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Pest categorisation of *Toumeyella parvicornis*

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Abstract

The EFSA Panel on Plant Health performed a pest categorisation of *Toumeyella parvicornis* (Cockerell) (Hemiptera: Coccidae) for the EU territory. This species is not included in EU Commission Implementing Regulation 2019/2072. *T. parvicornis* is a soft-scale insect native to North America and has been introduced to the Caribbean region and the EU. It has been present in Italy since 2014 (Abruzzo, Campania, Lazio, and Apulia regions) and in France since 2021 (Provence–Alpes–Côte d'Azur region) and is under official control. It develops on *Pinus* spp. (Pinaceae), feeding on the needles and twigs, especially on new growth. It is sexually reproductive, has one or more generations each year (three in southern Italy), and adult females overwinter on the *Pinus* needles. It has a high fecundity, up to 1,014 eggs per female in Italy, with an average of 199 eggs for the summer generation and 730 for the overwintering generation. The main natural dispersal stage is the first instar, which crawls over the plant or may be dispersed further by wind and animals. The species can be transported over longer distances with plants for planting. Large populations cause yellowing, needle loss, reduction in growth and recruitment, flagging, dieback and tree mortality. It has had a significant impact to *P. pinea* (stone pine) in Italy and caused a catastrophic decline of *P. caribbea* var. *bahamensis* (Caribbean pine) in the Turks and Caicos Islands. Adult and immature *T. parvicornis* could enter the EU with *Pinus* plants for planting; however, the import of *Pinus* from third countries where the scale is found is prohibited. Host availability and climate suitability indicate that most of the EU would be suitable for establishment. Phytosanitary measures are available to inhibit further introductions and slow the spread within the EU. *T. parvicornis* satisfies all the criteria that are within the remit of EFSA to assess for it to be regarded as a potential Union quarantine pest.

Keywords: pest risk, plant health, plant pest, quarantine, *Pinus*, pine tortoise scale, Hemiptera, Coccidae

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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

Toumeyella parvicornis is one of a number of pests listed in Annex 1 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 EU 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 as a result of media monitoring and PeMoScoring and subsequent discussion in PAFF in 2020, resulting in it being included in the current mandate within the list of pests identified by Horizon Scanning and selected for pest categorisation.

2. Data and methodologies

2.1. Data

2.1.1. Literature search

A literature search on *Toumeyella parvicornis* 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 European and Mediterranean Plant Protection Organization (EPPO) Global Database (EPPO, online), the CABI databases and scientific literature databases as referred above in Section 2.1.1.

Data about the import of commodity types that could potentially provide a pathway for the pest to enter the EU and about the area of hosts grown in the EU were obtained from EUROSTAT (Statistical Office of the European Communities).

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 (Phyto-Sanitary 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, and 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 *Toumeyella parvicornis* which 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 *T. parvicornis*, following guiding principles and steps presented in the EFSA guidance on quantitative pest risk assessment (EFSA PLH Panel, 2018), the EFSA guidance on the use of the weight of evidence approach in scientific assessments (EFSA Scientific Committee, 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) is 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, 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. Whilst 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, 2018). 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 impact?
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 *Toumeyella parvicornis* (Cockerell) is the accepted name.

Toumeyella parvicornis (Figure 1) is an insect within the order Hemiptera and family Coccidae. It is commonly known as pine tortoise scale.

It was first described as *Lecanium parvicorne* by Cockerell (1897) from specimens collected in Florida (USA) on loblolly pine, *Pinus taeda,* and longleaf pine, *P. palustris* (Pinaceae), and later assigned to the genus *Toumeyella* by Cockerell (1902). It was subsequently described as *Lecanium (Toumeyella) numismaticum* by Pettit and McDaniel (1920) from specimens collected in Wisconsin (USA) on Scots pine, *P. sylvestris*.

The EPPO code[1] (Griessinger and Roy, 2015; EPPO, 2019) for this species is: TOUMPA (EPPO, online).

[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 (Griessinger & Roy, 2015; EPPO, 2019)

Figure 1: *Toumeyella parvicornis*: adult females feeding on apical twig (left) and heavily infested *Pinus pinea* showing severe needle loss and dieback (right) (Source: Lacy Hyche, Auburn University, Bugwood.org (left) and Chris Malumphy (right))

3.1.2. Biology of the pest

The number of generations that *T. parvicornis* completes each year depends on climatic conditions. It is univoltine towards the northern limit of its range in Canada and north-eastern USA (Cooper and Cranshaw, 2004), bivoltine in Virginia (Williams and Kosztarab, 1972) and multivoltine in Georgia and Florida (Clarke, 2013). It has at least three, partially overlapping, generations each year in southern Italy where the pest was recently introduced (Garonna et al., 2018) and is suspected to have five or more generations in the Turks and Caicos Islands (Malumphy et al., 2012). Table 2 summarises key features of the biology of each life stage.

T. parvicornis populations are frequently attended by ants and this symbiotic relationship was reported to be obligatory by Bishop and Bristow (2001) in its native range. They found that populations of *T. parvicornis* were larger in pine forest in Michigan (USA) with high densities of the ant, *Formica exsectoides* Forel, when compared with areas with low or no *F. exsectoides*. The primary benefit for the scale insects appears to be protection from predators and parasitoids (Way, 1963).

In Puerto Rico, the scale insect is associated with two highly invasive ant species: imported fire ant, *Solenopsis invicta* Burén and little fire ant, *Wasmannia auropunctata* (Roger) (Segarra-Carmona and Cabrera-Asencio, 2010).

Table 2: Important features of the life history strategy of *Toumeyella parvicornis*

Life stage	Phenology and relation to host	Other relevant information
Egg	Ovoviviparous. The average number of eggs laid per female in Italy varied among the generations and ranged from 199 for the summer generation to 730 for the overwintering generation. The highest recorded fecundity was 1014 eggs. Eggs hatch within a few hours of being laid (Garonna et al., 2018).	
Nymph	Found on apical twigs and needles. Females have three nymphal instars, and the males have four. The final two male nymph instars (called prepupa and pupa) do not feed. In northern parts of its range, the first-generation crawlers are present in late April to early May. In tropical areas, it breeds continuously, with overlapping generations, and all instars may be found throughout the year.	First-instar nymphs (known as 'crawlers') are mobile and disperse by walking to other parts of the same plant or are carried by the wind, phoresy (attached to other animals, including birds) or incidentally by forestry machinery and workers, to other areas (Malumphy et al., 2012,2016). Once a suitable feeding site is located, they insert their stylets to feed and remain anchored to the host.
Adult	See the notes for the nymphs. Males have wings and females are wingless (neotenic and larviform). Fertilised adult females overwinter in areas with cold winters.	Sexually reproductive. Adult males have no functional mouthparts and are short-lived during which time they disperse by flight, although they are weak flyers, and seek a female to mate with.

3.1.3. Host range/Species affected

T. parvicornis develops on specific *Pinus* species (Pinaceae) listed in Appendix A, including: *Pinus banksiana, P. caribaea* var. *bahamensis, P. caribaea* var. *hondurensis, P. contorta, P. echinate, P. elliottii, P. glabra, P. mugo, P. nigra* subsp. *laricio, P. palustris, P. pinaster, P. pinea, P. resinosa, P. sylvestris, P. taeda* and *P. virginiana*. The primary hosts for *T. parvicornis* in the Northern parts of its range in North America are *P. banksiana* and *P. sylvestris* (Clarke, 2013). In Italy, higher population densities and survival rates were observed on *P. pinea* than on other *Pinus* species (Garonna et al., 2018). The hosts *P. mugo, P. nigra* subsp. *laricio, P. pinaster, P. pinea* and *P. sylvestris* can be found in several countries throughout Europe. Only a limited number of *Pinus* spp. have been tested as hosts in Europe (Garonna et al., 2018). Therefore, there is uncertainty regarding the full potential host range within *Pinus* species of this insect in Europe.

3.1.4. Intraspecific diversity

Morphology of the adult female scales varies depending on feeding/development location on the host. Scales on the needles are usually more elongate and smaller than scales that develop on the bark. The needle form is dominant in the southern part of United States, whilst the twig or bark form is dominant in the northern parts of its distribution area across the Canada–USA border (Clarke, 2013). The reason for this difference in feeding site preference is unknown.

3.1.5. Detection and identification of the pest

Are detection and identification methods available for the pest?

Yes, *T. parvicornis* can be found during visual inspection of infested consignments of host plants; adult females, and nymphs can be found on the needles and bark. Morphological keys are available to identify specimens to species level.

Detection – Symptoms

T. parvicornis is gregarious and often forms dense colonies on new growth of their host plants. Feeding by *T. parvicornis* nymphs and adult females on the needles and twigs causes chlorosis, needle drop and branches to die (flagging) (Figure 1). Heavily attacked trees, particularly seedlings and saplings, turn yellow and finally die. The host plant and all surfaces below the scale infestation turn black with sooty mould growing on the egested honeydew.

Identification

The genus *Toumeyella* currently includes 18 species mostly distributed in the Nearctic and Neotropical Regions (García Morales et al., 2016). Detailed morphological descriptions and illustrations of the adult female are provided by Williams and Kosztarab (1972), Hamon and Williams (1984) and by Kosztarab (1996). Keys for the identification of *Toumeyella* species of north-eastern North America are provided by Kosztarab (1996), for Florida by Hamon and Williams (1984), for Virginia by Williams and Kosztarab (1972) and for Mexico by Kondo and Pellizzari (2011). *T. parvicornis* is easily separated morphologically from all other species by the unique character of dorsal bilocular pore aggregations (Williams and Kondo, 2008). Molecular diagnostic methods, based on the cytochrome c oxidase I (COI) sequence, are also available.

Description

Adult females are either oval when feeding on the bark (Figure 1), or elongate when on the needles, strongly convex, reddish-brown with black or dark brown stripes, or speckled with dark spots. They become uniform dark brown with maturity. When present at high density, the adult females overlap each other on the twigs or needles. They attain a maximum length of 4.4 mm and width of 3.9 mm. The male tests (a wax cover that protects the immature stages) are oval, white, translucent and about 3.0 mm long. Adult males are winged but rarely seen (Malumphy et al., 2012).

Eggs are ovoid, pinkish, almost transparent and about 0.4 mm long.

First-instar nymphs are oval, orange and have six short legs.

Second- and third-instar female nymphs are legless, reddish-orange, oval and convex.

3.2. Pest distribution

3.2.1. Pest distribution outside the EU

T. parvicornis is native to the Nearctic region. It occurs in Mexico, throughout the United States of America and southern Canada. It was introduced to Puerto Rico in 2009 and the Turks and Caicos Islands in 2005 (Malumphy et al., 2012) (Figure 2). It has recently been introduced to Europe (see Section 3.2.2 below).

Appendix B provides national and subnational records of occurrence (EPPO, online).

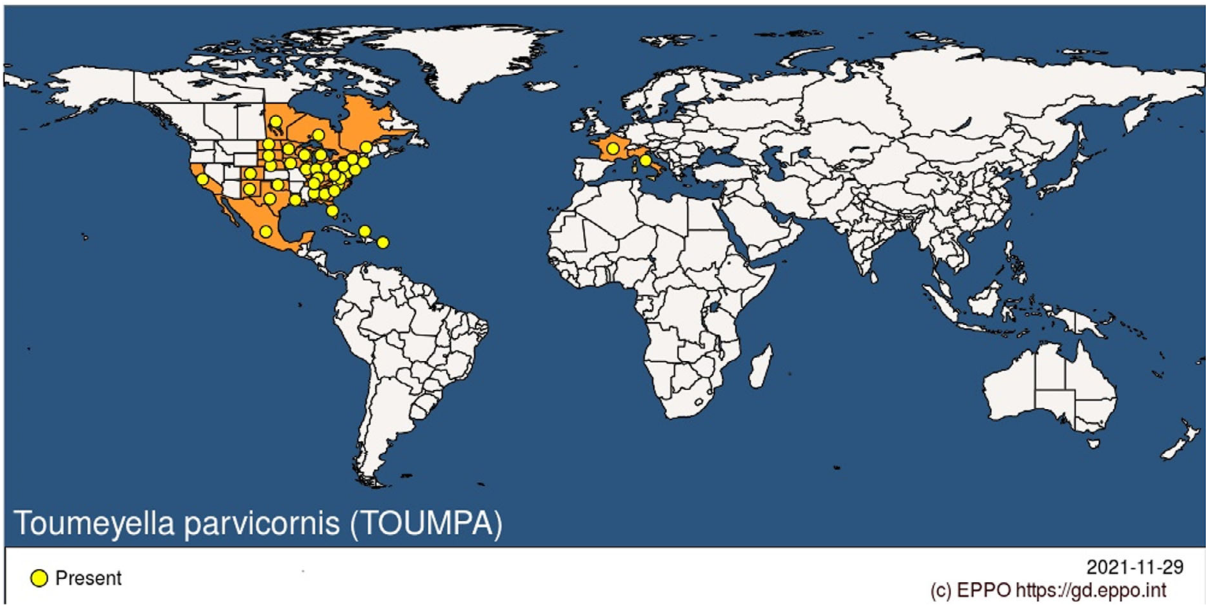

Figure 2: Global distribution of *Toumeyella parvicornis* (Source: EPPO Global Database accessed on 29 November 2021)

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.
Yes, *T. parvicornis* occurs in France (Provence–Alpes–Côte d’Azur region) and Italy (regions of Abruzzo, Campania, Lazio and Apulia).

T. parvicornis was first observed in Europe in 2014, in southern Italy, in the region of Campania (Naples and neighbouring municipalities) on stone pines (*Pinus pinea*), growing in urban areas (Garonna et al., 2015). In 2018, it was found in Rome, Lazio region, and in 2021, along the coast from Caserta to Salerno (Campania), causing serious damage to stone pines. In September 2021, it was also found in Abruzzo and Apulia regions. It is under official control in Italy (EPPO, online). In December 2021, it was found in southern France, in the region of Provence–Alpes–Côte d’Azur region (EPPO, online), and the regional plant protection services are conducting surveys to evaluate the extent of the infested zone, and are taking phytosanitary measures.

3.3. Regulatory status

3.3.1. Commission Implementing Regulation 2019/2072

T. parvicornis is not listed in Annex II of Commission Implementing Regulation (EU) 2019/2072, an implementing act of Regulation (EU) 2016/2031. It is under official control in Italy. In France, the regional plant protection services are currently defining a survey protocol to evaluate the extent of the infested zone, and phytosanitary measures to prevent the spread of the scale insect (EPPO, online).

3.3.2. Hosts or species affected that are prohibited from entering the Union from third countries

As specified in Annex VI of 2019/2072, all host plants of *T. parvicornis* (see Appendix A) are prohibited from entering the EU as plants for planting (Table 3).

Table 3: List of plants, plant products and other objects that are *Toumeyella parvicornis* 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	see 2019/2072 Annex VI for details	Third countries other than: specific third countries (see 2019/2072 Annex VI for details). *It is not present in any of the exempt countries*.

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, *T. parvicornis* has already entered the EU (France and Italy), and could enter again.

Comment on plants for planting as a pathway

In principle, *T. parvicornis* could enter the EU territory with *Pinus* plants for planting, branches of pine, and isolated bark of pine, although these pathways are closed from countries where *T. parvicornis* occurs (see Table 3).

Table 4: Potential pathways for *Toumeyella parvicornis* into the EU 27

Pathways	**Life stage**	**Relevant mitigations [e.g. prohibitions (Annex VI), special requirements (Annex VII) or phytosanitary certificates (Annex XI) within Implementing Regulation 2019/2072]**
Pinus plants for planting	Adult females and immatures	Prohibited (2019/2072 Annex VI). Pathway closed
Pinus plants (branches)	Adult females and immatures	Prohibited (2019/2072 Annex VI). Pathway closed
Isolated bark of pine (Pinales)	Adult females and immatures	Import of conifer bark from outside of the EU is regulated (special requirements specified in Annex VII, 82, i.e. fumigation or heat treatment and temporal limits in relation to transport)

It is strongly suspected that *T. parvicornis* was introduced into the Turks and Caicos Islands on cut *Pinus* trees imported from the US for use as Christmas trees (Malumphy et al., 2012,2016).

It is not known how the pest was introduced into Italy as prohibitions exist for the import of Pinaceae species from outside of the EU.

Table 4 provides a summary of potential pathways for the introduction of *T. parvicornis* into the EU. Adult females and all immature stages of *T. parvicornis* may be transported with *Pinus* plants for planting, excluding seed. Adult males are less likely to be transported than the other stages, as they are winged and likely to fly off when disturbed during processing for shipment.

There are derogations for dwarfed *Pinus* coming from Japan ((EU) 2020/1217) and the Republic of Korea (Commission Decision 2002/499/EC). However, *T. parvicornis* is not known to occur in these countries and this is not considered a pathway.

There is only a relatively small trade of coniferous wood products into the EU from North America where *T. parvicornis* is present. *T. parvicornis* may be found on the bark of living trees, but they are very unlikely to develop on isolated pieces of outer dead bark. The likelihood that bark, non-squared wood and woodchip could provide a pathway of introduction is very low for the following reasons: pre-export treatments, including drying, are likely to be very effective in killing the scale insects, but will not be applied to all imports; the import of coniferous woodchip and coniferous bark from outside the EU is regulated (import requirements specified in Annex VII. (81 and 82.). Even if living scale insects could enter the EU through these pathways, they would have difficulty transferring to a suitable host due to their limited mobility.

There is no indication that squared wood, wood packaging material or seeds are viable pathways for this pest. The scale insects feed on pine needles and apical branches and are not associated with the heartwood.

Pine branches and pinecones are commonly used in floristry and in the production of Christmas decorations. It is unclear if *T. parvicornis* could be associated with the import of pinecones but cut branches from infested hosts may carry the scale insects. However, the import of cut branches of pine from outside of the EU is prohibited.

First-instar nymphs may be carried by animals and on vehicles and are likely to be able to survive for approximately one day without feeding. However, there is not enough specific information about *T. parvicornis* to accurately assess the likelihood of hitchhiking as a pathway of entry.

Notifications of interceptions of harmful organisms began to be compiled in Europhyt in May 1994 and in TRACES in May 2020. As of 20 August 2021, there were no records of interception of *T. parvicornis* in the Europhyt and TRACES databases.

3.4.2. Establishment

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

Yes, *T. parvicornis* has established in southern France and Italy. Biotic factors such as host availability, and abiotic factors such as climate suitability suggest that large areas of the EU would be suitable for establishment.

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). Availability of. hosts is considered in Section 3.4.2.1 and climatic factors in Section 3.4.2.2.

3.4.2.1. EU distribution of main host plants

As noted in Appendix B, *T. parvicornis* is oligophagous on *Pinus* species with, e.g. *P. mugo, P. nigra* subsp. *laricio, P. pinaster, P. pinea* and *P. sylvestris* available throughout most of the EU (Figure 3 shows distribution of the *Pinus* spp.).

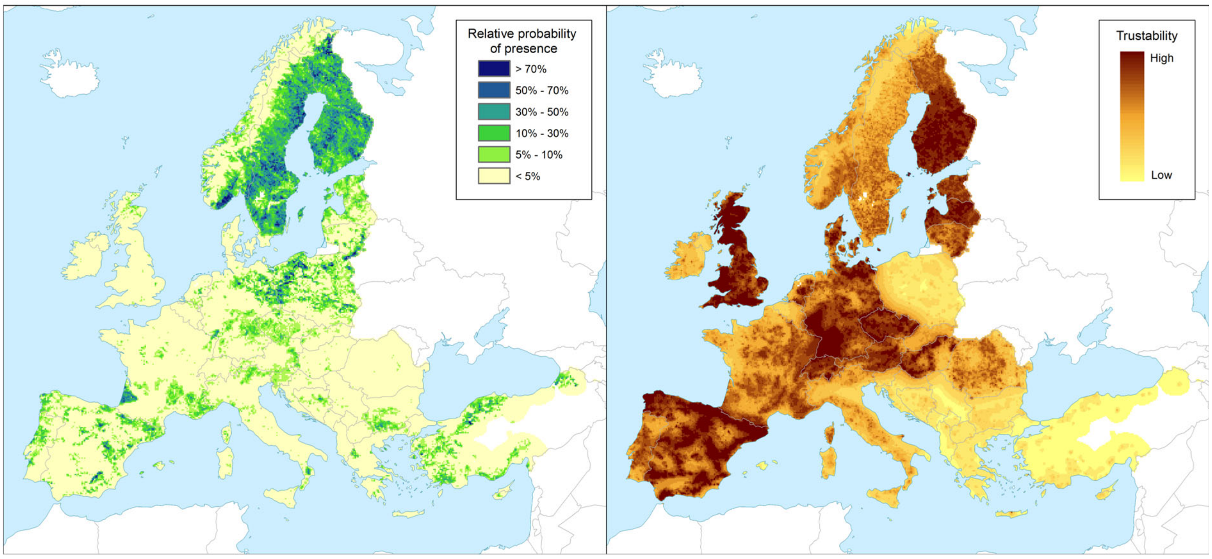

Figure 3: Left panel: Relative probability of the presence (RPP) of *Pinus* spp. in Europe, mapped at 100-km^2 resolution. The underlying data are from European-wide forest monitoring data sets and from national forestry inventories based on standard observation plots measuring in the order of hundreds 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)

3.4.2.2. Climatic conditions affecting establishment

T. parvicornis exhibits a remarkably wide climatic tolerance, occurring in tropical, subtropical and temperate areas. Figure 4 shows the World distribution of 10 Köppen–Geiger climate types that occur in the EU and which occur in areas where *T. parvicornis* has been reported.

T. parvicornis has the potential to establish throughout the EU, wherever suitable hosts occur.

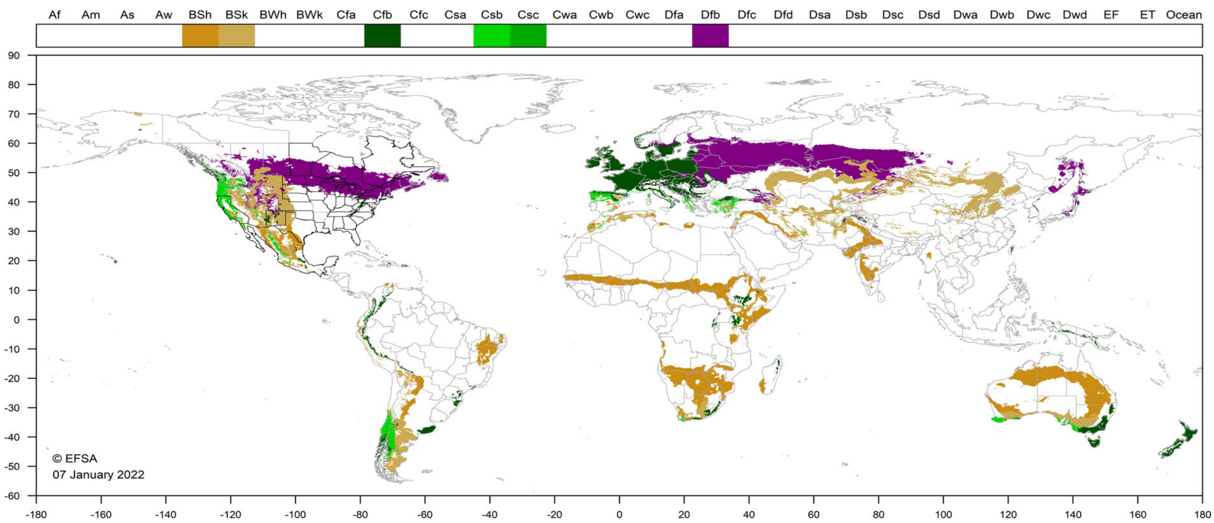

Figure 4: World distribution of Köppen–Geiger climate types that occur in the EU and which occur in countries where *Toumeyella parvicornis* has been reported

3.4.3. Spread

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

T. parvicornis is a free-living organism that is spreading in southern Italy and was recently found in southern France. Natural spread by the first instars crawling or being carried by wind, other animals, or machinery, will occur locally and usually relatively slowly. Despite being under official control, it might continue to spread given its natural dispersal ability.

Comment on plants for planting as a mechanism of spread

Adult females and immatures can be carried on *Pinus* spp plants for planting. This pathway presents a high likelihood of facilitating introduction and spread because the scale insects do not need to transfer to another host to find suitable host plants. The scale insect population will be able to develop on the imported plant before spreading to other suitable hosts.

T. parvicornis was first found in Italy in Naples and surrounding areas in 2014 and confirmed in 2015, and by 2018, large damaging populations were observed in Rome, more than 200 km from the original finding. In December 2021, it was found in southern France. It is not known how it spreads from Naples to Rome, or to France, or if these were separate introductions.

Natural dispersal by the first-nymphal instars or crawlers may occur by wind and/or phoresy. Wind-borne dispersal of the crawlers has been reported in several species of scale insect and it has been suggested that morphological characters, such as the dorsoventrally flattened body and long filamentous setae arising from the anal plates, reduce terminal air velocity allowing crawlers to stay airborne longer while drifting on air currents (Magsig-Castillo et al., 2010). In addition, crawlers of some species display behaviours that seem to be adapted for take-off in wind streams. Several species are positively phototropic resulting in them climbing up the plant, accumulating at the tips of leaves, where they are more exposed to air currents; and some have been observed orienting themselves downwind and standing on their mesothoracic and metathoracic legs, exposing the maximum body surface area to the wind, increasing frictional drag and enhancing removal by air currents (Washburn and Washburn, 1984). Crawlers have been recorded as being carried for a few metres and more rarely a few hundred kilometres (Gullan & Kosztarab, 1997). Airborne dispersal by *T. parvicornis* crawlers has been reported to occur up to a distance of 4.8 km (Rabkin and Lejeunne, 1954); however, this was the maximum limit that the traps were set and it is not known if the crawlers travelled further.

The importance of phoresy (being carried by other animals) for dispersal is unclear. Magsig-Castillo et al. (2010) demonstrated that each of the scale insect crawler's legs has four hairs (digitules) which end in a suction cup-like structure, reminiscent of the attachment structures possessed by phoretic mites, and in the laboratory, these digitules were observed being used to attach the crawlers to flies (*Musca domestica* L. and *Drosophila melanogaster* (Meigen), beetles (*Lindorus lophanthae* (Blaisdell), *Cryptolaemus montrouzieri* Mulsant) and an ant (*Linepithema humile* (Mayr)). Crawlers can remain attached to flying insects for considerable periods of time. Crawlers have also been found attached to birds (Williams, 2013).

Adult females and immatures can be moved over long distances with trade, which may explain the rapid spread of *T. parvicornis* in southern Italy and its introduction to France.

3.5. Impacts

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

Yes, *T. parvicornis* is harmful to *Pinus* spp., and is having a significant negative impact in Italy.

Feeding by *T. parvicornis* nymphs and adult females on the needles and twigs causes branches to die (flagging). Heavily attacked trees, particularly seedlings and saplings, may be killed. Reduced cone production by mature trees threatens ongoing recruitment into the pine population. *T. parvicornis* egest large quantities of honeydew, smothering the host plant and all surfaces below the scale infestation. The honeydew serves as a medium for the growth of black sooty moulds, which cover leaves, branches and plants and surfaces below. The sooty moulds hinder photosynthesis and gas exchange and contribute to tree decline. Ants often feed on the sugary honeydew.

T. parvicornis is having a serious economic, environmental and social impact in southern Italy. The scale is contributing to the severe decline in health and some mortality of stone pines, particularly in Naples and Rome, and surrounding areas.

Pinus pinea are iconic trees in Italy and have been showing a rapid decline in Campania and Lazio regions, due in part to the introduction of other invasive pests, including pine tortoise scale (*T. parvicornis), western conifer seed bug (Leptoglossus occidentalis* Heidemann*) and* the North American root rot pathogen of pines *Heterobasidion irregulare* (Gonthier et al., 2014). *The impact on tree health by T. parvicornis* may be amplified in combination with these other invasive pests.

T. parvicornis has caused a catastrophic decline of Caribbean pine in the Turks and Caicos Islands, completely changing the ecosystem (Malumphy et al., 2012). It is an occasional pest in North America, mainly in young pine plantations, seed orchards and Christmas tree farms (Clarke, 2013).

3.6. Available measures and their limitations

Are there measures available to prevent the entry into the EU (and spread for pests already present) such that the risk becomes mitigated?

Yes, there are measures available to prevent further introductions into the EU. The main host plants, *Pinus*, are already prohibited as plants for planting and as cut branches from third countries (see 3.3.2). The scale is under official control in France and Italy.

3.6.1. Identification of potential additional measures

Phytosanitary measures (prohibitions) are currently applied to host plants for planting (see Section 3.3.2). No additional measures would reduce likelihood of entry. Additional potential risk reduction options and supporting measures shown in Sections 3.6.1.1 and 3.6.1.2 relate to reducing likelihood of spread within the EU.

3.6.1.1. Additional potential risk reduction options

Potential additional control measures are listed in Table 5.

Table 5: Selected control measures (a full list is available in EFSA PLH Panel, 2018) for pest entry/establishment/spread/impact in relation to currently unregulated hosts and pathways. Control measures are measures that have a direct effect on pest abundance

Control measure/ Risk reduction option (Blue underline = Zenodo doc, Blue = WIP)	RRO summary	Risk element targeted (entry/ establishment/ spread/impact)
Require pest freedom	Used to mitigate likelihood of infestation by specified pest at origin, hence to mitigate entry. Source imports from pest-free area. The import of the host plants (*Pinus* spp.) is prohibited. There are derogations for dwarfed (bonsai) host plants for planting from Korea and Japan, countries in which *T. parvicornis* is not known to occur.	Spread
Managed growing conditions	Used to mitigate likelihood of infestation at origin. Dwarfed host plants can be grown in protected areas/cultivation (= screenhouse).	Spread
Growing plants in isolation	Used to mitigate likelihood of infestation by specified pest in vicinity of growing site. This could be considered because *T. parvicornis* has a low natural dispersal potential as adult females cannot fly; measures could be applied in vicinity of production nursery.	Spread
Chemical treatments on crops including reproductive material	Used to mitigate likelihood of infestation of pests susceptible to chemical treatments	Spread and Impact
Roguing and pruning	Used to mitigate likelihood of infestation by specified pest (usually a pathogen) at growing site where pest has limited dispersal. Pruning can be effective in reducing population levels and therefore impact	Spread and Impact

Control measure/ Risk reduction option (**Blue underline** = Zenodo doc, Blue = WIP)	RRO summary	Risk element targeted (entry/ establishment/ spread/impact)
Chemical treatments on consignments or during processing	Used to mitigate likelihood of infestation of pests susceptible to chemical treatments. Clarke (2013) discusses direct control of *T. parvicornis* using contact and systemic insecticides, insect growth regulators, insecticidal soaps and mineral oils.	Spread and Impact
Biological control and behavioural manipulation	In its native area of distribution, *T. parvicornis* population is usually regulated by predators and parasitoids. Ant control may also help reduce *T. parvicornis* population. *Metaphycus flavus* is a commercially available biocontrol agent in the EU (promoted for greenhouses).	Impact
Conditions of transport	Used to mitigate likelihood of entry of pests that could otherwise infest material post-production	Spread
Post-entry quarantine (PEQ) and other restrictions of movement in the importing country	Plants in PEQ are held in conditions that prevent the escape of pests; they can be carefully inspected and tested to verify they are of sufficient plant health status to be released, or may be treated, re-exported or destroyed. Tests on plants are likely to include laboratory diagnostic assays and bioassays on indicator hosts to check whether the plant material is infected with pests.	Spread

3.6.1.2. Additional supporting measures

Potential additional supporting measures are listed in Table 6.

3.6.1.3. Biological or technical factors limiting the effectiveness of measures

Table 6: Selected supporting measures (a full list is available in EFSA PLH Panel, 2018) in relation to currently unregulated hosts and pathways. Supporting measures are organisational measures or procedures supporting the choice of appropriate risk reduction options that do not directly affect pest abundance

Supporting measure (**Blue underline** = Zenodo doc, Blue = WIP)	Summary	Risk element targeted (entry/establishment/ spread/impact)
Inspection and trapping	Inspections of material when moving plants for planting within the EU from regions where *T. parvicornis* occurs could reduce likelihood of spread. Yellow sticky traps have been used to detect the presence of first-instar *T. parvicornis* (Malumphy et al., 2016).	Spread
Sampling	Necessary as part of other RROs	
Phytosanitary certificate and plant passport	An official paper document or its official electronic equivalent, consistent with the model certificates of the IPPC, attesting that a consignment meets phytosanitary import requirements (ISPM 5) a) export certificate (import) b) plant passport (EU internal trade)	Spread (plant passport)
Certification of reproductive material (voluntary/official)	Used to mitigate against pests that are included in a certification scheme	Spread
Delimitation of Buffer zones	As an organism that is already in the EU, buffer zones could be used to inhibit spread.	Spread
Surveillance	Surveillance to guarantee that plants and produce originate from a pest-free area could be an option.	Spread

- Low-density populations of *T. parvicornis* are difficult to detect as they are small and cryptic in nature. They also develop in the canopy which can be difficult to survey adequately without a cherry picker.
- Limited information on the effectiveness of control measures in Europe, such as contact and systemic insecticide treatments, dormant oils, and biological control.

3.7. Uncertainty

There is uncertainty how the pest was introduced into Italy when the main pathway, *Pinus* plants for planting, is closed. There is uncertainty regarding the distribution in Italy due to difficulties surveying canopies of tall trees. It is often only noticed once populations have developed to a level where they are causing conspicuous damage.

There is also uncertainty regarding the modes of dispersal, specifically how it has spread so rapidly in Italy. The significance (distance) of aerial dispersal of the first instars in Europe is uncertain.

There is uncertainty whether the occurrence in France is spread from Italy or a new introduction.

It is too early to assess the impact of recruitment by natural enemies, particularly coccinellid beetles and parasitoid wasps, on the population levels of *T. parvicornis*.

4. Conclusions

T. parvicornis is a significant pest of *Pinus* species, particularly *P. pinea*. It is native to North America and has spread to parts of the Caribbean and Europe. It has recently been reported in France and Italy, where it is under official control and has a limited distribution, although it appears to have spread 200 km from Naples within 4 years. *T. parvicornis* 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 7).

Table 7: 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 *Toumeyella parvicornis* (Cockerell) is the accepted name.	None
Absence/presence of the pest in the EU (Section 3.2)	*T. parvicornis* is present in the EU and has a restricted distribution in France (Provence–Alpes–Côte d'Azur region) and Italy (regions of Abruzzo, Campania, Lazio and Apulia).	None
Pest potential for entry, establishment and spread in the EU (Section 3.4)	Adult and immature *T. parvicornis* may enter the EU with imported plants for planting. The host genera, *Pinus*, are prohibited. Biotic factors (host availability) and abiotic factors (climate suitability) suggest that most of the EU would be suitable for establishment. The pest is a free-living organism and could spread within the EU, facilitated by movement of host plants in trade and passive dispersal.	None
Potential for consequences in the EU (Section 3.5)	Adults and nymphs are harmful to *Pinus* species and economic and environmental impacts would be expected if *T. parvicornis* spreads in the EU.	None
Available measures (Section 3.6)	Plants of *Pinus* are prohibited from third countries where the pest is known to be present. Additional options (prohibition of isolated bark) are available to reduce the likelihood of pest entry into, whilst risk reduction options to limit spread within the EU are also available.	None
Conclusion (Section 4)	*T. parvicornis satisfies all the criteria that are within the remit of EFSA to assess for it to be regarded as a potential Union quarantine pest.*	
Aspects of assessment to focus on/scenarios to address in future if appropriate:	There is uncertainty regarding the frequency and range of dispersal, and potential impact by recruitment by natural enemies.	

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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, 2018)
Control (of a pest)	Suppression, containment or eradication of a pest population (FAO, 2018)
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, 2018)
Eradication (of a pest)	Application of phytosanitary measures to eliminate a pest from an area (FAO, 2018)
Establishment (of a pest)	Perpetuation, for the foreseeable future, of a pest within an area after entry (FAO, 2018)
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 and 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, 2018)
Pathway	Any means that allows the entry or spread of a pest (FAO, 2018)
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, 2018)
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, 2018)
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. An 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, 2018)

Appendix A – *Toumeyella parvicornis* host plants/species affected

Source: EPPO Global Database (EPPO online)

Host status	Host name	Plant family	Common name
Cultivated hosts	*Pinus banksiana*	Pinaceae	Grey/jack/scrub pine
	Pinus caribaea var. bahamensis	Pinaceae	Caribbean pine
	Pinus caribaea var. hondurensis	Pinaceae	Honduran pine
	Pinus contorta	Pinaceae	Beach/shore pine
	Pinus echinata	Pinaceae	Shortleaf pine
	Pinus elliottii	Pinaceae	American pitch/slash pine
	Pinus glabra	Pinaceae	Cedar/spruce pine
	Pinus mugo	Pinaceae	Dwarf mountain/mountain pine
	Pinus nigra subsp. laricio	Pinaceae	Calabrian black/Corsican pine
	Pinus palustris	Pinaceae	Long-leaf/southern pitch/southern yellow pine
	Pinus pinaster	Pinaceae	Maritime/seaside pine
	Pinus pinea	Pinaceae	Italian stone/stone/umbrella pine
	Pinus resinosa	Pinaceae	Red pine
	Pinus sylvestris	Pinaceae	Scots pine
	Pinus taeda	Pinaceae	Loblolly pine
	Pinus virginiana	Pinaceae	Jersey/poverty/scrub/Virginia pine

Appendix B – Distribution of *Toumeyella parvicornis*

Distribution records based on EPPO Global Database (EPPO, online).

Region	Country	Subnational (e.g. State)	Status
Central America	Mexico		Present, no details
	Puerto Rico		Present, no details
	Turks and Caicos Islands		Present, widespread
North America	Canada		Present, restricted distribution
		Manitoba	Present, no details
		Ontario	Present, no details
		Québec	Present, no details
	United States of America		Present, restricted distribution
		Alabama	Present, no details
		California	Present, no details
		Florida	Present, no details
		Georgia	Present, no details
		Illinois	Present, no details
		Indiana	Present, no details
		Iowa	Present, no details
		Kentucky	Present, no details
		Louisiana	Present, no details
		Massachusetts	Present, no details
		Michigan	Present, no details
		Minnesota	Present, no details
		Nebraska	Present, no details
		New Jersey	Present, no details
		New Mexico	Present, no details
		New York	Present, no details
		North Carolina	Present, no details
		North Dakota	Present, no details
		Ohio	Present, no details
		Oklahoma	Present, no details
		Pennsylvania	Present, no details
		South Carolina	Present, no details
		South Dakota	Present, no details
		Tennessee	Present, no details
		Texas	Present, no details
		Virginia	Present, no details
		West Virginia	Present, no details
		Wisconsin	Present, no details
Europe	France		Present, restricted distribution
	Italy		Present, restricted distribution

Appendix C – Methodological notes on Figure 3

The relative probability of presence (RPP) reported here for *Pinus* spp. In Figure 3 and in the European Atlas of Forest Tree Species (de Rigo et al., 2016; San-Miguel-Ayanz et al., 2016) is the probability of that genus to occur in a given spatial unit (de Rigo et al., 2017). In forestry, such a probability for a single taxon is called 'relative'. The maps of RPP are produced by means of the constrained spatial multiscale frequency analysis (C-SMFA) (de Rigo et al., 2014, 2017) of species presence data reported in geolocated plots by different forest inventories.

C.1. Geolocated plot databases

The RPP models rely on five geodatabases that provide presence/absence data for tree species and genera: four European-wide forest monitoring data sets and a harmonised collection of records from national forest inventories (de Rigo et al., 2014, 2016, 2017). The databases report observations made inside geolocalised 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 data sets was performed 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). Given the heterogeneity of strategies of field sampling design and establishment of sampling plots in the various national forest inventories (Chirici et al., 2011a,b), and also given legal constraints, the information from the original data sources was harmonised to refer 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, https://spatialreference.org/ref/epsg/etrs89-etrs-laea/).

C.1.1. European National Forestry Inventories database

This data set was 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).

C.1.2. 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 and Hiederer, 2009). The complete Forest Focus data set covers 30 European countries with more than 8,600 sample points.

C.1.3. BioSoil data set

This data set was produced by one of a number of demonstration studies performed 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 data set 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 3,300 sample points in 19 European Countries.

C.1.4. European Information System on Forest Genetic Resources (EUFGIS)

EUFGIS (https://portal.eufgis.org) is a smaller geodatabase providing information on tree species composition in over 3,200 forest plots in 34 European countries. The plots are part of a network of

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

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.

C.1.5. Georeferenced Data on Genetic Diversity (GD2)

GD2 (https://gd2.pierroton.inra.fr) provides information about 63 species of interest for genetic conservation. The database covers 6,254 forest plots located in stands of natural populations that are traditionally analysed in genetic surveys. While this database covers fewer species than the others, it covers 66 countries in Europe, North Africa and the Middle East, making it the data set with the largest geographic extent.

C.2. 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 comprising 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 heterogeneous 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. Furthermore, statistical resampling is systematically applied to mitigate the cumulated data-driven uncertainty. The presence or absence of a given forest tree species then refers to an idealised standard field sample of negligible size compared with the 1-km^2 pixel size of the harmonised grid. The modelling methodology considered these presence/absence measures as if they were random samples of a binary quantity (the punctual presence/absence, not the pixel one). This binary quantity is a random variable having its own probability distribution which is a function of the unknown average probability of finding the given tree species within a plot of negligible area belonging to the considered 1-km^2 pixel (de Rigo et al., 2014). This unknown statistic is denoted hereinafter with the name of 'probability of presence'. C-SMFA preforms 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, the model estimates kernel densities over a range of kernel sizes to estimate the probability that a given species is present in that cell. The entire array of multiscale 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 multiscale aggregation of the entire arrays of kernels and data sets 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 defines the semantic array programming modelling paradigm (de Rigo, 2012). The probability to find a single species (e.g. a particular coniferous tree species) in a 1-km^2 grid cell cannot be higher than the probability of the presence of all the coniferous species combined. The same logical constraints applied to the case of single broadleaved species with respect to the probability of the presence of all the broadleaved species combined. Thus, to improve the accuracy of the maps, the preliminary RPP values were constrained so as not to exceed the local forest-type cover fraction with an iterative refinement (de Rigo et al., 2014). The forest-type cover fraction was estimated from the classes of the Corine Land Cover (CLC) maps which contain a component of forest trees (Bossard et al., 2000; Büttner et al., 2012). The resulting probability of presence is relative to the specific tree taxon, irrespective of the potential co-occurrence of other tree taxa with the measured plots, and should not be confused with the absolute abundance or proportion of each taxon in the plots. RPP represents the probability of finding at least one individual of the taxon in a plot placed randomly within the grid cell, assuming that the plot has negligible area compared with the cell. As a consequence, the sum of the RPP associated with different taxa in the same area is not constrained to be 100%. For example, in a forest with two codominant tree species which are homogeneously mixed, the RPP of both may be 100% (see e.g. the Glossary in San-Miguel-Ayanz et al. (2016), https://forest.jrc.ec.europa.eu/media/atlas/Glossary.pdf). 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 the 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 a particular species (de Rigo et al., 2014, 2016). The RPP and relative trustability range from 0 to 1 and are mapped at a 1-km spatial resolution. To improve visualisation, these maps can be aggregated to coarser scales (i.e. 10 9 10 pixels or 25 9 25 pixels, respectively, summarising the information for aggregated spatial cells of 100 and 625 km^2) by averaging the values in larger grid cells.