State
PLH EFSA Panel on Plant Health
PZ protected zone
TFEU Treaty on the Functioning of the European Union
ToR Terms of Reference

GLOSSARY

Containment (of a pest) application of phytosanitary measures in and around an infested area to prevent spread of a pest (FAO, 2023)
Control (of a pest) suppression, containment or eradication of a pest population (FAO, 2023)
Entry (of a pest) movement of a pest into an area where it is not yet present, or present but not widely distributed and being officially controlled (FAO, 2023)
Eradication (of a pest) application of phytosanitary measures to eliminate a pest from an area (FAO, 2023)
Establishment (of a pest) perpetuation, for the foreseeable future, of a pest within an area after entry (FAO, 2023)
Greenhouse a walk-in, static, closed place of crop production with a usually translucent outer shell, which allows controlled exchange of material and energy with the surroundings and prevents release of plant protection products (PPPs) into the environment.
Hitchhiker an organism sheltering or transported accidentally via inanimate pathways including with machinery, shipping containers and vehicles; such organisms are also known as contaminating pests or stowaways (Toy & Newfield, 2010).
Impact (of a pest) the impact of the pest on the crop output and quality and on the environment in the occupied spatial units
Introduction (of a pest) the entry of a pest resulting in its establishment (FAO, 2023)
Pathway any means that allows the entry or spread of a pest (FAO, 2023)
Phytosanitary measures any legislation, regulation or official procedure having the purpose to prevent the introduction or spread of quarantine pests, or to limit the economic impact of regulated non-quarantine pests (FAO, 2023)
Quarantine pest a pest of potential economic importance to the area endangered thereby and not yet present there, or present but not widely distributed and being officially controlled (FAO, 2023)
Risk reduction option (RRO) a measure acting on pest introduction and/or pest spread and/or the magnitude of the biological impact of the pest should the pest be present. A RRO may become a phytosanitary measure, action or procedure according to the decision of the risk manager
Spread (of a pest) expansion of the geographical distribution of a pest within an area (FAO, 2023)

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CONFLICT OF INTEREST

If you wish to access the declaration of interests of any expert contributing to an EFSA scientific assessment, please contact interestmanagement@efsa.europa.eu.

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NOTE

This pest categorisation on *Dendrolimus punctatus* was first adopted by the Plant Health Panel on 30 November 2023. After this date, while working on the categorisation of other *Dendrolimus* species, the Panel found information relevant to subspecies of *D. punctatus*. Therefore, the adopted pest categorisation on *D. punctatus* was updated with taxonomical and biological information on the subspecies (*D. punctatus punctatus, D. punctatus hebes, D. punctatus tehchangensis* and *D. punctatus wenchanensis*), and re-adopted by the Plant Health Panel on 1 February 2024.

REFERENCES

Baker, R. H. A. (2002). Predicting the limits to the potential distribution of alien crop pests. In G. J. Hallman & C. P. Schwalbe (Eds.), *Invasive arthropods in agriculture: Problems and solutions* (pp. 207–241). Science Publishers Inc.

Bao, Y., Han, A., Zhang, J., Liu, X., Tong, Z., & Bao, Y. (2022). Contribution of the synergistic interaction between topography and climate variables to pine caterpillar (*Dendrolimus* spp.) outbreaks in Shandong Province, China. *Agricultural and Forest Meteorology*, *322*, 109023.

Bao, Y., Na, L., Han, A., Guna, A., Wang, F., Liu, X., … Bao, Y. (2020). Drought drives the pine caterpillars (*Dendrolimus* spp.) outbreaks and their prediction under different RCPs scenarios: A case study of Shandong Province, China. *Forest Ecology and Management*, *475*, 118446.

Bassus, W. (1974). On the biology and ecology of *Dendrolimus punctatus* Walk. (Lepidoptera: Lasiocampidae), the most important pest of pines in the Democratic Republic of Vietnam. *Archiv fur Phytopathologie und Pflanzenschutz*, *10*(1), 61–69. [From CAB direct; only abstract available].

Billings, R. F. (1991). The pine caterpillar *Dendrolimus punctatus* in Vietnam; recommendations for integrated pest management. *Forest Ecology and Management*, *39*(1–4), 97–106.

Bossard, M., Feranec, J., & Otahel, J. (2000). *CORINE land cover technical guide – Addendum 2000*. Tech. Rep. 40, European Environment Agency. https://www.eea.europa.eu/ds_resolveuid/032TFUPGVR

Büttner, G., Kosztra, B., Maucha, G., & Pataki, R. (2012). *Implementation and achievements of CLC2006*. (Technical report). European Environment Agency. http://www.eea.europa.eu/ds_resolveuid/GQ4JECM8TB

CABI. (online). *Dendrolimus punctatus (Masson pine caterpillar)*. CABI Compendium, CABI International. Available online: https://doi.org/10.1079/cabicompendium.18368

Cai, B. H., & Liu, Y. Q. (1962). A study of the genus *Dendrolimus* (Lasiocampidae) of China with descriptions of two new species and one new subspecies. *Acta Zoologica Sinica*, *11*, 237–252. (In Chinese; relevant parts Google-translated).

Chang, Y. C. (1991). Integrated pest management of several forest defoliators in Taiwan. *Forest Ecology and Management*, *39*, 65–72.

Chang, Y. C., & Sun, J. C. (1984). Survey on insect pests of economic tree (or bamboo) species in Taiwan. (V) The important insect pests of *Pinus* species. *Quarterly Journal of Chinese Forestry*, *17*, 37–45.

Chen, S. W., Chen, E. H., Suo, Q. H., Duan, Z. R., & Hu, G. H. (1997). *Dendrolimus* virus resources and their application in Yunnan. *Chinese Journal of Biological Control*, *13*, 122–124. (In Chinese; English abstract).

Dai, Q.-Y., Gao, Q., Wu, C.-S., Chesters, D., Zhu, C.-D., & Zhang, A.-B. (2012). Phylogenetic reconstruction and DNA barcoding for closely related pine moth species (*Dendrolimus*) in China with multiple gene markers. *PLoS One*, *7*(4), e32544. https://doi.org/10.1371/journal.pone.0032544

de Lajonquière, Y. (1973). Genres *Dendrolimus* Germar, *Hoenimnema*, n. gen., *Cyclophragma* Turner. 10e Contribution a l'Étude des Lasiocampides. *Annales de la Société Entomologique de France (N.S.)*, *9*(3), 509–592. https://doi.org/10.1080/21686351.1973.12278935

de Rigo, D. (2012). Semantic array programming for environmental modelling: Application of the Mastrave library. In R. Seppelt, A. A. Voinov, S. Lange, & D. Bankamp (Eds.), *International Environmental Modelling and Software Society (iEMSs) 2012 international congress on environmental modelling and software – Managing resources of a limited planet: Pathways and visions under uncertainty, sixth Biennial meeting*, by the Civil and Environmental Engineering at BYU ScholarsArchive (pp. 1167–1176). http://scholarsarchive.byu.edu/iemssconference/2012/Stream-B/69

de Rigo, D., Caudullo, G., Busetto, L., & San-Miguel-Ayanz, J. (2014). Supporting EFSA assessment of the EU environmental suitability for exotic forestry pests: Final report. *EFSA Supporting Publications*, *11*(3), 434E.

de Rigo, D., Caudullo, G., Houston Durrant, T., & San-Miguel-Ayanz, J. (2016). The European atlas of forest tree species: Modelling, data and information on forest tree species. In J. San-Miguel-Ayanz, D. de Rigo, G. Caudullo, T. Houston Durrant, & A. Mauri (Eds.), *European atlas of forest tree species* (pp. 40–45). Publication Office of the European Union. https://w3id.org/mtv/FISE-Comm/v01/e01aa69

de Rigo, D., Caudullo, G., San-Miguel-Ayanz, J., & Barredo, J. I. (2017). *Robust modelling of the impacts of climate change on the habitat suitability of forest tree species*. Publication Office of the European Union. https://doi.org/10.2760/296501

Easton, E. R., & Pun, W. (1996). New records of moths from Macau, Southeast China. *Tropical Lepidoptera*, *7*(2), 113–118.

EFSA PLH Panel (EFSA Panel on Plant Health), Bragard, C., Baptista, P., Chatzivassiliou, E., Di Serio, F., Jaques Miret, J. A., Justesen, A. F., MacLeod, A., Magnusson, C. S., Milonas, P., Navas-Cortes, J. A., Parnell, S., Potting, R., Reignault, P. L., Stefani, E., Thulke, H.-H., Van der Werf, W., Vicent Civera, A., Yuen, J., … Gonthier, P. (2022). Scientific opinion on the commodity risk assessment of bonsai plants from China consisting of *Pinus parviflora* grafted on *Pinus thunbergii*. *EFSA Journal*, *20*(2), 7077. https://doi.org/10.2903/j.efsa.2022.7077

EFSA PLH Panel (EFSA Panel on Plant Health), Bragard, C., Dehnen-Schmutz, K., DiSerio, F., Gonthier, P., Jacques, M.-A., Jaques Miret, J. A., Justesen, A. F., MacLeod, A., Magnusson, C. S., Milonas, P., Navas-Cortes, J. A., Parnell, S., Reignault, P. L., Thulke, H.-H., Van der Werf, W., Civera, A. V., Yuen, J., ZappalaL, B. A., … Potting, R. (2019). Scientific opinion on the commodity risk assessment of black pine (*Pinus thunbergii* Parl.) bonsai from Japan. *EFSA Journal*, *17*(5), 5667. https://doi.org/10.2903/j.efsa.2019.5667

EFSA PLH Panel (EFSA Panel on Plant Health), Jeger, M., Bragard, C., Caffier, D., Candresse, T., Chatzivassiliou, E., Dehnen-Schmutz, K., Gregoire, J.-C., Jaques Miret, J. A., MacLeod, A., Navajas Navarro, M., Niere, B., Parnell, S., Potting, R., Rafoss, T., Rossi, V., Urek, G., Van Bruggen, A., Van Der Werf, W., … Gilioli, G. (2018a). Guidance on quantitative pest risk assessment. *EFSA Journal*, *16*(8), 5350. https://doi.org/10.2903/j.efsa.2018.5350

EFSA PLH Panel (EFSA Panel on Plant Health), Jeger, M., Bragard, C., Caffier, D., Candresse, T., Chatzivassiliou, E., Dehnen-Schmutz, K., Gilioli, G., Jaques Miret, J. A., MacLeod, A., Navajas Navarro, M., Niere, B., Parnell, S., Potting, R., Rafoss, T., Rossi, V., Urek, G., Van Bruggen, A., Van der Werf, W., … Grégoire, J.-C. (2018b). Scientific opinion on pest categorisation of *Dendrolimus sibiricus*. *EFSA Journal*, *16*(6), 5301. https://doi.org/10.2903/j.efsa.2018.5301

EFSA Scientific Committee, Hardy, A., Benford, D., Halldorsson, T., Jeger, M. J., Knutsen, H. K., More, S., Naegeli, H., Noteborn, H., Ockleford, C., Ricci, A., Rychen, G., Schlatter, J. R., Silano, V., Solecki, R., Turck, D., Benfenati, E., Chaudhry, Q. M., Craig, P., … Younes, M. (2017). Scientific opinion on the guidance on the use of the weight of evidence approach in scientific assessments. *EFSA Journal*, *15*(8), 4971. https://doi.org/10.2903/j.efsa.2017.4971

EPPO (European and Mediterranean Plant Protection Organization). (2018). Commodity-specific phytosanitary measures. PM 8/2 (3) Coniferae. *EPPO Bulletin*, *48*(3), 463–494.

EPPO (European and Mediterranean Plant Protection Organization). (2019). *EPPO codes*. https://www.eppo.int/RESOURCES/eppo_databases/eppo_codes

EPPO (European and Mediterranean Plant Protection Organization). (online). *EPPO global database*. https://gd.eppo.int

EUFGIS (European Information System on Forest Genetic Resources). (online). *EUFGIS database*. http://portal.eufgis.org

FAO (Food and Agriculture Organization of the United Nations). (2013). *ISPM (International Standards for Phytosanitary Measures) 11 – Pest risk analysis for quarantine pests*. FAO. https://www.ippc.int/sites/default/files/documents/20140512/ispm_11_2013_en_2014-04-30_201405121523-494.65%20KB.pdf

FAO (Food and Agriculture Organization of the United Nations). (2023). *ISPM (International Standards for Phytosanitary Measures) No 5. Glossary of phytosanitary terms*. FAO, Rome, 40 pp. Available online: https://assets.ippc.int/static/media/files/publication/en/2023/07/ISPM_05_2023_En_Glossary_PostCPM-17_2023-07-12_Fixed.pdf

Ge, Q. J., Guan, L. Q., Li, Z. Z., Xue, X. Q., & Zhou, X. G. (1988). A study on the control threshold of *Dendrolimus punctatus* Walker. *Journal of Nanjing Forestry University*, *3*, 94–100. (In Chinese with an English abstract).

Griessinger, D., & Roy, A.-S. (2015). *EPPO codes: A brief description*. https://www.eppo.int/media/uploaded_images/RESOURCES/eppo_databases/A4_EPPO_Codes_2018.pdf

Hajek, A. E., & van Frankenhuyzen, K. (2017). Chapter 21. Use of entomopathogens against forest pests. In L. A. Lacey (Ed.), *Microbial control of insect and mite pests. From theory to practice* (pp. 313–330). Elsevier.

Hiederer, R., Houston Durrant, T., Granke, O., Lambotte, M., Lorenz, M., Mignon, B., & Mues, V. (2007). *Forest focus monitoring database system – Validation methodology. Vol. EUR 23020 EN of EUR – Scientific and technical research*. Office for Official Publications of the European Communities. https://doi.org/10.2788/51364

Hiederer, R., Houston Durrant, T., & Micheli, E. (2011). *Evaluation of BioSoil demonstration project – Soil data analysis. Vol. 24729 of EUR – Scientific and technical research*. Publications Office of the European Union. https://doi.org/10.2788/56105

Hou, T. Q. (1987). *The pine caterpillars in China*. Science Press.

Houston Durrant, T., & Hiederer, R. (2009). Applying quality assurance procedures to environmental monitoring data: A case study. *Journal of Environmental Monitoring*, *11*(4), 774–781. https://doi.org/10.1039/b818274b

Houston Durrant, T., San-Miguel-Ayanz, J., Schulte, E., & Suarez Meyer, A. (2011). *Evaluation of BioSoil demonstration project: Forest biodiversity – Analysis of biodiversity module. Vol. 24777 of EUR – Scientific and technical research*. Publications Office of the European Union. https://doi.org/10.2788/84823

Huang, L., Xue, F., Wang, G., Han, R., & Ge, F. (2005). Photoperiodic response of diapause induction in the pine caterpillar, *Dendrolimus punctatus*. *Entomologia Experimentalis et Applicata*, *117*(2), 127–133.

Huang, L. L., Wang, G. H., He, Z., & Ge, F. (2008). Effect of pine foliage damage on the incidence of larval diapause in the pine caterpillar *Dendrolimus punctatus* (Lepidoptera: Lasiocampidae). *Insect Science*, *15*(5), 441–445.

INRA, online. *INRA, Biogeco, EvolTree*. GD^2 database. http://gd2.pierroton.inra.fr

Kong, X.-B., Liu, K.-W., Wang, H.-B., Zhang, S.-F., & Zhang, Z. (2012). Identification and behavioral evaluation of sex pheromone components of the Chinese pine caterpillar moth, *Dendrolimus tabulaeformis*. *PLoS One*, *7*(3), e33381. https://doi.org/10.1371/journal.pone.0033381

Kononov, A., Ustyantsev, K., Wang, B., Mastro, V. C., Fet, V., Blinov, A., & Baranchikov, Y. (2016). Genetic diversity among eight *Dendrolimus* species in Eurasia (Lepidoptera: Lasiocampidae) inferred from mitochondrial COI and COII, and nuclear ITS2 markers. *BMC Genetics*, *17*, 173–182.

Kottek, M., Grieser, J., Beck, C., Rudolf, B., & Rubel, F. (2006). World map of the Köppen_Geiger climate classification updated. *Meteorologische Zeitschrift*, *15*, 259–263. https://doi.org/10.1127/0941-2948/2006/0130

Li, J., Jin, Q., Zhu, G. P., Jiang, C., & Zhang, A. B. (2019). Phylogeography of *Dendrolimus punctatus* (Lepidoptera: Lasiocampidae): Population differentiation and last glacial maximum survival. *Ecology and Evolution*, *9*(13), 7480–7496. https://doi.org/10.1002/ece3.5278

Li, Z. (2007). *Beauveria bassiana* for pine caterpillar management in the People's Republic of China. In C. Vincent, M. S. Goettel, & G. Lazarovits (Eds.), *Biological control: A global perspective* (pp. 300–310). CAB International.

Lord, J. C. (2005). From Metchnikoff to Monsanto and beyond: The path of microbial control. *Journal of Invertebrate Pathology*, *89*(1), 19–29.

Luo, D., Lai, M., Xu, C., Shi, H., & Liu, X. (2018). Life history traits in a capital breeding pine caterpillar: Effect of host species and needle age. *BMC Ecology*, *18*, 1–8.

MacLeod, A., & Korycinska, A. (2019). Detailing Köppen–Geiger climate zones at sub-national to continental scale: A resource for pest risk analysis. *EPPO Bulletin*, *49*(1), 73–82.

Qian, G., Song, X., Sun, J., Zhang, S., Zhou, X., Zhang, G., Zou, Y., Fang, G., Zhang, Z., Yan, P., & Bi, S. (2020). Prediction of peak occurrence of *Dendrolimus punctatus* larvae based on Bayes discriminant method. *Entomological Research*, *50*, 393–401.

Qi, X., Liu, J., Chen, G., & Yu, K. (2010). Studies on monitoring of *Dendrolimus punctatus* damage with MODIS data. *Journal of Southwest Forestry University*, 30(1), 42–54.

Qin, J., Li, J., Gao, Q., Wilson, J. J., & Zhang, A. B. (2019). Mitochondrial phylogeny and comparative mitogenomics of closely related pine moth pests (Lepidoptera: *Dendrolimus*). *PeerJ*, *7*, e7317. https://doi.org/10.7717/peerj.7317

Quang, D. N., Thu, P. Q., Chi, N. M., Binh, L. V., Thong, N. Q., Thu, N. H., Nguyen, V. D., & Dell, B. (2021). Management of needle-eating caterpillars associated with *Pinus massoniana* and *P. merkusii* in Vietnam. *Forests*, *12*(11), 1610.

San-Miguel-Ayanz, J. (2016). The European Union Forest strategy and the forest information system for Europe. In J. San-Miguel-Ayanz, D. de Rigo, G. Caudullo, T. Houston Durrant, & A. Mauri (Eds.), *European atlas of Forest tree species*. Publication Office of the European Union. https://w3id.org/mtv/FISE-Comm/v01/e012228

San-Miguel-Ayanz, J., de Rigo, D., Caudullo, G., Houston Durrant, T., & Mauri, A. (Eds.). (2016). *European atlas of forest tree species*. Publication Office of the European Union. https://w3id.org/mtv/FISE-Comm/v01

Sayers, E. W., Cavanaugh, M., Clark, K., Ostell, J., Pruitt, K. D., & Karsch-Mizrachi, I. (2020). Genbank. *Nucleic Acids Research*, 48, D84–D86. https://doi.org/10.1093/nar/gkz956

Shao, Y., Feng, Y., Tian, B., Wang, T., He, Y., & Zong, S. (2018). Cold hardiness of larvae of *Dendrolimus tabulaeformis* (Lepidoptera: Lasiocampidae) at different stages during the overwintering period. *European Journal of Entomology*, *115*, 198–207. https://doi.org/10.14411/eje.2018.018

Tanaka, E., Watabiki, D., Yoshimatsu, S. I., & Toguchi, A. (2020). Discovery of the masson pine moth, *Dendrolimus punctatus*, from Japan with taxonomic notes on *D. superans*, *D. spectabilis*, and *D. okinawanus* Lepidoptera: Lasiocampidae. *Japanese Journal of Applied Entomology and Zoology*, *64*, 27–36.

Tang, W., & Tian, Y. (2003). Transgenic loblolly pine (*Pinus taeda* L.) plants expressing a modified δ-endotoxin gene of *Bacillus thuringiensis* with enhanced resistance to *Dendrolimus punctatus* Walker and *Crypyothelea formosicola* Staud. *Journal of Experimental Botany*, *54*(383), 835–844.

Tian, W. Y., & Xu, H. C. (2012). The prediction model of *Dendrolimus punctatus* Walker in coastal shelterbelt of Zhejiang. *Huanjing Kunchong Xuebao*, *34*, 401–406.

Toy, S. J., & Newfield, M. J. (2010). The accidental introduction of invasive animals as hitchhikers through inanimate pathways: A New Zealand perspective. *Revue scientifique et technique (International Office of Epizootics)*, *29*, 123–133.

Tsai, P. H., & Liu, Y. C. (1962). Study of the genus *Dendrolimus* (Lasiocampidae) of China with descriptions of two new species and one new subspecies. *Acta Entomologica Sinica*, *11*(3), 237–252.

Tsai, P. H., & Liu, Y. C. (1964). A study of the genus *Dendrolimus* (Lasiocampidae) from southwest China with descriptions of three new species and three new subspecies. *Acta Entomologica Sinica*, *13*(2), 240–245.

Wang, G., Liu, X., Ren, Q., & Hu, Y. (2008). Content variation of secondary metabolites in damaged *Pinus massoniana* needles and its effect on the growth and development of *Dendrolimus punctatus*. *Acta Agriculturae Universitatis Jiangxiensis*, *30*(4), 581–585.

Xu YanXi, X. Y., Sun XuGen, S. X., Han RuiDong, H. R., & He Zhong, H. Z. (2006). Parasitoids of *Dendrolimus punctatus* in China. *Chinese Journal of Applied Entomology*, 43, 767–773.

Xu, Z., Huang, X., Lin, L., Wang, Q., Liu, J., Yu, K., & Chen, C. (2020). BP neural networks and random forest models to detect damage by *Dendrolimus punctatus* Walker. *Journal of Forestry Research*, *31*, 107–121.

Yang, C. H., Yang, P. C., Li, J., Yang, F., & Zhang, A. B. (2016). Transcriptome characterization of *Dendrolimus punctatus* and expression profiles at different developmental stages. *PLoS One*, *11*(8), e0161667.

Yang, Y. L. (1971). *The pine caterpillar (Dendrolimus punctatus Walker)*. Bulletin of Taiwan Forestry Research Institute.

Ying, S.-L. (1986). A decade of successfull control of pine caterpillar, *Dendrolimus punctatus* walker (Lepidoptera: Lasiocampidae), by microbial agents. *Forest Ecology and Management*, *15*(1), 69–74.

Zhang, A. B., Tan, S. J., Gao, W., Li, D. M., Tu, J. B., Wang, R., Hao, Q. A., Chen, L. S., & Chen, L. M. (2001). Monitoring of *Dendrolimus punctatus* with synthetic sex pheromone. *Entomological Knowledge*, *38*(3), 211–214.

Zhang, A. B., Wang, Z. J., Tan, S. J., & Li, D. M. (2003). Monitoring the masson pine moth, *Dendrolimus punctatus* (Walker)(Lepidoptera: Lasiocampidae) with synthetic sex pheromone-baited traps in Qianshan County, China. *Applied Entomology and Zoology*, *38*(2), 177–186.

Zhang, N., Wang, Y., & Zhang, Y. (2020). Extraction of tree crowns damaged by *Dendrolimus tabulaeformis* Tsai et Liu via spectral-spatial classification using UAV-based hyperspectral images. *Plant Methods*, *16*, 135. https://doi.org/10.1186/s13007-020-00678-2

Zhang, L. L., Li, Z. Y., Li, H. L., Han, R. D., & Zhao, Y. L. (2005). *Influences of different damaged pines on growth and development of pine caterpillar larvae*. *Journal of Beijing Forestry University*, *27*(6), 83–88.

Zhang, S., Kong, X., & Zhang, Z. (2022). Research progress on the *Dendrolimus* spp. pheromone: From identification to molecular recognition., *10*, 829826. https://doi.org/10.3389/fcell.2022.829826

Zhang, S., Shen, S., Peng, J., Zhou, X., Kong, X., Ren, P., Liu, F., Han, L., Zhan, S., Huang, Y., & Zhang, Z. (2020). Chromosome-level genome assembly of an important pine defoliator, *Dendrolimus punctatus* (Lepidoptera; Lasiocampidae). *Molecular Ecology Resources*, *20*(4), 1023–1037.

Zhang, S., Zhang, Z., Kong, X., & Wang, H. (2013). Sexual dimorphism in antennal morphology and sensilla ultrastructure of *Dendrolimus tabulaeformis* Tsai et Liu (Lepidoptera: Lasiocampidae). *Microscopy Research and Technique*, *76*, 50–57.

Zhang, S. F., Zhang, Z., Kong, X. B., & Wang, H. B. (2014). Molecular characterization and phylogenetic analysis of three odorant binding protein gene transcripts in *Dendrolimus* species (Lepidoptera: Lasiocampidae). *Insect Science*, *21*, 597–608.

Zhao, Q. S., Wu, W. B., Lu, G. P., Yuan, X., Li, S. K., & Jiang, J. C. (1992). Hybridization experiments with two species of *Dendrolimus*. *Acta Entomologica Sinica*, *35*(1), 29–32. https://doi.org/10.1016/j.chnaes.2014.12.007

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APPENDIX A

Dendrolimus punctatus host plants/species affected

Host status	Host name	Native continent	Common name	Damage reported	References[a]
Cultivated hosts	*Pinus armandii*	Asia	Armand pine		Zhang et al. (2013)
	Pinus bungeana	Asia	Lace bark pine		Zhang et al. (2013)
	Pinus caribaea	Caribbean	Caribbean Pine		Billings (1991)
	Pinus densiflora	Asia	Japanese umbrella pine		Luo et al. (2018) Zhang et al. (2013)
	Pinus echinata	North America	Shortleaf pine		CABI (online) Chang and Sun (1984)
	Pinus elliottii	North America	Slash pine	+	Easton and Pun (1996) Ying (1986) Luo et al. (2018) Zhang et al. (2003)
	Pinus fenzeliana	Asia			Qian et al. (2020)
	Pinus kesiya	Asia	Khasi pine		Billings (1991)
	Pinus latteri	Asia	Tenasserim pine		CABI (online) Tian and Xu (2012)
	Pinus luchuensis	Asia	Luchu pine	+	Ying (1986)
	Pinus massoniana[b]	Asia	Masson pine[b]	+	Easton and Pun (1996) Huang et al. (2005, 2008) Quang et al. (2021) Qi et al. (2010) Wang et al. (2008) in CABI (online) Xu et al. (2006) in CABI (online) Ying (1986) Zhang et al. (2005) in CABI (online) Yang et al. (2016)
	Pinus merkusii	Asia	Tenasserim pine	+	Bassus (1974) Billings (1991) Quang et al. (2021)
	Pinus morrisonicola	Asia			Chang and Sun (1984)
	Pinus oocarpa	Central and North America	Mexican yellow pine		Billings (1991)
	Pinus parviflora	Asia	Japanese white pine		CABI (online)
	Pinus rigida	North America			Qian et al. (2020)
	Pinus sylvestris var. mongolica	Asia	–		Kong et al. (2012) Zhang et al. (2014)
	Pinus tabulaefomis	Asia	Chinese pine	+	Zhang et al. (2013, 2020)
	Pinus taeda[2]	North America	Loblolly pine		CABI (online) Luo et al. (2018)
	Pinus taiwanensis	Asia	Taiwan pine		CABI (online) Yang (1971)
	Pinus thunbergii	Asia	Japanese black pine		CABI (online) Luo et al. (2018)

[a]CABI (online) when no direct reference.
[b]Industrially planted in the EU (north-western France).

APPENDIX B

Distribution of *Dendrolimus punctatus*

Region	Country	Sub-national (e.g. state)	Status	Reference
North America			No records, presumed absent	
Central America			No records, presumed absent	
Caribbean			No records, presumed absent	
South America			No records, presumed absent	
EU (27)			No records, presumed absent	
Other Europe			No records, presumed absent	
Africa			No records, presumed absent	
Asia	China	Anhui	Present	Cai and Liu (1962)
		Beijing	Present	Zhang et al. (2001)
		Fujian	Present	Cai and Liu (1962)
		Guangdong	Present	Cai and Liu (1962)
		Guangxi	Present	Cai and Liu (1962)
		Guizhou	Present	Cai and Liu (1962)
		Hainan	Present	Cai and Liu (1962)
		Hebei	Present	Li et al. (2019)
		Henan	Present	Cai and Liu (1962)
		Hong Kong	Present	Cai and Liu (1962)
		Hubei	Present	Cai and Liu (1962)
		Hunan	Present	Cai and Liu (1962)
		Jiangsu	Present	Cai and Liu (1962)
		Jiangxi	Present	Cai and Liu (1962)
		Shaanxi	Present	Hou (1987) in CABI (online)
		Sichuan	Present	Cai and Liu (1962)
		Yunnan	Present, localised	Cai and Liu (1962)
		Zhejiang	Present	Cai and Liu (1962)
		Macau	Present	Easton and Pun (1996)
	India	Manipur	Present	CABI (online)
	Japan	Ishigaki Island Iriomote Island	Present Present	Tanaka et al. (2020) Tanaka et al. (2020)
	Taiwan		Present	Cai and Liu (1962) Chang (1991) Ying (1986)
	Vietnam		Present	Bassus (1974) Billings (1991) Quang et al. (2021)
Oceania			No records, presumed absent	

APPENDIX C

Methodological notes on Figure 2

The relative probability of presence (RPP) reported here and in the European Atlas of Forest Tree Species (de Rigo et al., 2016; San-Miguel-Ayanz et al., 2016) is the probability of a species, and sometimes a genus, occurring in a given spatial unit (de Rigo et al., 2017). The maps of RPP are produced by spatial multi-scale frequency analysis (C-SMFA) (de Rigo et al., 2014, 2016) of species presence data reported in geolocated plots by different forest inventories.

Geolocated plot databases

The RPP models rely on five geo-databases that provide presence/absence data for tree species and genera (de Rigo et al., 2014, 2016, 2017). The databases report observations made inside geo-localised sample plots positioned in a forested area, but do not provide information about the plot size or consistent quantitative information about the recorded species beyond presence/absence.

The harmonisation of these datasets was performed as activity within the research project at the origin of the European Atlas of Forest Tree Species (de Rigo et al., 2016; San-Miguel-Ayanz, 2016; San-Miguel-Ayanz et al., 2016). All datasets were harmonised to an INSPIRE-compliant geospatial grid, with a spatial resolution of 1 km^2 pixel size, using the ETRS89 Lambert Azimuthal Equal-Area as geospatial projection (EPSG: 3035, http://spatialreference.org/ref/epsg/etrs89-etrs-laea/).

European National Forestry Inventories database: This dataset derived from National Forest Inventory data and provides information on the presence/absence of forest tree species in approximately 375,000 sample points with a spatial resolution of 1 km^2/pixel, covering 21 European countries (de Rigo et al., 2014, 2016).

Forest Focus/Monitoring data set: This project is a Community scheme for harmonised long-term monitoring of air pollution effects in European forest ecosystems, normed by EC Regulation No. 2152/2003.[2] Under this scheme, the monitoring is carried out by participating countries on the basis of a systematic network of observation points (Level I) and a network of observation plots for intensive and continuous monitoring (Level II). For managing the data, the JRC implemented a Forest Focus Monitoring Database System, from which the data used in this project were taken (Hiederer et al., 2007; Houston Durrant & Hiederer, 2009). The complete Forest Focus dataset covers 30 European Countries with more than 8600 sample points.

BioSoil data set: This data set was produced by one of a number of demonstration studies initiated in response to the 'Forest Focus' Regulation (EC) No. 2152/2003 mentioned above. The aim of the BioSoil project was to provide harmonised soil and forest biodiversity data. It comprised two modules: a Soil Module (Hiederer et al., 2011) and a Biodiversity Module (Houston Durrant et al., 2011). The dataset used in the C-SMFA RPP model came from the Biodiversity module, in which plant species from both the tree layer and the ground vegetation layer were recorded for more than 3300 sample points in 19 European Countries.

European Information System on Forest Genetic Resources (EUFGIS) is a smaller geo-database that provides information on tree species composition in over 3200 forest plots in 34 European countries. The plots are part of a network of forest stands managed for the genetic conservation of one or more target tree species. Hence, the plots represent the natural environment to which the target tree species are adapted (EEUFGIS, online).

Georeferenced Data on Genetic Diversity (GD^2) is a smaller geo-database as well. It provides information about a 63 species that are of interest for genetic conservation. It counts 6254 forest plots that are located in stands of natural populations that are traditionally analysed in genetic surveys. While this database covers fewer species than the others, it does covers 66 countries in Europe, North Africa and the Middle East, making it the data set with the largest geographic extent (INRA, online).

Modelling methodology

For modelling, the data were harmonised in order to have the same spatial resolution (1 km^2) and filtered to a study area that comprises 36 countries in the European continent. The density of field observations varies greatly throughout the study area, and large areas are poorly covered by the plot databases. A low density of field plots is particularly problematic in heterogenous landscapes, such as mountainous regions and areas with many different land use and cover types, where a plot in one location is not representative of many nearby locations (de Rigo et al., 2014). To account for the spatial variation in plot density, the model used here (C-SMFA) considers multiple spatial scales when estimating RPP.

C-SMFA performs spatial frequency analysis of the geolocated plot data to create preliminary RPP maps (de Rigo et al., 2014). For each 1 km^2 grid cell, it estimates kernel densities over a range of kernel sizes to estimate the probability that

[2]Regulation (EC) No 2152/2003 of the European Parliament and of the Council of 17 November 2003 concerning monitoring of forests and environmental interactions in the Community (Forest Focus). *Official Journal of the European Union* 46 (L 324), 1–8.

a given species is present in that cell. The entire array of multi-scale spatial kernels is aggregated with adaptive weights based on the local pattern of data density. Thus, in areas where plot data are scarce or inconsistent, the method tends to put weight on larger kernels. Wherever denser local data are available, they are privileged, ensuring a more detailed local RPP estimation. Therefore, a smooth multi-scale aggregation of the entire arrays of kernels and datasets is applied instead of selecting a local 'best performing' one and discarding the remaining information. This array-based processing and the entire data harmonisation procedure are made possible thanks to the semantic modularisation which define semantic array programming modelling paradigm (de Rigo, 2012).

The probability to find a single species in a 1 km^2 grid cell cannot be higher than the probability of presence of all the broadleaved (or coniferous) species combined, because all sample plots are localised inside forested areas. Thus, to improve the accuracy of the maps, the preliminary RPP values were constrained to not exceed the local forest-type cover fraction (de Rigo et al., 2014). The latter was estimated from the 'broadleaved forest', 'coniferous forest' and 'mixed forest' classes of the Corine Land Cover (CLC) maps (Bossard et al., 2000; Büttner et al., 2012), with 'Mixed forest' cover assumed to be equally split between broadleaved and coniferous.

The robustness of RPP maps depends strongly on sample plot density, as areas with few field observations are mapped with greater uncertainty. This uncertainty is shown qualitatively in maps of 'RPP trustability'. RPP trustability is computed on the basis of aggregated equivalent number of sample plots in each grid cell (equivalent local density of plot data). The trustability map scale is relative, ranging from 0 to 1, as it is based on the quantiles of the local plot density map obtained using all field observations for the species. Thus, trustability maps may vary among species based on the number of databases that report it (de Rigo et al., 2014; de Rigo et al., 2016).

The RPP and relative trustability range from 0 to 1 and are mapped at 1 km spatial. To improve visualisation, these maps can be aggregated to coarser scales (i.e. 10×10 pixels or 25×25 pixels, respectively, summarising the information for aggregated spatial cells of 100 and 625 km^2) by averaging the values in larger grid cells.