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Pest categorisation of *Ips cembrae*

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Abstract

The Panel on Plant Health performed a pest categorisation of the large larch bark beetle, *Ips cembrae* (Heer) (Coleoptera: Curculionidae, Scolytinae), for the EU. *I. cembrae* is a well-defined and distinguishable species, native to Europe and recognised mainly as a pest of larch (*Larix* spp.) and occasionally of pine (*Pinus* spp.) and spruce (*Picea* spp.). It is distributed in 16 Member States of the EU and listed in Annex IIB of Council Directive 2000/29/EC. Protected zones are in place in Greece, Ireland and the United Kingdom (Northern Ireland and Isle of Man). Wood, wood products, bark and wood packaging material are considered as pathways for this pest, which is also able to disperse by flight. The insects normally establish on fallen or weakened trees but, when their populations are high, can also mass-attack healthy trees. The males produce aggregation pheromones that attract conspecifics of both sexes. The insects also inoculate pathogenic fungi to their hosts. There are one to two generations per year. Before establishing their broods, the young adults need to proceed to maturation feeding either within the bark of the tree where they developed or in 2–18 years old twigs. *I. cembrae* has been expanding its geographical range in Europe during the second half of the 20th century. Sanitary thinning or clear felling is the major control methods. Quarantine measures are implemented to prevent entry in the protected zones. All criteria for consideration as potential protected zone quarantine pest are met. The criteria for considering *I. cembrae* as a potential regulated non-quarantine pest are not met since plants for planting are not viewed as a major pathway.

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Keywords: Curculionidae, European Union, large larch bark beetle, pest risk, plant health, plant pest, quarantine

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1. Introduction

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

1.1.1. Background

Council Directive 2000/29/EC[1] on protective measures against the introduction into the Community of organisms harmful to plants or plant products and against their spread within the Community establishes the present European Union plant health regime. The Directive lays down the phytosanitary provisions and the control checks to be carried out at the place of origin on plants and plant products destined for the Union or to be moved within the Union. In the Directive's 2000/29/EC annexes, the list of harmful organisms (pests) whose introduction into or spread within the Union is prohibited, is detailed together with specific requirements for import or internal movement.

Following the evaluation of the plant health regime, the new basic plant health law, Regulation (EU) 2016/2031[2] on protective measures against pests of plants, was adopted on 26 October 2016 and will apply from 14 December 2019 onwards, repealing Directive 2000/29/EC. In line with the principles of the above mentioned legislation and the follow-up work of the secondary legislation for the listing of EU regulated pests, EFSA is requested to provide pest categorizations of the harmful organisms included in the annexes of Directive 2000/29/EC, in the cases where recent pest risk assessment/pest categorisation is not available.

1.1.2. Terms of Reference

EFSA is requested, pursuant to Article 22(5.b) and Article 29(1) of Regulation (EC) No 178/2002[3], to provide scientific opinion in the field of plant health.

EFSA is requested to prepare and deliver a pest categorisation (step 1 analysis) for each of the regulated pests included in the appendices of the annex to this mandate. The methodology and template of pest categorisation have already been developed in past mandates for the organisms listed in Annex II Part A Section II of Directive 2000/29/EC. The same methodology and outcome is expected for this work as well.

The list of the harmful organisms included in the annex to this mandate comprises 133 harmful organisms or groups. A pest categorisation is expected for these 133 pests or groups and the delivery of the work would be stepwise at regular intervals through the year as detailed below. First priority covers the harmful organisms included in Appendix 1, comprising pests from Annex II Part A Section I and Annex II Part B of Directive 2000/29/EC. The delivery of all pest categorisations for the pests included in Appendix 1 is June 2018. The second priority is the pests included in Appendix 2, comprising the group of Cicadellidae (non-EU) known to be vector of Pierce's disease (caused by *Xylella fastidiosa*), the group of Tephritidae (non-EU), the group of potato viruses and virus-like organisms, the group of viruses and virus-like organisms of Cydonia Mill., Fragaria L., Malus Mill., Prunus L., Pyrus L., Ribes L., Rubus L. and Vitis L.. and the group of Margarodes (non-EU species). The delivery of all pest categorisations for the pests included in Appendix 2 is end 2019. The pests included in Appendix 3 cover pests of Annex I part A section I and all pests categorisations should be delivered by end 2020.

For the above mentioned groups, each covering a large number of pests, the pest categorisation will be performed for the group and not the individual harmful organisms listed under "such as" notation in the Annexes of the Directive 2000/29/EC. The criteria to be taken particularly under consideration for these cases, is the analysis of host pest combination, investigation of pathways, the damages occurring and the relevant impact.

Finally, as indicated in the text above, all references to 'non-European' should be avoided and replaced by 'non-EU' and refer to all territories with exception of the Union territories as defined in Article 1 point 3 of Regulation (EU) 2016/2031.

[1] Council Directive 2000/29/EC of 8 May 2000 on protective measures against the introduction into the Community of organisms harmful to plants or plant products and against their spread within the Community. OJ L 169/1, 10.7.2000, p. 1–112.

[2] Regulation (EU) 2016/2031 of the European Parliament of the Council of 26 October 2016 on protective measures against pests of plants. OJ L 317, 23.11.2016, p. 4–104.

[3] Regulation (EC) No 178/2002 of the European Parliament and of the Council of 28 January 2002 laying down the general principles and requirements of food law, establishing the European Food Safety Authority and laying down procedures in matters of food safety. OJ L 31/1, 1.2.2002, p. 1–24.

1.1.2.1. Terms of Reference: Appendix 1

List of harmful organisms for which pest categorisation is requested. The list below follows the annexes of Directive 2000/29/EC.

Annex IIAI

(a) Insects, mites and nematodes, at all stages of their development

Aleurocantus spp.
Anthonomus bisignifer (Schenkling)
Anthonomus signatus (Say)
Aschistonyx eppoi Inouye
Carposina niponensis Walsingham
Enarmonia packardi (Zeller)
Enarmonia prunivora Walsh
Grapholita inopinata Heinrich
Hishomonus phycitis
Leucaspis japonica Ckll.
Listronotus bonariensis (Kuschel)
Numonia pyrivorella (Matsumura)
Oligonychus perditus Pritchard and Baker
Pissodes spp. (non-EU)
Scirtothrips aurantii Faure
Scirtothrips citri (Moultex)
Scolytidae spp. (non-EU)
Scrobipalpopsis solanivora Povolny
Tachypterellus quadrigibbus Say
Toxoptera citricida Kirk.
Unaspis citri Comstock

(b) Bacteria

Citrus variegated chlorosis
Erwinia stewartii (Smith) Dye
Xanthomonas campestris pv. *oryzae* (Ishiyama) Dye and pv. *oryzicola* (Fang. et al.) Dye

(c) Fungi

Alternaria alternata (Fr.) Keissler (non-EU pathogenic isolates)
Anisogramma anomala (Peck) E. Müller
Apiosporina morbosa (Schwein.) v. Arx
Ceratocystis virescens (Davidson) Moreau
Cercoseptoria pini-densiflorae (Hori and Nambu) Deighton
Cercospora angolensis Carv. and Mendes
Elsinoe spp. Bitanc. and Jenk. Mendes
Fusarium oxysporum f. sp. *albedinis* (Kilian and Maire) Gordon
Guignardia piricola (Nosa) Yamamoto
Puccinia pittieriana Hennings
Stegophora ulmea (Schweinitz: Fries) Sydow & Sydow
Venturia nashicola Tanaka and Yamamoto

(d) Virus and virus-like organisms

Beet curly top virus (non-EU isolates)
Black raspberry latent virus
Blight and blight-like
Cadang-Cadang viroid
Citrus tristeza virus (non-EU isolates)
Leprosis
Little cherry pathogen (non- EU isolates)
Naturally spreading psorosis
Palm lethal yellowing mycoplasm
Satsuma dwarf virus
Tatter leaf virus
Witches' broom (MLO)

Annex IIB

(a) Insect mites and nematodes, at all stages of their development

Anthonomus grandis (Boh.)
Cephalcia lariciphila (Klug)
Dendroctonus micans Kugelan
Gilphinia hercyniae (Hartig)
Gonipterus scutellatus Gyll.
Ips amitinus Eichhof
Ips typographus Heer
Ips duplicatus Sahlberg
Ips sexdentatus Börner
Ips typographus Heer
Sternochetus mangiferae Fabricius

(b) Bacteria

Curtobacterium flaccumfaciens pv. flaccumfaciens (Hedges) Collins and Jones

(c) Fungi

Glomerella gossypii Edgerton

Gremmeniella abietina (Lag.) Morelet

Hypoxylon mammatum (Wahl.) J. Miller

1.1.2.2. Terms of Reference: Appendix 2

List of harmful organisms for which pest categorisation is requested per group. The list below follows the categorisation included in the annexes of Directive 2000/29/EC.

Annex IAI

(a) Insects, mites and nematodes, at all stages of their development

Group of Cicadellidae (non-EU) known to be vector of Pierce's disease (caused by *Xylella fastidiosa*), such as:

1) *Carneocephala fulgida* Nottingham
2) *Draeculacephala minerva* Ball
3) *Graphocephala atropunctata* (Signoret)

Group of Tephritidae (non-EU) such as:

1) *Anastrepha fraterculus* (Wiedemann)
2) *Anastrepha ludens* (Loew)
3) *Anastrepha obliqua* Macquart
4) *Anastrepha suspensa* (Loew)
5) *Dacus ciliatus* Loew
6) *Dacus curcurbitae* Coquillet
7) *Dacus dorsalis* Hendel
8) *Dacus tryoni* (Froggatt)
9) *Dacus tsuneonis* Miyake
10) *Dacus zonatus* Saund.
11) *Epochra canadensis* (Loew)
12) *Pardalaspis cyanescens* Bezzi
13) *Pardalaspis quinaria* Bezzi
14) *Pterandrus rosa* (Karsch)
15) *Rhacochlaena japonica* Ito
16) *Rhagoletis completa* Cresson
17) *Rhagoletis fausta* (Osten-Sacken)
18) *Rhagoletis indifferens* Curran
19) *Rhagoletis mendax* Curran
20) *Rhagoletis pomonella* Walsh
21) *Rhagoletis suavis* (Loew)

(c) Viruses and virus-like organisms

Group of potato viruses and virus-like organisms such as:

1) Andean potato latent virus
2) Andean potato mottle virus
3) Arracacha virus B, oca strain
4) Potato black ringspot virus
5) Potato virus T
6) non-EU isolates of potato viruses A, M, S, V, X and Y (including Yo, Yn and Yc) and Potato leafroll virus

Group of viruses and virus-like organisms of Cydonia Mill., Fragaria L., Malus Mill., Prunus L., Pyrus L., Ribes L.,Rubus L. and Vitis L., such as:

1) Blueberry leaf mottle virus
2) Cherry rasp leaf virus (American)
3) Peach mosaic virus (American)
4) Peach phony rickettsia
5) Peach rosette mosaic virus
6) Peach rosette mycoplasm
7) Peach X-disease mycoplasm
8) Peach yellows mycoplasm
9) Plum line pattern virus (American)
10) Raspberry leaf curl virus (American)
11) Strawberry witches' broom mycoplasma
12) Non-EU viruses and virus-like organisms of *Cydonia Mill., Fragaria L., Malus Mill., Prunus L., Pyrus L., Ribes L., Rubus L.* and *Vitis L.*

Annex IIAI

(a) Insects, mites and nematodes, at all stages of their development

Group of *Margarodes* (non-EU species) such as:

1) *Margarodes vitis* (Phillipi)
2) *Margarodes vredendalensis* de Klerk
3) *Margarodes prieskaensis* Jakubski

1.1.2.3. Terms of Reference: Appendix 3

List of harmful organisms for which pest categorisation is requested. The list below follows the annexes of Directive 2000/29/EC.

Annex IAI

(a) Insects, mites and nematodes, at all stages of their development

Acleris spp. (non-EU)
Amauromyza maculosa (Malloch)
Anomala orientalis Waterhouse
Arrhenodes minutus Drury
Choristoneura spp. (non-EU)
Conotrachelus nenuphar (Herbst)
Dendrolimus sibiricus Tschetverikov
Diabrotica barberi Smith and Lawrence
Diabrotica undecimpunctata howardi Barber
Diabrotica undecimpunctata undecimpunctata Mannerheim
Diabrotica virgifera zeae Krysan & Smith
Diaphorina citri Kuway
Heliothis zea (Boddie)
Hirschmanniella spp., other than *Hirschmanniella gracilis* (de Man) Luc and Goodey
Liriomyza sativae Blanchard
Longidorus diadecturus Eveleigh and Allen
Monochamus spp. (non-EU)
Myndus crudus Van Duzee
Nacobbus aberrans (Thorne) Thorne and Allen
Naupactus leucoloma Boheman
Premnotrypes spp. (non-EU)
Pseudopityophthorus minutissimus (Zimmermann)
Pseudopityophthorus pruinosus (Eichhoff)
Scaphoideus luteolus (Van Duzee)
Spodoptera eridania (Cramer)
Spodoptera frugiperda (Smith)
Spodoptera litura (Fabricus)
Thrips palmi Karny
Xiphinema americanum Cobb sensu lato (non-EU populations)
Xiphinema californicum Lamberti and Bleve-Zacheo

(b) Fungi

Ceratocystis fagacearum (Bretz) Hunt
Chrysomyxa arctostaphyli Dietel
Cronartium spp. (non-EU)
Endocronartium spp. (non-EU)
Guignardia laricina (Saw.) Yamamoto and Ito
Gymnosporangium spp. (non-EU)
Inonotus weirii (Murril) Kotlaba and Pouzar
Melampsora farlowii (Arthur) Davis
Mycosphaerella larici-leptolepis Ito et al.
Mycosphaerella populorum G. E. Thompson
Phoma andina Turkensteen
Phyllosticta solitaria Ell. and Ev.
Septoria lycopersici Speg. var. *malagutii* Ciccarone and Boerema
Thecaphora solani Barrus
Trechispora brinkmannii (Bresad.) Rogers

(c) Viruses and virus-like organisms

Tobacco ringspot virus
Tomato ringspot virus
Bean golden mosaic virus
Cowpea mild mottle virus
Lettuce infectious yellows virus
Pepper mild tigré virus
Squash leaf curl virus
Euphorbia mosaic virus
Florida tomato virus

(d) Parasitic plants

Arceuthobium spp. (non-EU)

Annex IAII

(a) Insects, mites and nematodes, at all stages of their development

Meloidogyne fallax Karssen
Popillia japonica Newman
Rhizoecus hibisci Kawai and Takagi

(b) Bacteria

Clavibacter michiganensis (Smith) Davis et al. ssp. *sepedonicus* (Spieckermann and Kotthoff) Davis et al.
Ralstonia solanacearum (Smith) Yabuuchi et al.

(c) Fungi

Melampsora medusae Thümen
Synchytrium endobioticum (Schilbersky) Percival

Annex I B

(a) Insects, mites and nematodes, at all stages of their development

Leptinotarsa decemlineata Say
Liriomyza bryoniae (Kaltenbach)

(b) Viruses and virus-like organisms

Beet necrotic yellow vein virus

1.2. Interpretation of the Terms of Reference

Ips cembrae is one of a number of pests listed in the Appendices to the Terms of Reference (ToR) to be subject to pest categorisation to determine whether it fulfils the criteria of a quarantine pest or those of a regulated non-quarantine pest (RNQP) for the area of the European Union (EU) excluding Ceuta, Melilla and the outermost regions of Member States (MSs) referred to in Article 355 (1) of the Treaty on the Functioning of the European Union (TFEU), other than Madeira and the Azores.

Since *I. cembrae* is regulated in the protected zones (PZs) only, the scope of the categorisation is the territory of the PZ (Greece, Ireland and the United Kingdom: Northern Ireland, Isle of Man); thus, the criteria refer to the PZ instead of the EU territory.

2. Data and methodologies

2.1. Data

2.1.1. Literature search

A literature search on *I. cembrae* 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. Relevant papers 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, 2017) as well as from the relevant literature.

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

The Europhyt database was consulted for pest-specific notifications on interceptions and outbreaks. Europhyt is a web-based network launched by the Directorate General for Health and Consumers (DG SANCO) and is a subproject of PHYSAN (Phyto-Sanitary Controls) specifically concerned with plant health information. The Europhyt database manages 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 MSs and the phytosanitary measures taken to eradicate or avoid their spread.

2.2. Methodologies

The Panel performed the pest categorisation for *I. cembrae*, following guiding principles and steps presented in the EFSA guidance on the harmonised framework for pest risk assessment (EFSA PLH Panel, 2010) and as defined in the International Standard for Phytosanitary Measures No 11 (FAO, 2013) and No 21 (FAO, 2004).

In accordance with the guidance on a harmonised framework for pest risk assessment in the EU (EFSA PLH Panel, 2010), this work was initiated following an evaluation of the EU's plant health regime. Therefore, to facilitate the decision-making process, in the conclusions of the pest categorisation, the Panel addresses explicitly each criterion for a Union quarantine pest and for a Union RNQP in accordance with Regulation (EU) 2016/2031 on protective measures against pests of plants and includes additional information required in accordance with the specific ToR received by the European Commission. In addition, for each conclusion, the Panel provides a short description of its associated uncertainty.

Table 1 presents the Regulation (EU) 2016/2031 pest categorisation criteria on which the Panel bases its conclusions. All relevant criteria have to be met for the pest to potentially qualify either as a quarantine pest or as a RNQP. If one of the criteria is not met, the pest will not qualify. Note that a pest that does not qualify as a quarantine pest may still qualify as a RNQP that needs to be addressed in the opinion. For the pests regulated in the PZs only, the scope of the categorisation is the territory of the PZ; thus, the criteria refer to the PZ instead of the EU territory.

It should be noted that 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, the Panel will present a summary of the observed pest impacts. Economic impacts are expressed in terms of yield and quality losses and not in monetary terms, whereas addressing social impacts is outside the remit of the Panel, in agreement with EFSA guidance on a harmonised framework for pest risk assessment (EFSA PLH Panel, 2010).

Table 1: Pest categorisation criteria under evaluation, as 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	Criterion in Regulation (EU) 2016/2031 regarding Union quarantine pest	Criterion in Regulation (EU) 2016/2031 regarding protected zone quarantine pest (articles 32–35)	Criterion in Regulation (EU) 2016/2031 regarding Union regulated non-quarantine pest
Identity of the pest (Section 3.1)	Is the identity of the pest established, or has it been shown to produce consistent symptoms and to be transmissible?	Is the identity of the pest established, or has it been shown to produce consistent symptoms and to be transmissible?	Is the identity of the pest established, 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 widely distributed within the EU? Describe the pest distribution briefly!	Is the pest present in the EU territory? If not, it cannot be a protected zone quarantine organism	Is the pest present in the EU territory? If not, it cannot be a regulated non-quarantine pest. (A regulated non-quarantine pest must be present in the risk assessment area)

Criterion of pest categorisation	Criterion in Regulation (EU) 2016/2031 regarding Union quarantine pest	Criterion in Regulation (EU) 2016/2031 regarding protected zone quarantine pest (articles 32–35)	Criterion in Regulation (EU) 2016/2031 regarding Union regulated non-quarantine pest
Regulatory status (Section 3.3)	If the pest is present in the EU but not widely distributed in the risk assessment area, it should be under official control or expected to be under official control in the near future	The protected zone system aligns with the pest-free area system under the International Plant Protection Convention (IPPC) The pest satisfies the IPPC definition of a quarantine pest that is not present in the risk assessment area (i.e. protected zone)	Is the pest regulated as a quarantine pest? If currently regulated as a quarantine pest, are there grounds to consider its status could be revoked?
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!	Is the pest able to enter into, become established in, and spread within, the protected zone areas? Is entry by natural spread from EU areas where the pest is present possible?	Is spread mainly via specific plants for planting, rather than via natural spread or via movement of plant products or other objects? Clearly state if plants for planting is the main pathway!
Potential for consequences in the EU territory (Section 3.5)	Would the pests' introduction have an economic or environmental impact on the EU territory?	Would the pests' introduction have an economic or environmental impact on the protected zone areas?	Does the presence of the pest on plants for planting have an economic impact, as regards the intended use of those plants for planting?
Available measures (Section 3.6)	Are there measures available to prevent the entry into, establishment within or spread of the pest within the EU such that the risk becomes mitigated?	Are there measures available to prevent the entry into, establishment within or spread of the pest within the protected zone areas such that the risk becomes mitigated? Is it possible to eradicate the pest in a restricted area within 24 months (or a period longer than 24 months where the biology of the organism so justifies) after the presence of the pest was confirmed in the protected zone?	Are there measures available to prevent pest presence on plants for planting such that the risk becomes mitigated?
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.	A statement as to whether (1) all criteria assessed by EFSA above for consideration as potential protected zone quarantine pest were met and (2) if not, which one(s) were not met	A statement as to whether (1) all criteria assessed by EFSA above for consideration as a potential regulated non-quarantine pest were met and (2) if not, which one(s) were not met

The Panel will not indicate in its conclusions of the pest categorisation whether to continue the risk assessment process but, following the agreed two-step approach, will continue only if requested by the risk managers. However, during the categorisation process, experts may identify key elements and knowledge gaps that could contribute significant uncertainty to a future assessment of risk. It would be useful to identify and highlight such gaps so that potential future requests can specifically target the major elements of uncertainty, perhaps suggesting specific scenarios to examine.

3. Pest categorisation

3.1. Identity and biology of the pest

3.1.1. Identity and taxonomy

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

Yes, the identity of the pest is established. *Ips cembrae* is an insect of the family Curculionidae, subfamily Scolytinae.[4] It can be identified to species using conventional entomological keys.

3.1.2. Biology of the pest

The biology of the pest has been described by, e.a., Crooke and Bevan (1957), Chararas (1962), Balogun (1970) and Holuša et al. (2014). The main host is larch (*Larix* spp.); but occasionally, spruce (*Picea* spp.) or pine (*Pinus* spp.) is also attacked (see Section 3.4.1). The insects overwinter as adults, larvae or pupae, generally under the bark of the attacked trees, but the adults can also overwinter in the litter. Dispersal occurs in the spring, and each male establishes a nuptial chamber in the phloem of a host, usually a fallen tree. However, standing, living trees can also be attacked when beetle populations are large, or when they have been weakened, for example, by previous defoliation by the nun moth, *Lymantria monacha* (L.) (Holuša et al., 2014) or by a drought (Grodzki, 2008). The male beetles then release aggregation pheromone (Renwick and Dickens, 1979; Francke and Vité, 1983), which attracts conspecific females and males. Two to five females join each male, and each of them starts an egg gallery from the nuptial chamber, first radiating in a stellate pattern, then following the fibres of the phloem. Single eggs are laid at regular intervals along the maternal galleries, and the larvae bore their own individual mine perpendicularly to the fibres. Up to ca. 50 eggs are laid singly along each maternal gallery. The adults often emerge from their first gallery and start a sister brood on another tree. According to elevation and climatic conditions, there are one to two generations per year. Before producing their own brood, the young adults need to proceed to maturation feeding, either within the bark of the tree where they developed or in 2–18 years old twigs, that could often be found, broken by the tunnelling, at the foot of trees.

3.1.3. Intraspecific diversity

A subspecies, *I. cembrae engadinensis* Fuchs is described in the literature (e.g. EPPO, 2017) but, based on mitochondrial DNA sequences and fungal associates, Stauffer et al. (2001) did not find any difference between the samples of *I. cembrae engadinensis* and *I. cembrae* they analysed.

3.1.4. Detection and identification of the pest

Are detection and identification methods available for the pest?

Yes, *Ips cembrae* can be detected by visual searching, often after symptoms of damage are seen, and by pheromone trapping. The species can be identified by examining morphological features, for which keys exist, e.g. Balachowsky (1949); Grüne (1979); Schedl (1981); Wood (1982). Possibilities of confusion with *Ips subelongatus* exist however (see below).

The adults of *I. cembrae* are dark brown to black and are 4.0–5.5 mm long. The maternal galleries are often sinuated, which may allow distinguishing them from those of *Ips typographus*. Twigs cut by maturation feeding can often be found at the foot of living larches in attacked stands. Trees killed by *I. cembrae* shed their needles, and their bark flakes off, revealing distinctive gallery patterns.

Although the gallery patterns of *I. cembrae*, *Ips amitinus* and *I. typographus* generally differ, and despite the fact that the main host of *I. cembrae* is larch instead of spruce, the adults of these species

[4] Although the leading taxonomists in the 2000s (Wood, 1982; Bright and Skidmore, 2002) still considered the Scolytidae to be a family distinct from the Curculionidae according to morphological criteria, modern phylogenetics supports the position of scolytine beetles (subfamily Scolytinae) within the family Curculionidae (Knížek and Beaver, 2004; Hulcr et al., 2015). This is reflected by the growing number of citations in Scopus (2017) referring to Scolytinae (18 in 1990 vs 177 in 2016), as opposed to citations referring to Scolytidae (50 in 1990 vs 15 in 2016). The Scolytinae includes two subcategories, the'bark beetles', which live in the phloem, and the'ambrosia beetles', which live in the sapwood.

are extremely difficult to distinguish from each other. Balachowsky (1949) provides morphological characters based on the surface of the elytral declivity and the sutures of the antennal club, and Stauffer (1997) developed a molecular identification method based on the length of a mitochondrial DNA region between the COI and tRNA LEU genes.

Until recently, *I. cembrae* has often been confused with a very close species distributed in Asia, *I. subelongatus* Motschulsky. However, based on mitochondrial DNA sequences and on fungal associates, Stauffer et al. (2001) established small but clear differences between the two species. The earlier literature on *I. cembrae* in Asia (e.g. Zhang et al., 1992, 2000), therefore, concerns *I. subelongatus.* Because of the extreme proximity between these species, identification using only morphological characters is highly uncertain at the boundary of the distribution ranges of the two species, e.g. in Saint Petersburg or in the Kola peninsula (Voolma et al., 2004). *I. subelongatus* is absent in the EU and is not a quarantine pest, but it is recorded in the EPPO A2 list.

3.2. Pest distribution

3.2.1. Pest distribution outside the EU

Ips cembrae is present only in Europe. In non-EU Europe, the insect has been reported from central and northern Russia, Ukraine and Switzerland. The records from Asia actually refer to *I. subelongatus* (see Section 3.1.4).

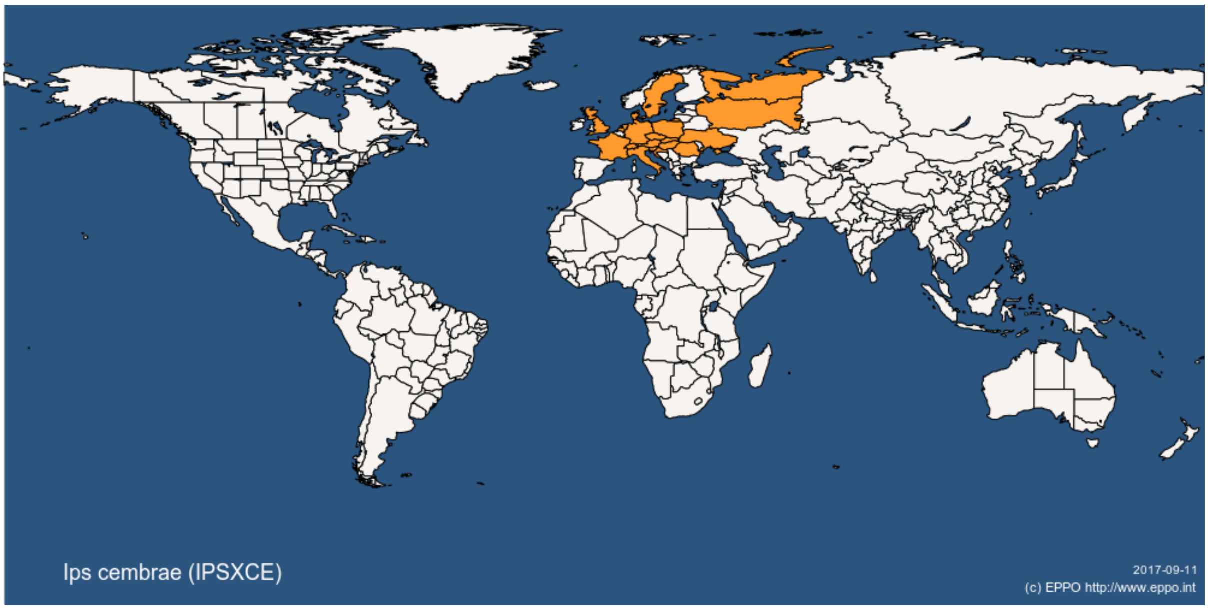


Figure 1: Global distribution map for *Ips cembrae* (extracted from EPPO global database accessed on 11 September 2017)

3.2.2. Pest distribution in the EU

Is the pest present in the EU territory? If present, is the pest widely distributed within the EU?
Yes, *Ips cembrae* is present and widely distributed in the EU, it has been reported from 16 MS (Table 2). It is absent in the protected zones: Greece, Ireland and the United Kingdom (Northern Ireland, Isle of Man).

Table 2: Current distribution of *Ips cembrae* in the 28 EU MS based on information from the EPPO Global Database and other sources

Country	EPPO Global Database (Last update: 12/7/2017 Last accessed: 11/9/2017)	Other sources
Austria	Present, no details	
Belgium	No information	Present (Moucheron, 2011)
Bulgaria	No information	
Croatia	Present, restricted distribution	
Cyprus	No information	
Czech Republic	Present, widespread	
Denmark	Present, no details	
Estonia	No information	Absent (Voolma et al., 2004)
Finland	Absent, intercepted only	
France	Present, restricted distribution	
Germany	Present, widespread	
Greece	Absent, confirmed by survey	
Hungary	Present, restricted distribution	
Ireland	Absent, confirmed by survey	
Italy	Present, restricted distribution	
Latvia	No information	
Lithuania	No information	
Luxembourg	No information	
Malta	No information	
Poland	Present, restricted distribution	
Portugal	Absent, confirmed by survey	
Romania	Present, no details	
Slovak Republic	Present, restricted distribution	
Slovenia	Present, widespread	
Spain	Absent, confirmed by survey	
Sweden	Present, restricted distribution	
Netherlands	Present, restricted distribution	
United Kingdom	Present, restricted distribution England and Scotland: Present, restricted distribution Northern Ireland: Absent, confirmed by survey	

3.3. Regulatory status

3.3.1. Council Directive 2000/29/EC

Ips cembrae is listed in Council Directive 2000/29/EC. Details are presented in Tables 3 and 4.

Table 3: *Ips cembrae* in Council Directive 2000/29/EC

Annex II, Part B	**Harmful organisms whose introduction into, and whose spread within, certain protected zones shall be banned if they are present on certain plants or plant products**		
(a)	Insects, mites and nematodes, at all stages of their development		
	Species	Subject of contamination	Protected zones
6 (b)	*Ips cembrae*	Plants of *Abies* Mill., *Larix* Mill., *Picea* A.Dietr., *Pinus* L. and *Pseudotsuga* Carr., over 3 m in height, other than fruit and seeds, wood of conifers (*Coniferales*) with bark, isolated bark of conifers	EL, IRL, UK (Northern Ireland, Isle of Man)

3.3.2. Legislation addressing plants and plant parts on which *Ips cembrae* is regulated

Table 4: Regulated hosts and commodities that may involve *Ips cembrae* in Annexes III, IV and V of Council Directive 2000/29/EC

Annex III, Part A	**Plants, plant products and other objects the introduction of which shall be prohibited in all Member States**		
	Description		Country of origin
1.	Plants of *Abies* Mill., [. . .] *Larix* Mill., *Picea* A. Dietr., *Pinus* L., *Pseudotsuga* Carr., [. . .], other than fruit and seeds		Non-European Countries
Annex IV, Part B	**Special requirements which shall be laid down by all member states for the introduction and movement of plants, plant products and other objects into and within certain protected zones**		
	Plants, plant products and other objects	Special requirements	Protected zone(s)
5.	Wood of conifers (*Coniferales*)	Without prejudice to the requirements applicable to the wood listed in Annex IV(A)(I)(1.1), (1.2), (1.3), (1.4), (1.5), (1.6), (1.7), where appropriate, and Annex IV(B)(1), (2), (3), (4): (a) the wood shall be stripped of its bark; or (b) official statement that the wood originates in areas known to be free from *Ips cembrae* Heer; or (c) there shall be evidence by a mark 'Kiln-dried', 'KD' or another internationally recognised mark, put on the wood or on its packaging in accordance with current commercial usage, that it has undergone kiln-drying to below 20% moisture content, expressed as a percentage of dry matter, at time of manufacture, achieved through an appropriate time/temperature schedule.	EL, IRL, UK (Northern Ireland, Isle of Man)
11.	Plants of *Abies* Mill., *Larix* Mill., *Picea* A. Dietr., *Pinus* L., *Pseudotsuga* Carr., over 3 m in height, other than fruit and seeds	Without prejudice to the provisions applicable to the plants listed in Annex III(A)(1), Annex IV(A)(I)(8.1), (8.2), (9), (10), Annex IV(A)(II)(4), (5), and Annex IV(B)(7), (8), (9), (10) where appropriate, official statement that the place of production is free from *Ips cembrae* Heer.	EL, IRL, UK (Northern Ireland, Isle of Man)
14.3	Isolated bark of conifers (*Coniferales*)	Without prejudice to the provisions applicable to the bark listed in Annex IV(B)(14.1), (14.2), official statement that the consignment: (a) has been subjected to fumigation or other appropriate treatments against bark beetles; or (b) originates in areas known to be free from *Ips cembrae* Heer.	EL, IRL, UK (Northern Ireland, Isle of Man)
Annex V	**Plants, plant products and other objects which must be subject to a plant health inspection (at the place of production if originating in the Community, before being moved within the Community—in the country of origin or the consignor country, if originating outside the Community) before being permitted to enter the Community**		
Part A	Plants, plant products and other objects originating in the Community		

Section II	Plants, plant products and other objects produced by producers whose production and sale is authorised to persons professionally engaged in plant production, other than those plants, plant products and other objects which are prepared and ready for sale to the final consumer, and for which it is ensured by the responsible official bodies of the Member States, that the production thereof is clearly separate from that of other products
2.1	Plants intended for planting other than seeds of the genera *Abies* Mill., [. . .] *Larix* Mill., [. . .], *Picea* A. Dietr., *Pinus* L., *Pseudotsuga* Carr., [. . .]

3.3.3. Legislation addressing the organisms vectored by *Ips cembrae* (Directive 2000/29/EC)

Several ophiostomatoid fungi, including pathogenic species, have been described by Stauffer et al. (2001), Kirisits (2004) and Jankowiak et al. (2007) as associated with *I. cembrae* (see also Section 3.5). Some of these species (e.g. *Ceratocystis laricicola*) have been found to be pathogenic in the field (Redfern et al., 1987) and in inoculation tests (Kirisits, 2004). However, there is currently no legislation addressing these species.

3.4. Entry, establishment and spread in the EU

3.4.1. Host range

Larch (*Larix decidua, Larix kaempferi*) is the main host; pine (*Pinus cembra, Pinus* spp.) and spruce (*Picea* spp.) are also attacked (EPPO, 2017).

Although there are requirements in the EU legislation for *Abies* spp. and *Pseudotsuga* spp., there is no scientific evidence that these species are hosts of *I. cembrae*.

3.4.2. Entry

Is the pest able to enter into the Protected Zones of the EU territory? If yes, identify and list the pathways!

Yes, the pest is already established in 16 MSs and can enter the protected zones by human assisted spread or by natural spread from EU areas where the pest is present.

The main pathways of entry are:

- wood of *Larix* spp., *Picea* spp. and *Pinus* spp. from countries where the pest occurs;
- wood chips of conifers from countries where the pest occurs;
- bark of conifers from countries where the pest occurs;
- wood packaging material and dunnage from countries where the pest occurs.

The capacity of *I. cembrae* to enter new areas, notwithstanding geographical barriers, is illustrated by the pest's recent expansion history. It was first observed in Britain in 1955, supposedly from shipments of German timber that had arrived into several ports in north-eastern Scotland in the period 1946–1948 (Crooke and Bevan, 1957). The first report from the Netherlands dates from 1974 (Luitjes, 1974). The first finding in Belgium dates from 2005 (Moucheron, 2011). The first finding in Sweden dates from 2011 (Lindelöw et al., 2015).

I. species are regularly intercepted on wood, wood packaging material and dunnage. During the period 1985–2000, among the 2,740 Scolytinae intercepted at the US ports of entry and identified to species, 10 *I. cembrae* were found (against 157 *Ips sexdentatus* and 286 *I. typographus*) (Haack, 2001). Lundberg (1988) reports the finding of *I. cembrae* in coniferous timber imported into Sweden from Southern Germany and Czechoslovakia.

Between 1994 and 2015, there was one record of interception of *I. cembrae* on wood and bark in the Europhyt database.

Given the overlap in host plants with *I. typographus,* the conifer wood trade data presented for *I. typographus* (EFSA PLH Panel, 2017) could also apply to *I. cembrae*. This would imply that there is trade of wood (0.4 million tonnes from 2011 to 2015) from EU countries to PZ countries, according to Eurostat.

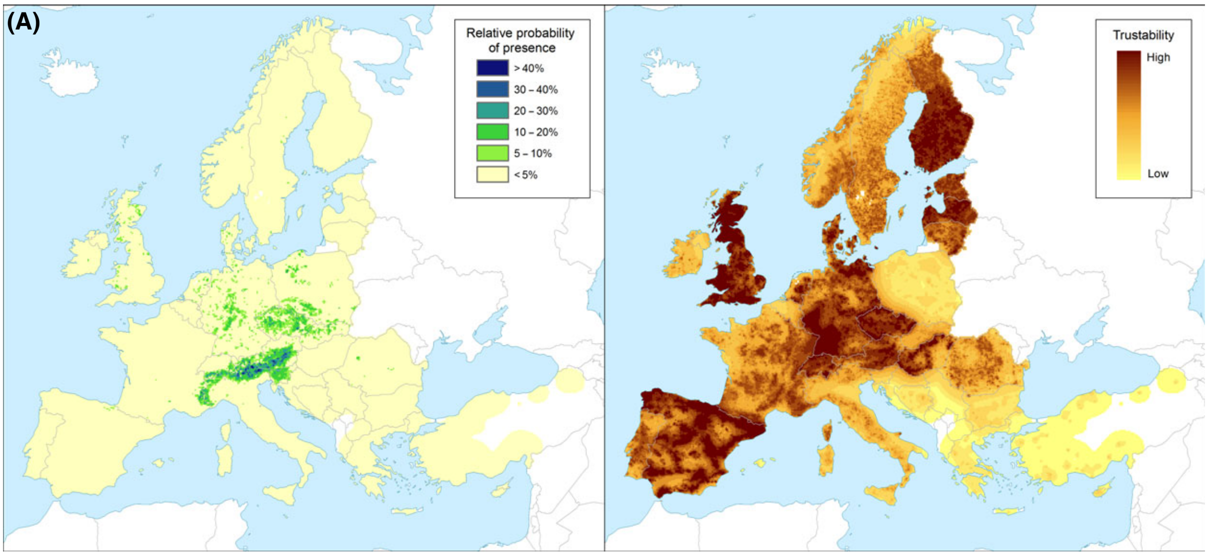
There are no records of interception of *I. cembrae* on plants for planting. Yet, two features could allow these commodities to constitute a pathway: (a) maturation feeding occurs in the shoots and (b) massive attacks on young forest trees, 8–12 years old, have been reported (Grodzki, 2008). However, the shoots attacked for maturation feeding often fall down, and mass-attacked trees die, which would not pass unnoticed. Hence, plants for planting are not considered as a major pathway, with some uncertainty.

3.4.3. Establishment

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

Yes, the pest is already established in 16 MSs. The climate of the EU Protected Zones is similar to that of the MSs where *Ips cembrae* is established, and the pest's main host plants are present (Figures 2A–C)

3.4.3.1. EU distribution of main host plants



A. Distribution map of the genus *Larix* in the European Union territory (based on data from the species: *Larix decidua, Larix kaempferi, Larix sibirica*).
B. Distribution map of the genus *Pinus* in the European Union territory (based on data from the species: *P. sylvestris, P. pinaster, P. halepensis, P. nigra, P. pinea, P. contorta, P. cembra, P. mugo, P. radiata, P. canariensis, P. strobus, P. brutia, P. banksiana, P. ponderosa, P. heldreichii, P. leucodermis, P. wallichiana*).
C. Distribution map of the genus *Picea* in the European Union territory (based on data from the species: *P. abies, P. sitchensis, P. glauca, P. engelmannii, P. pungens, P. omorika, P. orientalis*).

Figure 2: Left panel: Relative probability of presence (RPP) of the genera *Larix*, *Pinus* and *Picea* 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 A (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 A)

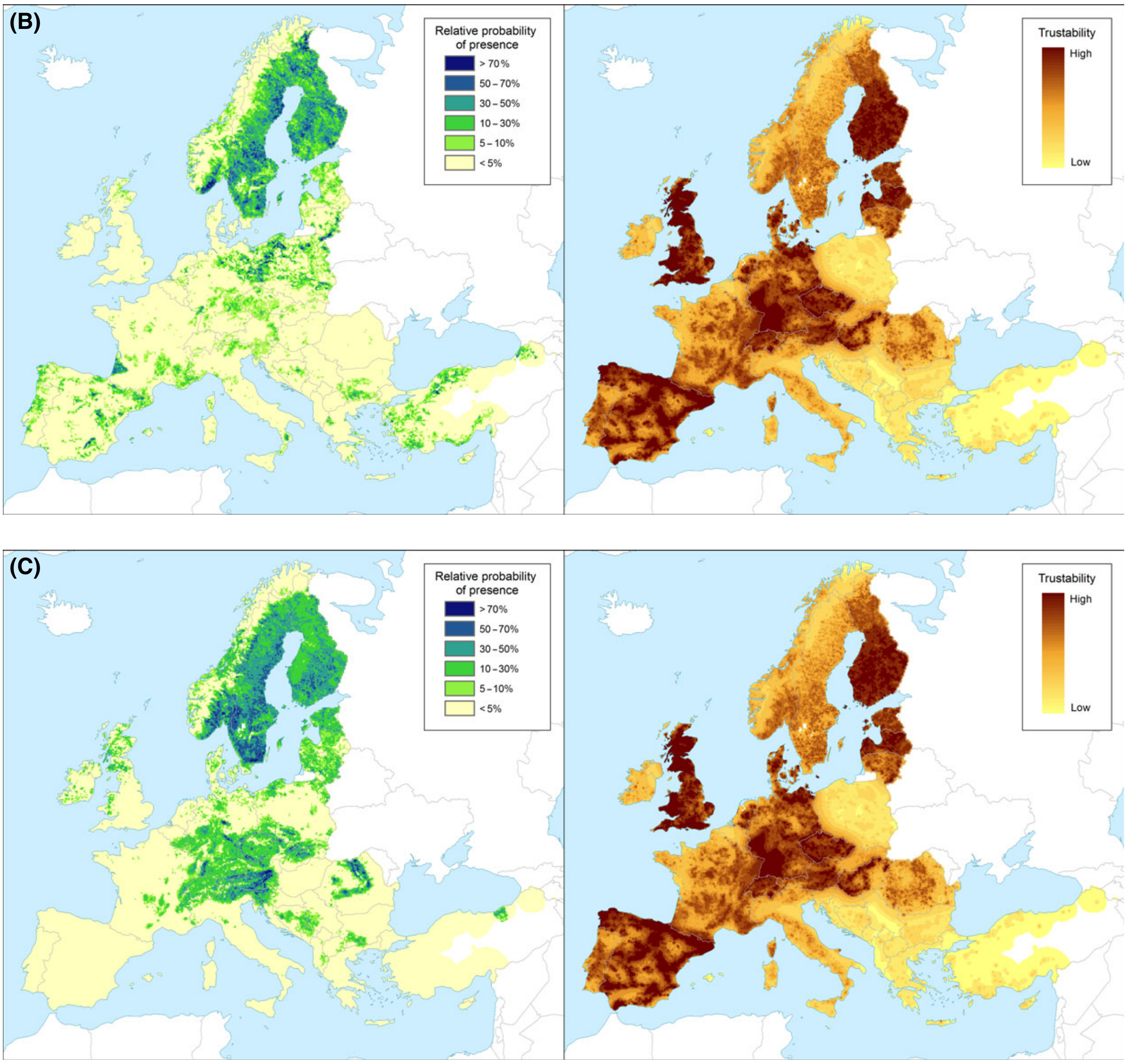


Figure 2: Continued

3.4.3.2. Climatic conditions affecting establishment

Given the current distribution of *I. cembrae*, the whole EU area (including the PZs) is suitable for establishment. Figure 3 shows Köppen–Geiger climate types (colours) and presence of *I. cembrae*.

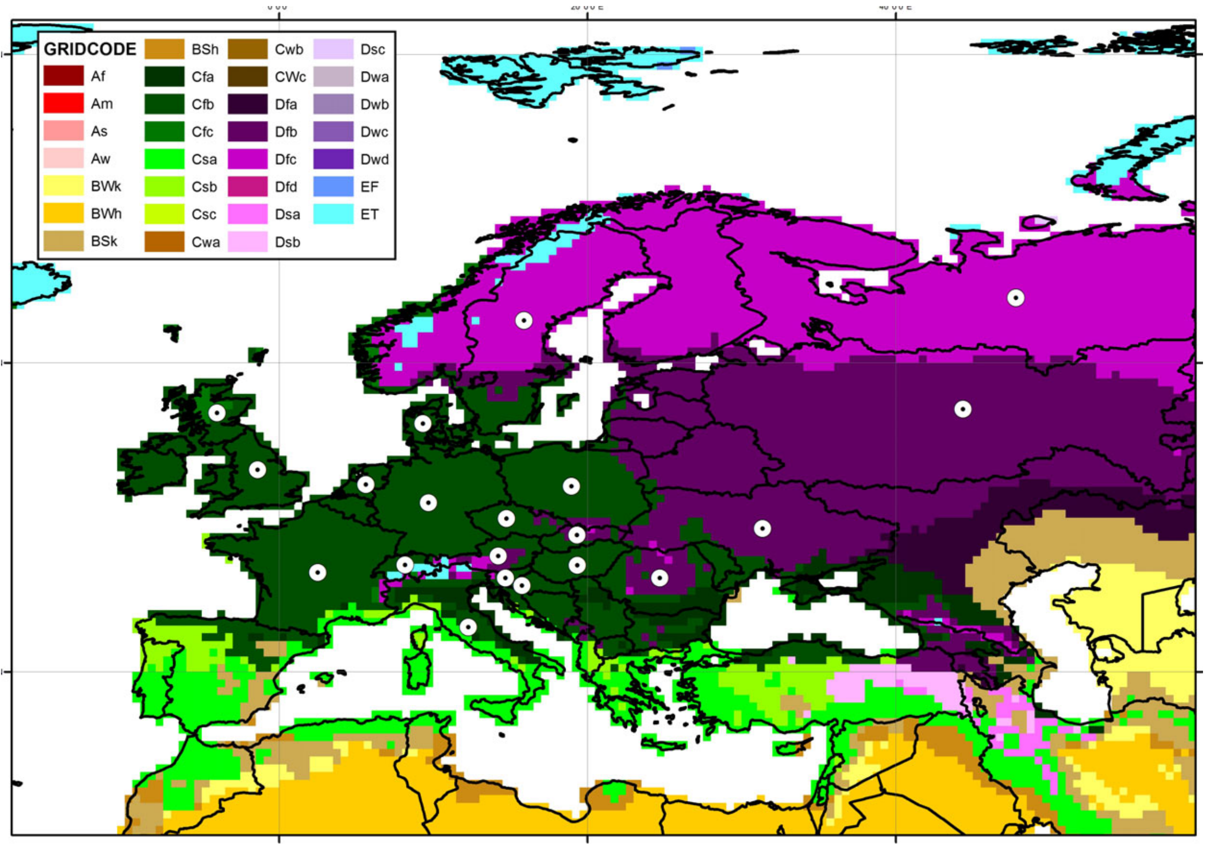


Figure 3: The current distribution of *Ips cembrae* presented by white dots on the Köppen-Geiger climate classification map (Kottek et al., 2006)

3.4.4. Spread

Is the pest able to spread within the protected zones of the EU territory following establishment? How?

Yes, as illustrated by the spread of the species within the EU during the 20th and 21st century (see Section 3.4.2 for more details).

RNQPs: Is spread mainly via specific plants for planting, rather than via natural spread or via movement of plant products or other objects?

No, plants for planting are a minor pathway.

3.5. Impacts

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

Yes, on weakened trees or when the population levels are high.

RNQPs: Does the presence of the pest on plants for planting have an economic impact, as regards the intended use of those plants for planting?

Yes, the pest attacks 8–12 years old trees and these trees die.

I. cembrae is seen as an important forest pest in several European countries (Grégoire and Evans, 2004). For example, Grodzki (2008)reports damage among young larches over 23,000 ha in Poland in the end of the 1990s; Krehan and Cech (2004) describe damage in Austria after the hot and dry summer of 2003.

Apart from the beetles themselves, some fungi associated to *I. cembrae* are likely to harm the trees. A number of ophiostomatoid fungi, including pathogenic species, has been described by Stauffer et al. (2001), Kirisits (2004) and Jankowiak et al. (2007) as associated with *I. cembrae*. The most common are *C. laricicola*, *Graphium laricis*, *Graphium* sp., *Ophiostoma brunneo-ciliatum*, but other species were recorded as well: *Ceratocystiopsis* cf. *alba*, *C. minuta*; *C.* sp.; *Ophiostoma piceae*, *O. bicolor*, *O.* cf. *piceaperdum, Ophiostoma* sp., (*Ophiostoma fusiforme*), (*Ophiostoma lunatum*), *Pesotum* spp. Some of these species (e.g. *C. laricicola*) have been found to be highly pathogenic in the field (Redfern et al., 1987) and in inoculation tests (Kirisits, 2004).

3.6. Availability and limits of mitigation measures

Are there measures available to prevent the entry into, establishment within or spread of the pest within the protected zones of the EU such that the risk becomes mitigated?

Yes, in isolated areas (e.g. islands) that cannot be reached by natural spread, measures can be put in place to prevent the introduction with wood and bark. Debarking wood and heat treatment of wood, bark and chips is effective as specified in annex IVB of 2000/29/EC. When such geographical barriers do not exist, the pest will eventually be able to enter new territories by natural dispersal.

RNQPs: Are there measures available to prevent pest presence on plants for planting such that the risk becomes mitigated?

Yes, although plants for planting are viewed as a minor pathway, they could be monitored and, if necessary, sprayed before transportation.

3.6.1. Biological or technical factors limiting the feasibility and effectiveness of measures to prevent the entry, establishment and spread of the pest

- Even though timber should be debarked, some small bark pieces are likely to remain.
- Infestations under the bark can be cryptic.
- Spread by natural means cannot be prevented.

3.6.2. Control methods

- Visual monitoring of external damage (killed trees, shoots on the ground) by forest operators is a current practice.
- Silvicultural methods are the usual control methods. They include sanitation thinning and clear-felling with rapid removal of the infested material (Stadelmann et al., 2013; Fettig and Hilszczanski, 2015; Grégoire et al., 2015).

3.7. Uncertainty

The Panel identified two main sources of uncertainty: (i) the morphological similarity between *I. cembrae* and *I. subelongatus*, which makes it difficult to determine the limits of the geographical range of both species and could raise a quarantine issue since *I. subelongatus* carries different pathogenic fungi and (ii) the possibility that some maturating adults still tunnelling in shoots travel with plants for planting.

4. Conclusions

I. cembrae meets the criteria assessed by EFSA for consideration as a potential PZ quarantine pest for the territory of the PZs: Greece, Ireland and the United Kingdom (Northern Ireland and Isle of Man) (Table 5).

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

Criterion of pest categorisation	Panel's conclusions against criterion in Regulation (EU) 2016/2031 regarding protected zone quarantine pest (articles 32–35)	Panel's conclusions against criterion in Regulation (EU) 2016/2031 regarding Union regulated non-quarantine pest	Key uncertainties
Identity of the pest (Section 3.1)	The identity of the pest is established. It can be identified to the species level using conventional entomological keys and molecular methods	The identity of the pest is established. It can be identified to the species level using conventional entomological keys and molecular methods	The pest is morphologically and biologically extremely close to an Asian species absent in Europe, *Ips subelongatus*
Absence/presence of the pest in the EU territory (Section 3.2)	*Ips cembrae* is present and widely distributed in the EU, it has been reported from 16 MSs. It is a Protected Zone quarantine pest in Greece, Ireland and the United Kingdom (Northern Ireland and Isle of Man) (Annex IIB)	*Ips cembrae* is present and widely distributed in the EU, it has been reported from 16 MSs. It is a Protected Zone quarantine pest in Greece, Ireland and the United Kingdom (Northern Ireland and Isle of Man) (Annex IIB)	None
Regulatory status (Section 3.3)	The pest is currently officially regulated by 2000/29/EC on plants of *Abies, Larix, Picea, Pinus* and *Pseudotsuga* over 3 m in height, other than fruit and seeds, wood of conifers (*Coniferales*) with bark, isolated bark of conifers *I. cembrae* is regulated as a quarantine pest in protected zones (Annex IIB): Greece, Ireland and the United Kingdom (Northern Ireland and Isle of Man)	The pest is currently officially regulated by 2000/29/EC on plants of *Abies, Larix, Picea, Pinus* and *Pseudotsuga* over 3 m in height, other than fruit and seeds, wood of conifers (*Coniferales*) with bark, isolated bark of conifers *I. cembrae* is regulated as a quarantine pest in protected zones (Annex IIB): Greece, Ireland and the United Kingdom (Northern Ireland and Isle of Man)	Although the pest is regulated on *Abies* and *Pseudotsuga* spp., there is no scientific evidence in the literature that *Abies* and *Pseudotsuga* spp. are hosts for *I. cembrae*
Pest potential for entry, establishment and spread in the EU territory (Section 3.4)	Entry: the pest is already established in 16 MSs. Since entry by natural spread from EU areas where the pest is present is possible, only isolated areas (e.g. islands) can be long-term protected zones Establishment: the climate of the EU protected zones is similar to that of MSs where *I. cembrae* is established, and the pest's main host plants are present Spread: adults can disperse naturally. They can fly over tens of kilometers. The pest can also spread by human assistance, e.g. with the transportation of wood, wood chips, bark, wood packaging material, dunnage of conifers and possibly plants for planting	Plants for planting are not a major pathway	Uncertainty regarding the capacity of maturating adults to be transported in the shoots of young plants

Criterion of pest categorisation	Panel's conclusions against criterion in Regulation (EU) 2016/2031 regarding protected zone quarantine pest (articles 32–35)	Panel's conclusions against criterion in Regulation (EU) 2016/2031 regarding Union regulated non-quarantine pest	Key uncertainties
Potential for consequences in the EU territory (Section 3.5)	The pest usually attacks dead or dying trees, but is known to have killed thousands of healthy trees after triggering events such as storms or dry summers	Massive attacks on young forest trees, 8–12 years old, have been reported; maturation feeding occurs in young shoots	None
Available measures (Section 3.6)	In isolated areas (e.g. islands) that cannot be reached by natural spread, measures can be put in place to prevent the introduction with wood, wood products, wood chips, bark and plants for planting. Debarking wood and heat treatment of wood, bark and chips and inspection of plants for planting are effective When such geographical barriers do not exist, there is no possibility to prevent the entry, establishment and spread of *I. cembrae* by natural dispersal	Although it is not common practice, plants for planting can be produced in pest-free places of production and can be sprayed with an insecticide prior to shipment	Uncertainty regarding the capacity of maturating adults to be transported in the shoots of young plants
Conclusion on pest categorisation (Section 4)	All criteria assessed by EFSA above for consideration as potential protected zone quarantine pest were met	The criteria for considering *I. cembrae* as a potential regulated non-quarantine pest are not met since plants for planting are not the main pathway	See uncertainties listed above
Aspects of assessment to focus on/ scenarios to address in future if appropriate	The pest is morphologically and biologically extremely close to *Ips subelongatus*, an Asian species still absent in Europe and which can introduce new pathogens The capacity of maturating adults to be transported inconspicuously in the shoots of young plants is still unknown		

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Abbreviations

CLC	Corine Land Cover
EPPO	European and Mediterranean Plant Protection Organization
EUFGIS	European Information System on Forest Genetic Resources
EU MS	European Union Member State
FAO	Food and Agriculture Organization
GD^2	Georeferenced Data on Genetic Diversity

IPPC	International Plant Protection Convention
JRC	Joint Research Centre of the European Commission
PLH	EFSA Panel on Plant Health
PZ	protected zone
RNQP	regulated non-quarantine pest
RPP	relative probability of presence
RRO	risk reduction option
SMFA	spatial multiscale frequency analysis
TFEU	Treaty on the Functioning of the European Union
ToR	Terms of Reference

Appendix A – Methodological notes on Figure 2

The relative probability of presence (RPP) reported here for *Larix*, *Pinus* and *Picea* spp. in Figure 2 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.

A.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, http://spatialreference.org/ref/epsg/etrs89-etrs-laea/).

A.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).

A.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[5]. 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.

A.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.

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

EUFGIS (http://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

[5] Council of the European Union, 2003. 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.

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.

A.1.5. Georeferenced Data on Genetic Diversity (GD^2)

GD^2 (http://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.

A.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 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 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 co-dominant 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), http://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. 10×10 pixels or 25×25 pixels, respectively summarising the information for aggregated spatial cells of 100 km^2 and 625 km^2) by averaging the values in larger grid cells.