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Pest categorisation of *Sirex nitobei*

EFSA Panel on Plant Health (PLH),
Claude Bragard, Paula Baptista, Elisavet Chatzivassiliou, Francesco Di Serio, Paolo Gonthier, Josep Anton Jaques Miret, Annemarie Fejer Justesen, Christer Sven Magnusson, Panagiotis Milonas, Juan A Navas-Cortes, Stephen Parnell, Roel Potting, Philippe Lucien Reignault, Emilio Stefani, Hans-Hermann Thulke, Wopke Van der Werf, Antonio Vicent Civera, Jonathan Yuen, Lucia Zappalà, Jean-Claude Grégoire, Chris Malumphy, Virag Kertesz, Andrea Maiorano and Alan MacLeod

Abstract

The EFSA Panel on Plant Health performed a pest categorisation of *Sirex nitobei* (Hymenoptera: Siricidae), the nitobe horntail, for the territory of the EU. *S. nitobei* is not listed in Annex II of Commission Implementing Regulation (EU) 2019/2072 but was identified as a potential regulated pest in a commodity risk assessment of *Pinus thunbergii* artificially dwarfed plants from Japan. This species is present in Japan (except Hokkaidō), the Republic of Korea and 13 Chinese provinces. *S. nitobei* attacks several *Pinus* species and has been reported less frequently on *Abies firma* and *Larix* spp., including *L. leptolepis*. The females oviposit into the sapwood. Eggs are deposited together with a phytotoxic mucus and a symbiotic fungus, *Amylostereum areolatum* or *A. chailletii*. The combined action of the venom and the fungus results in the death of the host trees. The fungus degrades the lignocellulosic components of the wood, and the larvae feed on the liquid fraction of the digested residues left by the fungus. All immature stages live in the hosts sapwood. The lifecycle of the pest lasts 1 year. *S. nitobei* can travel with conifer wood, wood packaging material or plants for planting, but these pathways from third countries are closed by prohibition. However, a derogation exists for artificially dwarfed Japanese black pine (*Pinus thunbergii*) from Japan, which therefore provides a potential pathway. Climatic conditions in several EU member states and host plant availability in those areas are conducive for establishment. The introduction of *S. nitobei* is potentially damaging for pines. Phytosanitary measures are available to reduce the likelihood of entry and further spread, and there is a potential for biological control. *S. nitobei* 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: nitobe horntail, conifers, pest risk, plant health, plant pest, quarantine

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Correspondence: alpha@efsa.europa.eu

Panel members: Claude Bragard, Paula Baptista, Elisavet Chatzivassiliou, Francesco Di Serio, Paolo Gonthier, Josep Anton Jaques Miret, Annemarie Fejer Justesen, Alan MacLeod, Christer Sven Magnusson, Panagiotis Milonas, Juan A Navas-Cortes, Stephen Parnell, Roel Potting, Philippe L Reignault, Emilio Stefani, Hans-Hermann Thulke, Wopke Van der Werf, Antonio Vicent, Jonathan Yuen and Lucia Zappalà.

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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

Sirex nitobei 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

S. nitobei was identified as a potential regulated pest in a commodity risk assessment of *Pinus thunbergii* artificially dwarfed plants from Japan (EFSA PLH Panel, 2019).

2. Data and methodologies

2.1. Data

2.1.1. Literature search

A literature search on *S. nitobei* 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 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 (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 EU, 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 *Sirex nitobei* 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 *S. nitobei*, 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. 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, 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
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 the entry into, establishment in or spread of that pest within the EU and to mitigate the risks and impact thereof?
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 species is established and *Sirex nitobei* (Matsuruma) is the accepted name.

Sirex nitobei is an insect within the order Hymenoptera, family Siricidae. It is commonly known as the nitobe horntail.

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

3.1.2. Biology of the pest

The whole lifecycle of *S. nitobei* takes 1 year (Fukuda et al., 1993). The immature stages of *S. nitobei* live in the sapwood of conifers, mostly pines but also *Larix leptolepis*, *Larix* spp. and *Abies firma* (see Section 3.1.3). In Japan, the adults emerge mostly from late August to early November and live for about four days (Fukuda et al., 1993; Tabata et al., 2012). The females use a pointed ovipositor to drill holes into the wood of weakened trees (Kobayashi et al., 1978) or freshly felled trees (Fukuda and Hijii, 1996a,b). Each female can drill up to 200 holes (Fukuda and Hijii, 1996b). Each of these holes can divide into several separate branches into each of which a single egg is laid, or a

[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).

venom mixed with the spores of a symbiotic fungus is injected. Each female lays about 40–500 mature eggs, depending on body size (Fukuda et al., 1993; Fukuda and Hijii, 1996a). The fungus vectored by *S. nitobei* is either *Amylostereum areolatum* (Chaillet ex Fries) Boidin (in most cases) or *A. chailletii* (Pers.) Boidin (Kobayashi et al., 1978; Fitza et al., 2016; Wang et al., 2021). There are no records of both fungi being found together in any individual wasp. Both are white-rot fungi, capable of degrading the lignocellulosic components of the wood. Their spores are carried by the female wasps in an intersegmental sac (mycangium). The proteinic venom, produced only by the females in an abdominal venom gland, promotes colonisation by the fungi (Gao et al., 2021), the fungi degrade the lignocellulosic components of the wood, and the larvae feed on the liquid fraction of the digested residues left by the fungi (Thompson et al., 2014). The combined action of the venom and the fungi results in the death of the host trees, while the venom alone only induces the yellowing and wilting of needles (Gao et al., 2021), and the artificial inoculation of *A. areolatum* alone does not result in fungus establishment (Kobayashi et al., 1978).

Several natural enemies have been regularly observed in Japan. The Ichneumonid wasp *Megarhyssa praecellens* (Tosq.) is a larval ectoparasitoid, and the Ibaliid wasp *Ibalia leucospoides* (Hochenw.) is an egg and early larval instar endoparasitoid (Kanamitsu, 1978; Fukuda and Hijii, 1996b). Other Ichneumonid and Ibaliid species are considered worldwide as key biological control agents against *Sirex noctilio* (Cameron, 2012). The parasitic nematode *Deladenus nitobei* n. sp. (Tylenchomorpha: Allantonematidae) was isolated from *S. nitobei* in Japan (Kanzaki et al., 2016, 2018). Another species, *Deladenus* (=*Beddingia*) *sirícidicola,* parasitises *S. noctilio* and is considered worldwide as a key biological control agent against this pest (Slippers et al., 2012 and references therein). Kanzaki et al. (2018) observed that parasitised females of *S. nitobei* are smaller than healthy individuals and speculate that *D. nitobei* could have an impact on its host (reduced fecundity or sterility; reduced flight) similar to that of *D. siridicicola* on *S. noctilio*. Takatsuka (2007) reports an isolate of the entomopathogenic fungus *Beauveria bassiana* from *S. nitobei* in Japan.

Important features of the life history strategy of *S. nitobei* are summarised in Table 2.

Table 2: Important features of the life history strategy of *Sirex nitobei*

Life stage	Phenology and relation to host	Other relevant information
Eggs	Oviposition from late August to early November. A venom and a symbiotic fungus (*Amylostereum areolatum* or *A. chailletii*) are deposited at the same time as the egg(s).	Eggs laid singly, but several eggs can be laid, each in a separate branch of a same oviposition hole. One female can lay up to 500 mature eggs.
Larva/Nymph	The larvae live in the sapwood of the host trees and feed on lignocellulosic degradation products of the wood, obtained from their symbiotic fungi	
Pupa	Pupation occurs in the galleries	
Adult	They emerge from late August to early November, and live about four days	Nothing is known on the dispersal by flight of *S. nitobei*. However, in flight mill experiments with another species, *Sirex noctilio*, healthy females could fly up to 50 km (see Section 3.4.3)

3.1.3. Host range/Species affected

S. nitobei is considered a pest of commercial coniferous forests, mainly of *Pinus* and *Larix* species. In China, it is reported to attack *Pinus sylvestris* var. *mongolica*, *P. tabuliformis, P. armandii, P. thunbergia* and *P. massoniana* (Gao et al., 2021b). In Japan, it attacks damaged or moribund *P. densiflora, P. thunbergii* and *P. parviflora* (EFSA PLH Panel, 2019; Gao et al., 2021b). *Abies firma* has also been reported as a species affected by *S. nitobei* in Japan (Tabata et al., 2012). A list of hosts is provided in Appendix A.

3.1.4. Intraspecific diversity

No intraspecific diversity is reported for *S. nitobei*. However, the symbiotic fungus species has been observed to vary between individuals, with associations with either *Amylostereum areolatum* or *A.*

chailletii (Fitza et al., 2016). Intraspecific variation within *A. areolatum* has also been observed. Most *S. nitobei* carry *A. areolatum* IGS-D2 (characterised by the intergenic spacer (IGS) D2), but a few females carry *A. areolatum* IGS-B1D2 (MLG A13), presumably as a result from horizontal transmission from *S. noctilio*, when individuals of both species coexist in the same tree (Wang et al., 2021).

3.1.5. Detection and identification of the pest

Are detection and identification methods available for the pest?
Yes, detection and identification methods are available.

Detection

Attacked trees have discoloured foliage, lose their needles and some of them eventually die. White resin blobs appear on the surface of attacked trees after oviposition by *S. nitobei* (Kobayashi et al., 1978). Later, round emergence holes are visible on the trunks, and larval galleries can be found in the sapwood. The larvae have a small, dorsal 'horn' at the end of the abdomen (hence the common name 'horntail'). Figures 1 and 2 below relate to *Sirex noctilio*. *S. nitobei* causes similar symptoms but no pictures are available for this species. Because of a wide variability of size among *S. noctilio* adults, the diameter of their emergence holes varies largely (from about 3 to 7 mm). A similar variability is likely in *S. nitobei*.

Exit holes of *Sirex noctilio*.
Gyorgy Csoka, Hungary Forest Research Institute, Bugwood.org

Larva and larval gallery of *Sirex noctilio.*
Dennis Haugen, Bugwood.org

Figures 1 and 2: Symptoms of *Sirex* spp. attack

Identification

Full information about publications and a web site was kindly provided by Dr. D.R. Smith, emeritus at USDA, by email on 22 January 2022 (personal communication, Smith, 2022). *S. nitobei* is the only species with entirely black females in Japan and Korea. Diagnostic characteristics and pictures are available on the website of *Sawfly GenUS*, (Baine et al., 2019), which includes fact sheets and a key to the *Sirex* species of the world. Descriptions and keys have also been published by Takeuchi (1962), Naito et al. (2020) and Xiao and Wu (1983). Wang et al. (2020) used geometric morphometrics to compare the wing, ovipositor and cornus (the large hornlike projection on the last abdominal segment of the females, see Figure 3) of *S. noctilio* and *S. nitobei* but the practical use of this approach is unclear. Figures 3–6 show lateral and dorsal views of female and male *S. nitobei* adults. Fukuda and Hijii (1997) report that the ovipositor measures from 6 to 14 mm; from Figures 3 and 5, it can be deduced that the adult females measure 1–3 cm, approximately.

Gao et al. (2021a) have deposited the raw data of the *S. nitobei* venom transcriptome in GenBank (accession PRJNA718718). Guo et al. (2021) analysed 91 olfactory genes from *S. nitobei* (GenBank: accessions MK674426.1–MK674440.1; MK674448.1–MK674453.1; MK74930.1–MK749121.1). Sun et al. (2016) developed a species-specific cytochrome C oxidase subunit I (COI) PCR assay to identify *S. noctilio*, in the course of which the *S. nitobei* COI was also analysed.

The section on the suborder Symphyta of the *Hymenopterorum Catalogus* (van der Vecht and Shenefelt, eds.) is available online (Smith, 1977).

Figure 3: Lateral view of a *Sirex nitobei* female (size: 1–3 cm). Photo by J. Orr, WSDA, USDA APHIS PPQ ITP

Figure 4: Lateral view of a *Sirex nitobei* male. Photo by J. Orr, WSDA, USDA APHIS PPQ ITP

Figure 5: Dorsal view of a *Sirex nitobei* female. Photo by H. Goulet, CNC, USDA APHIS PPQ ITP, WSDA

Figure 6: Dorsal view of a *Sirex nitobei* male. Photo by J. Orr, WSDA, USDA APHIS PPQ ITP

Molecular techniques for species identification are available with a number of accessions in Genbank (see Section 2.1.2).

3.2. Pest distribution

3.2.1. Pest distribution outside the EU

S. nitobei is an Asian native wood wasp species. It is found in Japan (except in Hokkaidō according to Fukuda and Hijii, 1997), in China and in the Republic of Korea. It was first reported in China in 1980 and has currently spread into 13 provinces: Zhejiang, Beijing, Heilongjiang, Jilin, Liaoning, Inner Mongolia, Hebei, Shandong, Shaanxi, Gansu, Jiangsu, Anhui and Yunnan (Gao et al., 2021b) (Figure 7; Appendix B).

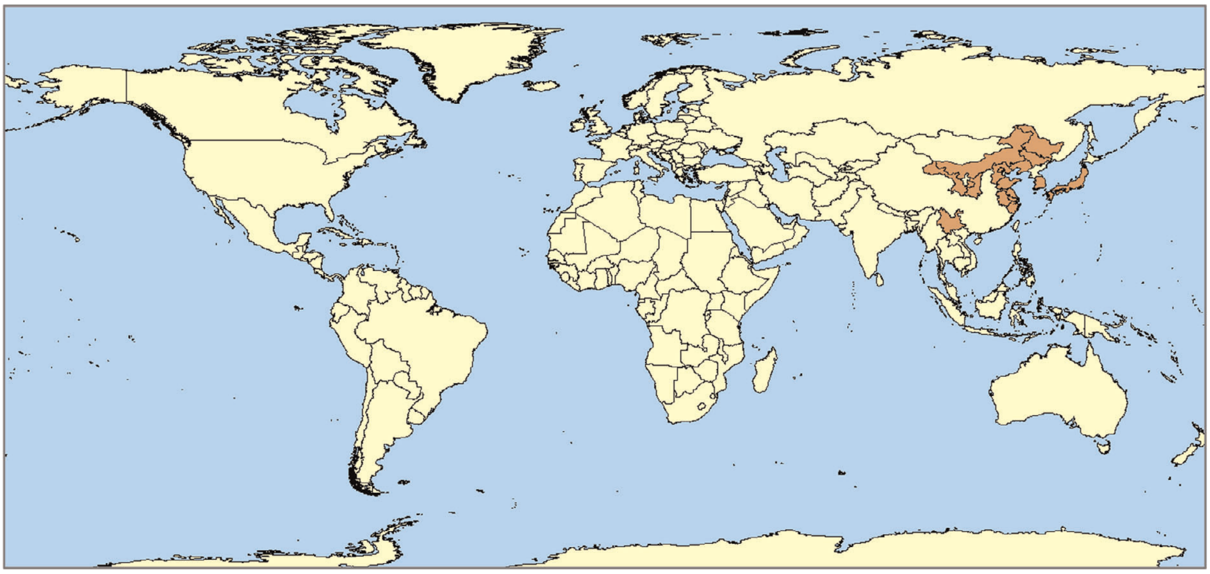

Figure 7: Global distribution of *Sirex nitobei* (Data source: EFSA PLH Panel, 2019; Gao et al., 2021b)

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. *Sirex nitobei* is not known to occur in the EU.

3.3. Regulatory status

3.3.1. Commission Implementing Regulation 2019/2072

S. nitobei is not listed in Annex II of Commission Implementing Regulation (EU) 2019/2072, an implementing act of Regulation (EU) 2016/2031, or in any emergency plant health legislation.

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

A number of *S. nitobei* hosts are prohibited from entering the EU under specific conditions (Table 3).

Table 3: List of plants, plant products and other objects that are *Sirex nitobei* 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 *Abies* Mill., *Cedrus* Trew, *Chamaecyparis* Spach, *Juniperus* L., *Larix* Mill., *Picea* A. Dietr., *Pinus* L., *Pseudotsuga* Carr. and *Tsuga* Carr., 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, Turkey, Ukraine and the United Kingdom

3.3.3. Legislation addressing the organisms vectored by Sirex nitobei (Commission Implementing Regulation 2019/2072)

The females of *S. nitobei* vector the white rot Basidiomycete fungi *Amylostereum areolatum* and *A. chailletii*. These fungal species are native to the EU and therefore are not included in the Annexes of Commission Implementing Regulation 2019/2072.

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, in principle the pest is able to enter into the EU territory, either with infested wood, wood packaging material or with plants for planting.

Comment on plants for planting as a pathway

The pathway is regulated and closed, except for a derogation regarding the import of artificially dwarfed Japanese black pine (*Pinus thunbergii* Parl.) from Japan (EFSA PLH Panel, 2019).

Table 4 provides broad descriptions of potential pathways for the entry of *S. nitobei* into the EU.

Table 4: Potential pathways for *Sirex nitobei* 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]**
Plants for planting	Eggs, larvae and pupae	Conifer plants for planting, potential hosts of *S. nitobei,* are prohibited to import from third countries (Regulation 2019/2072, Annex VI), (Table 3). There is derogation for artificially dwarfed pines (Regulation 2020/1217).
Conifer wood	Eggs, larvae and pupae	Wood of conifers hosts of *S. nitobei* imported from third countries is submitted to special requirements (Regulation 2019/2072, Annex VII, 76-77., Annex XI, part A.)
Wood packaging material	Larvae and pupae	ISPM 15 (measures)

Notifications of interceptions of harmful organisms began to be compiled in Europhyt in May 1994 and in TRACES in May 2020. As of 7 February 2022, there were no records of interception or outbreaks of *S. nitobei* in the Europhyt and TRACES databases. The UK have no interceptions reports of Siricidae in wood from Asia. However, on 6 October 2020, an interception of a pest belonging to the family Siricidae was recorded in the Czech Republic on wood packaging material imported from China, without indicating the species. It is reported that 'Wood packaging material was infested by living stages of pests despite marking of appropriate treatment'.

Unless moved with plants for planting (i.e. artificially dwarfed plants), there are uncertainties over the pests' ability to transfer to a suitable host following arrival into the EU. Since *S. nitobei* is likely to enter in small numbers in infested wood, uncertainties also include its ability to find a mate and other Allee effects (effects causing reduced survival of new colonies with a small number of individuals) (Tobin et al., 2011) as well as the impact of natural enemies in the EU.

3.4.2. Establishment

Is the pest able to become established in the EU territory?
Yes, there are areas in the EU territory with suitable climate and host plants.

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 et al., 2000; Baker, 2002). 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

Pinus spp. are major hosts of *S. nitobei*, distributed throughout the European territory (Figure 8).

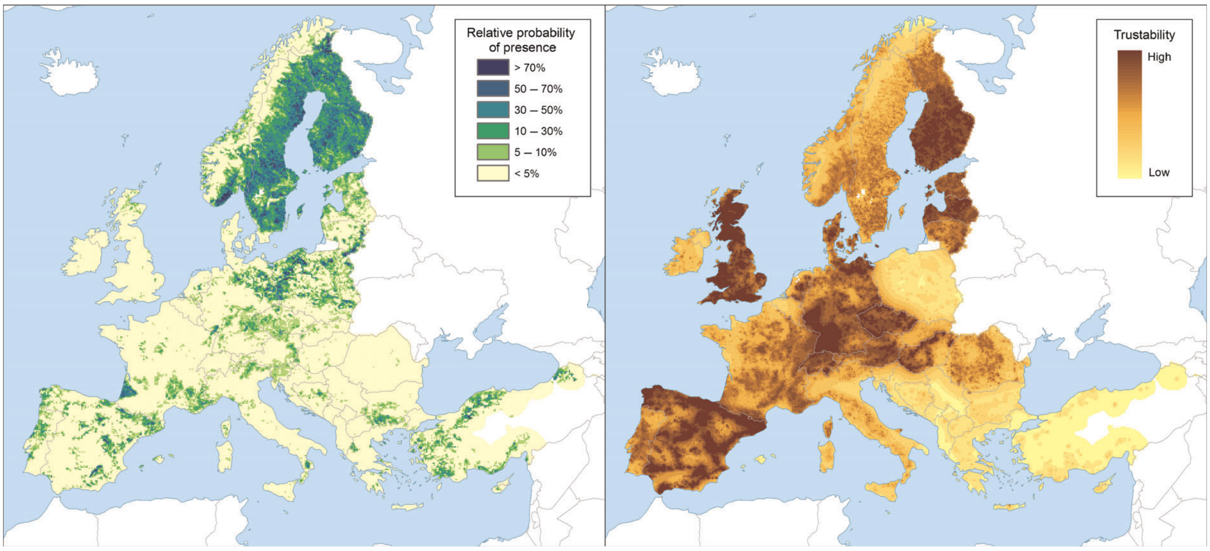

Figure 8: Left panel: Relative probability of presence (RPP) of the genus *Pinus* in Europe, mapped at 100 km^2 resolution. The underlying data are from European-wide forest monitoring data sets and from national forestry inventories based on standard observation plots measuring in the order of hundreds 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

Figure 9 shows that some Köppen-–Geiger climatic zones (Kottek et al., 2006) in the present distribution area of *S. nitobei* are also present in the EU territory, notably Cfa and Cfb, suggesting that a large climatic suitable territory would be available for the pest.

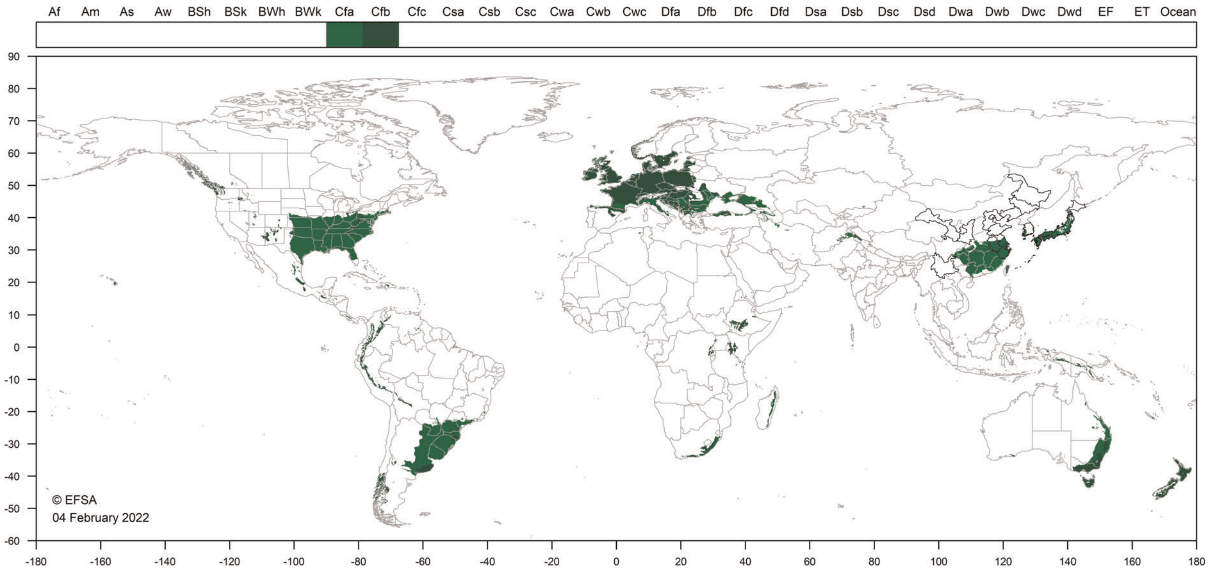

Figure 9: World distribution of two Köppen–Geiger climate types, Cfa, Cfb that occur in the EU and in countries where *Sirex nitobei* has been reported

Gao et al. (2021b) used a maximum entropy model to predict the potentially suitable areas for *S. nitobei* around the world. They found that 'the high and moderately suitable areas of *S. nitobei* are mainly concentrated in China, Japan, South Korea and North Korea'. The main drivers were the monthly total precipitation in July, the monthly average maximum temperature in February, the monthly average minimum temperature in July and the monthly total precipitation in December.

The areas identified by Gao et al. (2021b) as suitable for establishment overlap with Köppen-Geiger climate type Cfa which occurs in the EU (Figure 9).

3.4.3. Spread

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

The pest would be able to spread by flight, and with infested material (plants for planting and wood).

Comment on plants for planting as a mechanism of spread

Plant for planting would have to be of a minimal size to accommodate larvae capable to metamorphose into a 3 cm-long adult (see Section 3.1.5).

There is no direct information regarding the flight capacity of *S. nitobei*. However, Corley and Villacide (2012) measured the flight of *S. noctilio* in flight mill experiments and found that a healthy female wasp flew on the average 17.4 km during a one day-long trial, with one insect flying 49.7 km. Flight was also influenced by infection by *Deladenus siridicicola* (infected wasps flew shorter distances) as well as by body size and weight (larger, heavier individuals flew faster and longer).

The pest can also travel fast with commercial goods. Gao et al. (2021b) report that, between 1980 (date of the earliest record in China) and 2020, *S. nitobei* has 'expanded 1,750 km southwest, 1,450 km northwest, and 2,200 km northeast from the earliest discovery place'.

3.5. Impacts

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

YES, the pests' introduction could have an economic or environmental impact on the EU territory, although the species is not very aggressive in its original range. A close relative, *Sirex noctilio*, which is almost harmless in Europe, is considered a major pest following introduction in other parts of the world.

In Japan, *S. nitobei* mainly attacks weakened trees (Kobayashi et al., 1978) or freshly felled trees (Fukuda and Hijii, 1996a,b). In China, Gao et al. (2021a) refer to 'considerable economic and ecological damage' on *Pinus sylvestris* var. *mongolica* in Inner Mongolia, but the reference they cite (Wang et al., 2020) concerns *S. noctilio*. Thus, the most reliable literature does not highlight *S. nitobei* as an important pest in its original (Japan) or newly invaded range (China, the Republic of Korea).

However, the case of *S. noctilio* illustrates the fact that an innocuous insect in its home range could become a major pest in newly invaded areas. In Europe, the wasp mostly attacks dead or weakened pines, and populations increase only under dry conditions that inflict an additional stress to the trees (Wermelinger and Thomsen, 2012). But when *S. noctilio* moved to New Zealand, it inflicted massive damage in plantations of *Pinus radiata*. In a bioeconomic model for *S. noctilio* in eastern Canada, Yemshanov et al. (2009) estimate that the total harvest losses of local pines after 28 years of *S. noctilio* presence at CAN $0.7 to $2.1 billion. However, as in Europe, the harmfulness of *S. noctilio* seems to depend on the general state of health of the trees or the stands (see e.g. Cameron, 2012). Dodds et al. (2010) compared *Pinus resinosa* and *P. sylvestris* plantations in New York, USA, and Ontario, Canada, and found that the pest preferred weakened trees. However, the European *P. sylvestris* was more attacked than *P. resinosa*. They also suggested that silvicultural treatments could influence tree and stand resistance to the pest.

In conclusion, the pest does not appear to cause major damage in its area of origin. However, it has the potential to become harmful, as observed with *S. noctilio* outside of its original range.

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, prohibitions or special requirements are available (see Table 4, in section 3.4.1).

3.6.1. Identification of potential additional measures

Phytosanitary measures are currently applied to host plants for planting (conifer prohibitions), as well as to wood (special requirements). See Table 3 in Section 3.3.2. Several measures that are already in place target *Bursaphelenchus xylophilus* and are probably effective against *S. nitobei,* although the sensitivity of this pest to heat and kiln-drying is not yet known.

Additional potential risk reduction options and supporting measures are shown in Sections 3.6.1.1 and 3.6.1.2.

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	Pest free place of production (e.g. place of production and its immediate vicinity is free from pest over an appropriate time period, e.g. since the beginning of the last complete cycle of vegetation, or past 2 or 3 cycles). Pest free production site	Entry of artificially dwarfed black pines (*P. thunbergii*) from Japan, under derogation
Growing plants in isolation	Place of production is insect proof originate in a place of production with complete physical isolation	Entry of artificially dwarfed black pines (*P. thunbergii*) from Japan, under derogation
Managed growing conditions	Plants collected directly from natural habitats, have been grown, held and trained for at least two consecutive years prior to dispatch in officially registered nurseries, which are subject to an officially supervised control regime	Entry of artificially dwarfed black pines (P. thunbergii) from Japan, under derogation
Roguing and pruning	Sanitary thinning or clearfelling	Establishment/Spread/ Impact
Biological control and behavioural manipulation	Biological control is successfully implemented worldwide against *S. noctilio*, and similar natural enemies of *S. nitobei* exist in its present area	Spread/Impact
Chemical treatments on crops including reproductive material	Widespread use of insecticides in forestry is prohibitively expensive, environmentally damaging and inefficient against wood borers, even for eradicating a small outbreak in the EU. However, systemic insecticides could be used in nurseries.	Entry/Spread/Impact
Chemical treatments on consignments or during processing	Use of chemical compounds that may be applied to plants or to plant products after harvest, during process or packaging operations and storage. The treatments addressed in this information sheet are: a) fumigation; b) spraying/dipping pesticides; c) surface disinfectants; d) process additives; e) protective compounds	Entry/Establishment
Physical treatments on consignments or during processing	This information sheet deals with the following categories of physical treatments: irradiation/ionisation; mechanical cleaning (brushing, washing); sorting and grading, and; removal of plant parts (e.g. debarking wood). This information sheet does not address: heat and cold treatment (information sheet 1.14); roguing and pruning (information sheet 1.12).	Entry/Establishment/Spread
Waste management	Treatment of the waste (deep burial, composting, incineration, chipping, production of bio-energy, etc.) in authorised facilities and official restriction on the movement of waste.	Establishment/Spread
Heat and cold treatments	Controlled temperature treatments aimed to kill or inactivate pests without causing any unacceptable prejudice to the treated material itself. The measures addressed in this information sheet are: autoclaving; steam; hot water; hot air; cold treatment	Entry/Establishment/Spread

Control measure/ Risk reduction option (Blue underline = Zenodo doc, Blue = WIP)	RRO summary	Risk element targeted (entry/establishment/ spread/impact)
Controlled atmosphere	Treatment of plants by storage in a modified atmosphere (including modified humidity, O_2, CO_2, temperature, pressure).	Entry/Spread (via commodity)
Post-entry quarantine and other restrictions of movement in the importing country	Imported plants for planting can be subject to post-entry quarantine to ensure they are free from *S. nitobei*, before they are released.	Establishment/Spread

3.6.1.2. Additional supporting measures

Potential additional supporting measures are listed in Table 6.

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	Summary	Risk element targeted (entry/establishment/ spread/impact)
Inspection and trapping	Inspection is defined as the official visual examination of plants, plant products or other regulated articles to determine if pests are present or to determine compliance with phytosanitary regulations (ISPM 5). The effectiveness of sampling and subsequent inspection to detect pests may be enhanced by including trapping and luring techniques. No pest or symptoms detected at the place of production since the beginning of the last complete cycle of vegetation; Inspected prior to export and no pest found or symptoms detected, (could include testing)	Entry
Laboratory testing	Examination, other than visual, to determine if pests are present using official diagnostic protocols. Diagnostic protocols describe the minimum requirements for reliable diagnosis of regulated pests.	Entry
Sampling	According to ISPM 31, it is usually not feasible to inspect entire consignments, so phytosanitary inspection is performed mainly on samples obtained from a consignment. It is noted that the sampling concepts presented in this standard may also apply to other phytosanitary procedures, notably selection of units for testing. For inspection, testing and/or surveillance purposes the sample may be taken according to a statistically based or a non-statistical sampling methodology.	Entry
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) Export certificate (import)	Entry

Supporting measure	Summary	Risk element targeted (entry/establishment/spread/impact)
Certified and approved premises	Mandatory/voluntary certification/approval of premises is a process including a set of procedures and of actions implemented by producers, conditioners and traders contributing to ensure the phytosanitary compliance of consignments. It can be a part of a larger system maintained by the NPPO in order to guarantee the fulfilment of plant health requirements of plants and plant products intended for trade. Key property of certified or approved premises is the traceability of activities and tasks (and their components) inherent the pursued phytosanitary objective. Traceability aims to provide access to all trustful pieces of information that may help to prove the compliance of consignments with phytosanitary requirements of importing countries.	Entry
Delimitation of Buffer zones	ISPM 5 defines a buffer zone as 'an area surrounding or adjacent to an area officially delimited for phytosanitary purposes in order to minimize the probability of spread of the target pest into or out of the delimited area, and subject to phytosanitary or other control measures, if appropriate' (ISPM 5). The objectives for delimiting a buffer zone can be to prevent spread from the outbreak area and to maintain a pest free production place (PFPP), site (PFPS) or area (PFA).	Spread
Surveillance		Spread

3.6.1.3. Biological or technical factors limiting the effectiveness of measures

- The pest develops in the sapwood and cannot always be seen from the outside of the trees if symptoms (resin blobs, round exit holes) are lacking.
- No description of the larvae is available.
- There is no direct information about the flight capacity of *S. nitobei*.

3.7. Uncertainty

- It is unclear whether *S. nitobei* is absent from Hokkaidô because of the availability of host trees (pines are rare on the island) or for climatic reasons.
- Although *S. nitobei* is described in Japan as attacking weakened or freshly felled trees, it is considered as a pest in China (Gao et al., 2021a), although without substantial justification.

These uncertainties do not affect the categorisation conclusions because they do not substantially reduce the capacity for entry, establishment, spread and impact of the pest.

4. Conclusions

S. nitobei 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 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	Panel's conclusions against criterion in Regulation (EU) 2016/2031 regarding Union quarantine pest	Key uncertainties (casting doubt on the conclusion)
Identity of the pest (Section 3.1)	The identity of *S. nitobei* has been established	None

Criterion of pest categorisation	Panel's conclusions against criterion in Regulation (EU) 2016/2031 regarding Union quarantine pest	Key uncertainties (casting doubt on the conclusion)
Absence/presence of the pest in the EU (Section 3.2)	The pest is absent from the EU territory	None
Pest potential for entry, establishment and spread in the EU (Section 3.4)	*S. nitobei* could enter into, establish in and spread within the EU territory. The main pathways are plants for planting and conifer wood.	None
Potential for consequences in the EU (Section 3.5)	Should *S. nitobei* be introduced into the EU, an economic impact might occur although the species is not very aggressive in its original range. A close relative, *Sirex noctilio*, which is almost harmless in Europe, is considered a major pest following introduction in other parts of the world.	There is a possibility that *S. nitobei* would attack mainly weakened or freshly felled trees.
Available measures (Section 3.6)	There are measures available to prevent the likelihood of entry into the EU (i.e. import of plants for planting and of conifer wood is prohibited or submitted to special requirements).	None
Conclusion (Section 4)	*S. nitobei* satisfies all of 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:		

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Abbreviations

C-SMFA	spatial multi-scale frequency analysis
CLC	Corine Land Cover
DG SANTÉ	Directorate General for Health and Food Safety
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
RPP	relative probability of presence
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. 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, 2018)

Appendix A – *Sirex nitobei* host plants/species affected

Host status	Host name	Plant family	Common name	Reference
Cultivated hosts	*Abies firma*	Pinaceae	Japanese fir	Tabata et al. (2012)
	Larix spp.	Pinaceae		Gao et al. (2021b)
	Larix leptolepis	Pinaceae	Japanese larch	Smith (1978)
	Pinus spp.	Pinaceae		EFSA PLH Panel (2019)
	Pinus armandii	Pinaceae	Chinese white pine	Gao et al. (2021b)
	Pinus densiflora	Pinaceae	Japanese red pine	Tabata et al. (2012)
	Pinus massoniana	Pinaceae	Chinese pine	Gao et al. (2021b)
	Pinus parviflora	Pinaceae	Japanese white pine	EFSA PLH Panel (2019)
	Pinus sylvestris var. *mongolica*	Pinaceae		Gao et al. (2021b)
	Pinus. tabuliformis	Pinaceae	Chinese red pine	Gao et al. (2021b)
	Pinus thunbergii	Pinaceae	Japanese black pine	EFSA PLH Panel (2019)

Appendix B – Distribution of *Sirex nitobei*

Region	Country	Sub-national (e.g. State)	Status	Reference
Asia	China		Present	Gao et al. (2021b)
		Anhui	Present	Gao et al. (2021b)
		Beijing	Present	Gao et al. (2021b)
		Gansu	Present	Gao et al. (2021b)
		Hebei	Present	Gao et al. (2021b)
		Heilongjiang	Present	Gao et al. (2021b)
		Inner Mongolia	Present	Gao et al. (2021b)
		Jilin	Present	Gao et al. (2021b)
		Jiangsu	Present	Gao et al. (2021b)
		Liaoning	Present	Gao et al. (2021b)
		Shaanxi	Present	Gao et al. (2021b)
		Shandong	Present	Gao et al. (2021b)
		Yunnan	Present	Gao et al. (2021b)
		Zhejiang	Present	Gao et al. (2021b)
	Japan (except Hokkaidō)		Present, widespread	EFSA PLH Panel (2019) Fukuda and Hijii (1997)
	Republic of Korea		Present, no details	Gao et al. (2021b)

Appendix C – Methodological notes on Figure 8

The relative probability of presence (RPP) reported here for *Pinus* spp. in Figure 8 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 data sets 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 et al., 2016; San-Miguel-Ayanz, 2016). All data sets 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, https://spatialreference.org/ref/epsg/etrs89-etrs-laea/).

European National Forestry Inventories database This data set derived from National Forest Inventory data and provides information on the presence/absence of forest tree species in approximately 375000 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 and Hiederer, 2009). The complete Forest Focus data set covers 30 European Countries with more than 8,600 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 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 was recorded for more than 3,300 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 3,200 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 (EUFGIS, 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 6,254 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

[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.

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 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, it 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 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 data sets is applied instead of selecting a local 'best preforming' 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, 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.