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SCIENTIFIC OPINION

Risk assessment of the oriental chestnut gall wasp, *Dryocosmus kuriphilus* for the EU territory and identification and evaluation of risk management options[1]

EFSA Panel on Plant Health (PLH)[2, 3]

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ABSTRACT

The Panel on Plant Health was requested by the European Commission to deliver a scientific opinion on the risk posed by the oriental chestnut gall wasp, *Dryocosmus kuriphilus* to the EU territory and to identify and evaluate risk management options. Additional analyses were conducted by the Panel to a) determine the distribution of the endangered area within the EU territory; b) investigate the pattern and rate of pest diffusion and c) consider the environmental risk of introduction of the biological control agent *Torymus sinensis* identified as a potential management option. The Panel concluded in its assessment that a) *Castanea* plants for intended planting represent the main pathway for entry of *D. kuriphilus* to the EU; b) *D. kuriphilus* has a very high potential for establishment in the EU and the climate is suitable wherever *Castanea sativa* is grown in southern, central and western Europe; c) the average rate of spread of *D. kuriphilus* is estimated as 8 km/yr; d) spread within the EU is likely, due to adult dispersal by flight and the movement of plants containing eggs and larvae which remain undetected within dormant buds; e) the potential effects on fruit yield reduction are considered moderate and the environmental impact in *Castanea* woodland is considered as low; f) all EU chestnut production is endangered but the areas of fruit production with the highest degree day accumulations where *D. kuriphilus* is absent, e.g. in northern Portugal, northern Spain and south-west France, are identified as particularly at risk; g) management options to reduce likelihood of introduction and spread consist of certifying *Castanea* planting material from pest free areas/places of production; h) classical biological control and plant varietal resistance are identified as management options to reduce the magnitude of impact.

KEY WORDS

Castanea spp., *Dryocosmus kuriphilus*, EU territory, management options, oriental chestnut gall wasp, risk assessment.

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SUMMARY

Following a request from the European Commission, the Panel on Plant Health was asked to deliver a scientific opinion on the risk posed by the oriental chestnut gall wasp, *Dryocosmus kuriphilis* Yasumatsu to the EU territory. It was asked to identify risk management options and to evaluate their efficiency in reducing the risk to plant health posed by this organism.

The Panel conducted its assessment following the EFSA Guidance on a harmonised framework for pest risk assessment[4]. Additional analyses were conducted to a) determine the distribution of *Castanea* spp. and the endangered area within the EU territory b) investigate the mechanisms of pest diffusion based on historical records following first introduction of the pest into the EU in 2002 and c) consider the environmental risk of introduction of the biological control agent *Torymus sinensis* identified as a potential management option to reduce the magnitude of impact of *D. kuriphilus.*

From its analysis of the evidence, the Panel reached the following conclusions:

- The movement of *Castanea* spp. as living parts of plants, in particular bud-wood, cuttings and scions, and plants intended for planting represents the main pathway for entry of *D. kuriphilus* to the EU territory. There is a very high likelihood of establishment of *D. kuriphilus* in the EU and the climate is suitable wherever *C. sativa* is grown in southern, central and western Europe;

- *D. kuriphilus* is widely established in Italy and the spread of *D. kuriphilus* follows a stratified dispersal pattern. Analysis of local random diffusion suggests an average rate of short distance dispersal as 8 km/year, which is significantly less than 25 km/year reported in the literature. The long distance dispersal component via the movement of planting material contributed to the rate of colonization in Italy, Slovenia and France;

- There is a high likelihood of spread within the EU territory due to the presence of eggs and larvae within the bud tissue, which cannot be detected by visual inspection, in the absence of symptoms during the dormant period. Movement of adult dispersal stages of *D. kuriphilus* by flight (natural and human assisted e.g. in vehicles or clothing) contributes to further spread within the EU;

- The potential for yield reduction in *Castanea* and negative effects on production is estimated as moderate. Although reported as high in the literature, there is a high level of uncertainty relating to this estimate in the absence of quantitative data confirming the yield reduction attributed directly to *D. kuriphilus*;

- All EU fruit production is endangered but the areas of *C. sativa* for fruit production with the highest degree day accumulations where *D. kuriphilus* is absent, e.g. in northern Portugal, northern Spain and south-west France, are particularly at risk;

- Management options to reduce the likelihood of introduction and spread are identified as certification of planting material as originating from areas/places of production free from *D. kuriphilus*;

- Management options to reduce the magnitude of impact are identified as plant varietal resistance and biological control.

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[4] EFSA Panel on Plant Health (PLH); Guidance on a harmonised framework for pest risk assessment and the identification and evaluation of pest risk management options by EFSA. EFSA Journal 2010; 8(2):1495. [66 pp.].

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BACKGROUND AS PROVIDED BY THE EUROPEAN COMMISSION[5]

The current Community plant health regime is established by Council Directive 2000/29/EC 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, 10.7.2000, p.1).

The Directive lays down, amongst others, the technical phytosanitary provisions to be met by plants and plant products and the control checks to be carried out at the place of origin on plants and plant products destined for the Community or to be moved within the Community, the list of harmful organisms whose introduction into or spread within the EU is prohibited and the control measures to be carried out at the outer border of the Community on arrival of plants and plant products.

The Oriental chestnut gall wasp *Dryocosmus kuriphilus* Yasumatsu (Class Insecta; Order Hymenoptera; Family Cynipidae), is presently not listed as a harmful organism in Council Directive 2000/29/EC. However, a preliminary pest risk assessment carried out in 2003 by the Phytosanitary Sector of the Piemonte Region, Italy, has demonstrated that it may be one of the most damaging insects to chestnut (*Castanea* spp. Mill.). It could strongly reduce nut production and quality and there is some evidence it may even kill the trees. Chestnuts are often grown on marginal land in hills or mountains. Damage resulting from the spread of the insect could halt production of chestnuts for human consumption in those areas.

Consequently, the Commission adopted in 2006 provisional emergency measures to prevent the introduction into and the spread within the Community of *Dryocosmus kuriphilus* Yasumatsu (Commission Decision 2006/464/EC of 27 June 2006). The measures provided for in this Decision apply to the introduction or the spread of this organism, the production and movement of *Castanea* plants within the Community, the control of the organism and to a survey for the presence or continued absence of *Dryocosmus kuriphilus* Yasumatsu in the Member States. The results of these measures have been assessed yearly, based on the surveys carried out by Member States and their notifications of the suspected occurrence or confirmed presence of this organism in their territory. So far outbreaks of *Dryocosmus kuriphilus* Yasumatsu have been reported from three Member States (France, Italy and Slovenia).

Provisional emergency measures against a plant harmful organism adopted by the Commission are meant to be, as indicated by their name, temporary measures put in place against an imminent danger of introduction into or spread within the Community of that harmful organism. Based on the experience gained from the application of these measures over a period of time a decision will be taken whether permanent measures are needed (and what type of measures).

At the last review of the emergency measures within the meeting Standing Committee on Plant Health of February 2009 some Member States indicated that they would welcome the start of the discussions on the need to take permanent measures against *Dryocosmus kuriphilus* Yasumatsu. For that purpose there is a need for a pest risk analysis that takes into account the latest scientific and technical knowledge for this organism as well as its present distribution in the European Union and the experience gained from the implementation of the provisional emergency measures.

TERMS OF REFERENCE AS PROVIDED BY THE EUROPEAN COMMISSION

EFSA is requested, pursuant to Article 29(1) and Article 22(5) of Regulation (EC) No 178/2002, to provide a pest risk assessment of *Dryocosmus kuriphilus* Yasumatsu, to identify risk management

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[5] Submitted by the European Commission, ref. SANCO E1/GC/svi D(2009)510253

options and to evaluate their efficiency in reducing the risk to plant health posed by this organism. In dealing with the impacts it would be sufficient to describe these in biological and agronomic terms, such as yield and quality impacts, etc. The area to be covered by the requested pest risk assessment is the EU territory.

ASSESSMENT

1. Introduction

This document presents a pest risk assessment prepared by the Panel on Plant Health on the oriental chestnut gall wasp, *Dryocosmus kuriphilus* Yasumatsu, in response to a request from the European Commission. The assessment is undertaken for the whole EU territory, and includes identification and evaluation of risk management options in terms of their effectiveness in reducing the risk posed by the organism.

1.1. Purpose and Scope

Following the first finding of the pest in Europe in the Piemonte region of Italy in 2002, a pest risk analysis was prepared with the area under assessment being the region of the European and Mediteranean Plant Protection Organisation (EPPO) including the EU area (Bosio, 2003). It concluded that *D. kuriphilus* could be damaging to both cultivated and wild chestnut, and could result in negative social, economic and environmental consequences. It further identified the movement of *Castanea* plant material as the major pathway for introduction of the pest.

D. kuriphilus was first reported in France in 2005 on infested *Castanea* plants sourced from Italy (EPPO Rse, 2007/086) and in Slovenia on plants imported in 2004 (EPPO Rse 2006/101). Provisional emergency measures were introduced in June 2006 under Commission Decision 2006/464/EC[6] to prevent the introduction into and the spread of the pest within the Community. The Panel is requested to prepare a pest risk assessment for the whole EU territory to assist risk managers in consideration of phytosanitary measures to be taken under Council Directive 2000/29/EC[7].

1.2. Data and methodology

1.2.1. Data

Literature searches were performed consulting the following databases: ISI web of Knowledge database including Web of Science, Current Content Connect, CABI CAB Abstracts, Food Science and Technology Abstracts and Journal Citation Reports, Agricola, CAB Abstracts, Google Scholar, PRASSIS, PubMed. The key words used in the searches (individually or in combination) were *Dryocosmus kuriphilus* – cynipid – gall wasp – *Castanea* – sweet chestnut. Further references and information was obtained from experts, and from citations within references found, representing more than 150 reviewed documents.

Information from Member States on official surveys for *D. kuriphilus* undertaken between 2006 and 2009 was provided by FVO (Food and Veterinary Office) and additional information was obtained by contacting experts in areas where *D. kuriphilus* is reported (China, Japan, US, Italy, France, Slovenia and Switzerland).

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[6] Commission Decision 2006/464/EC of 27 June 2006 on provisional emergency measures to prevent the introduction into and the spread within the Community of *Dryocosmus kuriphilus* Yasumatsu *(notified under document number C(2006) 2881)*. OJ L 183, 5.7.2006, p.29-32.

[7] 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, 10.7.2000, 159 pp.

1.2.2. Methodology

The risk assessment was conducted in line with the principles described in the guidance document on a harmonised framework for pest risk assessment and the identification and evaluation of pest risk management options (EFSA Panel on Plant Health, 2010). In the development of this opinion, the Panel uses the adapted EPPO scheme and rating system presented in the guidance document. The ratings for individual questions of the scheme are provided in Appendix A, together with a short justification for the ratings given by the Panel.

The conclusions for the likelihood of entry, establishment, spread and impact are presented separately in the opinion with a justification to support the rating given. The Panel identifies potential risk management options and evaluates them with respect to their effectiveness and technical feasibility, i.e. consideration of technical aspects which influence their practical application. The evaluation of efficiency of management options in terms of the potential cost-effectiveness of measures and their implementation is not within the scope of the Panel evaluation.

1.2.3. Level of uncertainty

For each main section of the risk assessment, (i.e. entry, establishment, spread and impact) the uncertainties are described and rated as high, medium or low. Where the uncertainties are considered likely to influence the conclusions, their effect on the level of risk (i.e. increasing or decreasing) is indicated.

1.2.4. Additional analyses

Additional analyses were conducted by the Panel and are outlined in detail in the Appendices, as follows:

a) a climatic analysis to investigate the suitability of the European climate and the distribution of *Castanea sativa* to clarify the endangered area within the EU territory (Appendix B);

b) an analysis of the historical pattern of pest diffusion in the EU to interpret the mechanisms of pest diffusion and to model the potential spread of *D. kuriphilus* (Appendix C)*;*

c) a preliminary assessment of the environmental risk of introduction of the biological control agent *Torymus sinensis* into the EU (Appendix E).

2. Pest risk assessment

2.1. Pest characterisation

2.1.1. Identity of the pest

Dryocosmus kuriphilus Yasumatsu, is a cynipid gall wasp (class Insecta; order Hymenoptera; family Cynipidae, subfamily Cynipinae, tribe Cynipini) which feeds on *Castanea* spp., disrupting plant growth by inducing gall formation on new shoots and leaves (Ôtake, 1980). It was first recorded in western Japan in the Okayama Prefecture in 1941, where it was considered as an un-named *Biorhiza* species but later described as a new species (Yasumatsu, 1951).

The phylogenetic relationships between *Dryocosmus* and related genera of oak gallwasps are described in Ács et al. (2007). The tribe Cynipini is the most species-rich tribe in the subfamily Cynipinae, comprising approximately 1,000 species in 27 genera, found predominantly in the northern hemisphere, of which the oak gall wasps of the western palearctic are the most well-studied (Csóka et al., 2005). *D. kuriphilus* is one of only two species in the tribe Cynipini (and the only palearctic species) to induce galls on chestnut, *Castanea* spp. (Ács et al., 2007).

D. kuriphilus is univoltine (one generation per year) and thelytokous (females only are produced) (Moriya et al., 2003). The adult females are short-lived (2-10 days) (Yasumatsu, 1951). They emerge in early summer and immediately lay eggs inside chestnut buds that will develop the following spring. Each female may lay more than 100 eggs, with 20-30 eggs found in one bud (EPPO, 2005; Ôtake, 1980, 1989; Tamura, 1960). Eggs hatch in 30-40 days and first instar larvae remain within the egg and overwinter in the plant buds. At bud burst in spring, larval feeding induces the formation of green or rose-coloured galls 5-20mm in diameter on *Castanea crenata* in Japan (Ôtake, 1980, 1989; Tamura, 1960), 8-15mm on *C. sativa* or *C. sativa* X *C. crenata* in Europe (Breisch and Streito, 2004). Pupation occurs within the gall from mid-May to mid-July, and the adult females emerge and fly from the end of May until the end of July, depending on locality and chestnut cultivar.

2.1.2. Global occurrence

D. kuriphilus is native to China and has been reported in Japan in 1941 (Moriya et al., 2003), in Korea (Murakami et al., 1995), in the United States in 1974 (Rieske, 2007), in Nepal in 1999 (Abe et al., 2007) and in Europe (Italy) (Brussino et al., 2002). It feeds on *C. mollissima* Blume (Chinese chestnut) (Zhu et al., 2007), *C. crenata* Sieb. et Zucc. (Japanese chestnut) (Kato and Hijii, 1993), *C. dentata* (Marsh.) (American chestnut) (Anagnostakis, 2001), and *C. sativa* Mill. (European chestnut) (Brussino et al., 2002) and their hybrids. Following the introduction of *D. kuriphilus* into Japan in 1941 it spread rapidly, becoming distributed throughout most of the country by the end of the 1950s (Oho and Shimura, 1970) and one of the most intractable pests of chestnut in Japan (Shiga, 1999).

The global distribution of *D. kuriphilus* is shown in Figure 1 and the EU distribution is analysed further in Appendix B.

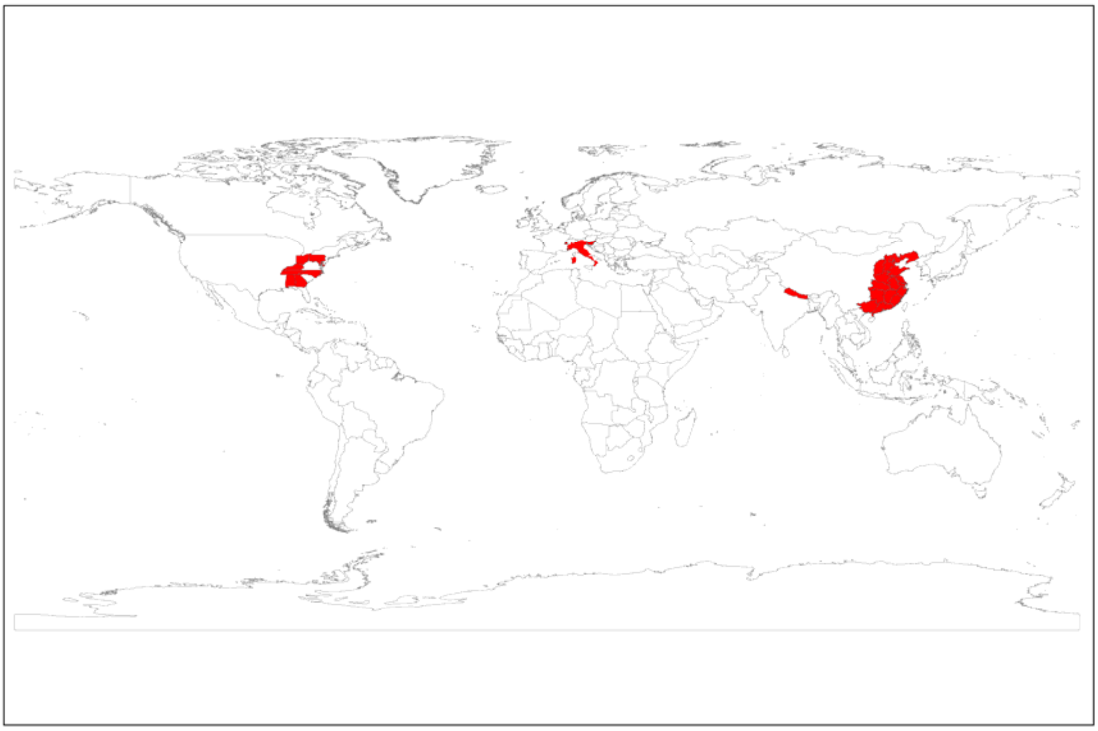

Figure 1: *Dryocosmus kuriphilus* global distribution

2.1.3. Risk assessment area

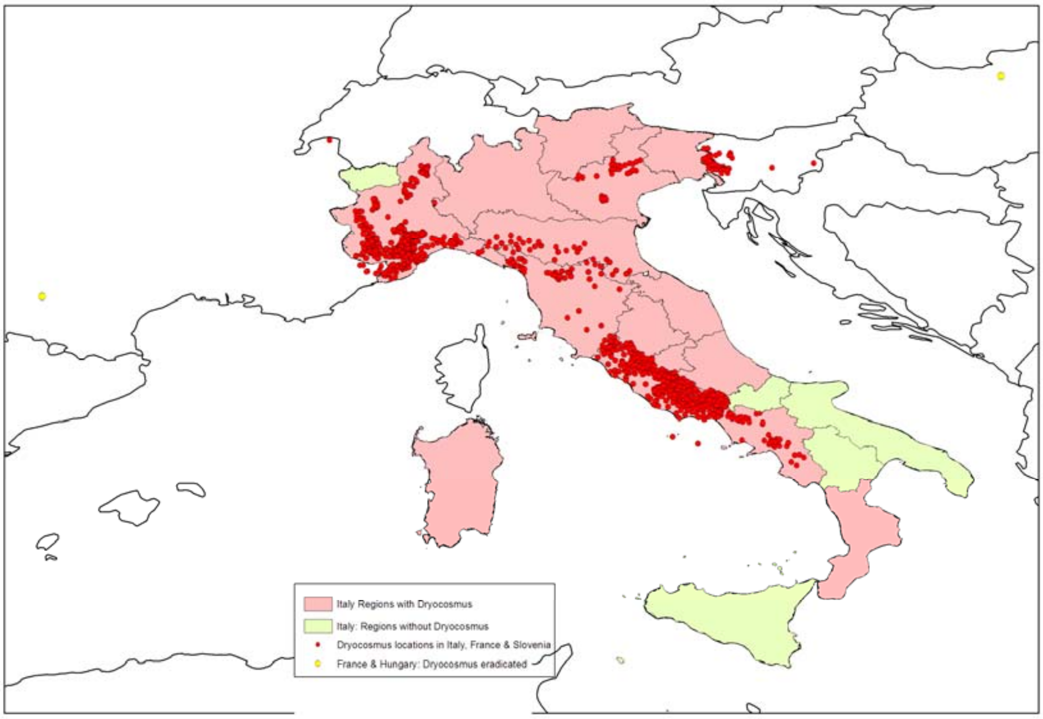

Figure 2: *D. kuriphilus* distribution in the EU (see also Appendix B).

Italy

It was reported for the first time in Europe in Piemonte, Cuneo province, Italy (Brussino et al. 2002) and is now widely distributed. In 2009, it was reported as being present and under official control in Abruzzo, Calabria, Campania, Emilia-Romagna, Friuli-Venezia Giulia, Lazio, Liguria, Lombardia, Marche, Toscana, Trentino-Alto Adige, Sardegna, Umbria, and Veneto (EPPO Rse, 2009/175). Further information was obtained from direct contact with the Italian regions to confirm that *D. kuriphilus* is present in 15 of the 20 Italian regions. It is absent from the extreme north-west (Val d’Aosta), three southern regions (Basilicata, Molise and Puglia) and Sicilia.

France

- 2005: First occurrence in Saint-Dalmas-Valdéblore (Alpes-Maritimes), on young trees imported from the Cuneo area in 2004 (EPPO Rse, 2007/086);

- 2007: *D. kuryphilus* observed in the Roya valley, Saint-Dalmas de Tende, Tende, La Brigue, Fontan and Saorge (Alpes-Maritimes), and in one nursery in Frouzins (Haute-Garonne). The infested lot in Frouzins had been originally produced by an Italian nursery near Brescia (Lombardia) before being re-exported from Spain to France (EPPO Rse, 2009/108). This movement from Italy to Spain probably occurred before Decision 2006/464/EC was implemented;

- 2008: 12 sites in the Roya Valley, and new infested trees in Frouzins (EPPO Rse, 2009/108). In 12/249 locations forests/parks/gardens: pest reported in 2008. In one nursery (1/270 :FVO);
- 2009: one site in Maxilly-sur-Léman (Boutte, 2009).

Slovenia

- Spring 2005: damage locally observed on young trees planted in 2004. Confirmed in 2 locations (Nova Gorica and Krško) (EPPO Rse, 2006/101);
- 2006: no infested tree found (198 locations surveyed; Gabrijel Seljak, pers. com., Ljubljana 24 November 2009);
- 2007: 219 locations surveyed, one orchard found infested over 3.5 ha in West Slovenia, Sabotin mountains. Trees planted in 2004 and originating from Cuneo, thus before the implementation of Decision 2006/464/EC (see below: 2.1.4). 125 infested trees destroyed (Knapič et al., 2009);
- 2008: the infested area on the Sabotin Mountain has expanded over at least 3 km around the primary focus. The infested area (mainly woodland) covers 20-30 km². Eradication considered as ineffective in this woodland area. 9 additional foci found within 34 km of this first focus (Knapič et al., 2009);
- 2009: 936 locations inspected (897 in forest, 39 in orchards and individual trees, 9 in nurseries). 38 new infestation spots found in woodlands and 15 in orchards. All infestation spots in western Slovenia (Gabrijel Seljak, pers. com., Ljubljana 24 November 2009).

Hungary

- 2009. One single chestnut (*Castanea sativa*) tree in a private garden in Üröm. The tree originating from Italy had been purchased at an international garden centre and planted during the autumn 2008 (Csóka et al., 2009).

[**Switzerland:** First report in 2009 in the centre of Mendrisio (Ticino) (EPPO Rse, 2009/107).]

Table 1: A summary of the spread of *Dryocosmus kuriphilus* in Europe

Year of first report	Italy	France	Slovenia	Hungary
2002	Piemonte			
2005	Abruzzo, Campania, Lazio, Toscana	Valdéblore (Provence-Alpes-Côte d'Azur region)	Zgornja Pohanca (Spodnjeposavska region), Znojile pri Krki (Osrednjeslovenska region), Renče-Merljaki and Bilje (Goriška region)	
2006	Lombardia			
2007	Liguria, Trentino Alto-Adige, Sardegna, Veneto	Roya valley (4 contaminated communes of Provence-Alpes-Côte d'Azur region); Frouzins (Midi-Pyrénées region) (movement of plants prior to implementation of emergency measures)	Sabotin mountain (Goriška region) (trees planted in 2004)	
2008	Emilia-Romagna, Friuli Venezia Giulia	Roya valley (4 + 2 more contaminated communes Provence-Alpes-Côte d'Azur region)	9 other foci (Goriška and Obalno-kraška regions)	
2009	Calabria, Marche, Umbria	Roya valley (4 + 2 more contaminated communes Provence-Alpes-Côte d'Azur region); Maxilly-sur-Léman (Rhône-Alpes region)	53 locations (Goriška and Obalno-kraška regions)	1 tree in Üröm (Budapest)

2.1.4. Regulatory status

The Commission Decision of 27 June 2006 on provisional emergency measures to prevent the introduction and spread within the Community of *D. kuriphilus* Yasumatsu (2006/464/EC) requires that:

(a) the plants have been grown throughout their life (or since their importation/introduction) to the Community in places of production in countries where the organism is not known to occur; or

(b) the plants have been grown throughout their life or since their introduction into the Community in places of production in a pest-free area, established by the national plant protection organisation in the country of origin in accordance with relevant International Standards for Phytosanitary Measures and under the rubric ‘place of origin’ the name of the pest-free area.

It further requires the establishment of demarcated zones following introduction of the pest. Measures in demarcated zones include the prohibition of movement of plants out of or within these zones. In cases where the presence of the organism has been confirmed on the plants at a place of production, it requires appropriate measures aiming at eradicating the harmful organism, consisting of at least destruction of the infested plants, all those plants showing symptoms caused by the organism and, where appropriate, all such plants belonging to the same lot at the time of planting and a monitoring of the presence of the organism through appropriate inspections during the period of potential presence of the inhabited galls.

The demarcated zones consist of the following parts:

(a) an infested zone where the presence of the organism has been confirmed and which includes all plants showing symptoms caused by the organism, and, where appropriate, all plants belonging to the same lot at the time of planting;

(b) a focus zone with a boundary at least 5 km beyond the boundary of the infested zone, and

(c) a buffer zone with a boundary at least 10 km beyond the boundary of the focus zone.

In cases where several buffer zones overlap or are geographically close, a wider demarcated area shall be defined which includes the relevant demarcated zones and the zones between them.

2.1.5. Potential for further establishment, spread and consequences in PRA area - conclusion of pest characterisation

Since the first report in the Cuneo area of Piemonte region in Italy, *D. kuriphilus* has established and spread throughout Italy and been reported also in France, Slovenia, Hungary and Switzerland.

In Europe, 2.25 million hectares of forest contain *Castanea sativa* as the major species (Conedera et al., 2004a). Chestnut orchards and plant nurseries are present in the PRA area and the Panel considers there is potential for further introduction, spread and consequences from the introduction of *D. kuriphilus* into areas of the EU territory where it is not currently present. This is analysed further below to to identify the endangered area of the EU and to determine the probability of entry, establishment and spread.

2.2. Probability of entry: from outside EU territory

2.2.1. List of pathways

The following pathways are identified for entry of the pest to the EU territory:

a) Movement of *Castanea* spp. as living parts of plants, in particular bud-wood, cuttings and scions, and plants intended for planting (containing eggs and larvae);

b) Movement of adults by flight.

The movement of infested plant material represents the main pathway and is examined in detail. Regarding the movement of adults by flight, this does not represent a pathway for introduction of the pest from outside the EU due to geographical isolation from Asia and North America where the pest is established. Movement of adults by active flight from areas within the EU territory where it is present is discussed in section 2.4. (i.e. as spread).

Chestnut fruit does not represent a pathway, as no life stage occurs on the fruit and there is no opportunity for contamination from free-living adult stages as they are not present during the fruit harvesting period (EPPO, 2005; Yasumatsu, 1951).

The movement of timber and wood packaging material does not represent a pathway due to the absence of bud and leaf tissue, which precludes the presence of immature stages as eggs and larvae.

Wood (firewood) is also considered to present a negligible risk as buds are unlikely to be present and, if infested, are unlikely to lead to transfer to a suitable host due to the intended use.

2.2.2. Pathway 1: Movement of infested plant material (and parts of plants scions/budwood) of *Castanea* spp. (immature stages)

Plants intended for planting represent the major pathway. Further diffusion of the pest has occurred by natural spread following its introduction, as evidenced by the history of the pest spread following introduction into Italy in 2002 (Csóka et al., 2009; EPPO Rse, 2009/108; Graziosi and Santi, 2008). The movement of *Castanea* plants from infested sites in Italy has been recorded as the source of introduction to new areas within the EU territory, at least in France (EPPO Rse, 2009/108), Slovenia (EPPO Rse 2006/101) and Hungary (Csóka et al., 2009), since the implementation of emergency measures requiring prohibition of movement of infested material (Commission Decision 2006/464/EC of 27 June 2006).

The unregulated movement of cuttings and plant material is thought to have contributed to further spread along this pathway.

2.2.2.1. Association of the pest with the pathway at origin

As the egg and early larval stage are present in the dormant buds, the pest is very likely to be associated with the pathway at origin as it cannot be detected by visual inspection due to the absence of external symptoms.

Vegetative propagation of *Castanea* and lack of treatment options for consignments lead to a high association of the pest with the pathway, in areas where the pest is present.

There is a high level of uncertainty regarding the volume of movement along the pathway due to a lack of data to quantify volume of imports of *Castanea* plants intended for planting into the EU. Regarding the frequency of movement along the pathway, evidence from country reports confirm the origin of introductions to new areas within the EU as infested plants intended for planting sourced from Italy. For example, the infested trees in Frouzins (France, Midi-Pyrénées region) had been originally produced by an Italian nursery near Brescia (Lombardia), sent to Spain and then re-exported to France (EPPO Rse, 2009/108). There is no evidence that the initial introduction into EU arose from a high number of introduction events (Graziosi and Santi, 2008). The informal local exchange of plant material is noted as frequently occurring in chestnut production areas of Italy (Giovanni Bosio, pers. com. 2009).

2.2.2.2. Survival during transport or storage

The immature stages of the pest are protected within the bud tissue and have a very high likelihood to survive during transport and storage. *D. kuriphilus* is univoltine and development will continue in bud tissue during transport or storage of plants. For plants held until emergence of the adults which disperse by flight in May-July, a single adult is able to lay eggs to increase the prevalence of the pest in bud material (Moriya et al., 2003).

2.2.2.3. Pest surviving the existing pest management procedures

Plants are most frequently transported during the dormant period. The eggs and immatures in dormant buds are undetectable by visual inspection. The pest is present most of the year as an egg in a dormant bud and thus is very likely to survive and remain undetected during management procedures based on visual inspection. Following bud burst in spring the infestations arising from eggs laid the previous growing season are first visible as (green) galls which become more distinctive as they redden. These galls and damaged leaves, as well as dry galls remaining on the plant from the previous year, can be detected by visual inspection.

2.2.2.4. Transfer to a suitable host

Infestation of host plants intended for planting and the practice of local exchange of plant material for vegetative propagation facilitate distribution of infested material, although there is uncertainty on the quantities and distance these plants can be transported. Plant consignments arrive at a suitable time of year for pest establishment as they are transported during the dormant season and are planted before the spring. Conditions are suitable for larval feeding within the host plant tissue and gall development. The presence of the pest in close association and protected within the host plant assures transfer to a suitable habitat. Further spread by emerging adult stage (natural dispersal unaided and human assisted) depends on local presence of host trees and phenological matching.

With respect to the relationship between adult activity and temperature, Tamura (1961) is reported to have found that the optimal temperature range was 25 to 30ºC, with decreased activity below 15ºC, and no activity below 10 ºC. The adult also requires very low wind speeds for flight (Oho and Shimura, 1970) and may be passively transported either with air currents or human-assisted on clothing or vehicles.

2.2.3. Conclusions

Conclusion on entry	**Description**
Moderately likely	The main pathway of entry is associated with plants intended for planting, as demonstrated by the history of introductions of *D. kuriphilus* to new areas. The risk of further entry into the EU from third countries outside the PRA area may be considered to be unlikely as the number of entry events appear to be low. Existing risk management measures for plants of *Castanea* spp. under 2000/29/EC include inspection to ensure freedom from signs or symptoms of harmful insects or to be dormant and free from leaves. However, due to the presence of the pest within the bud tissue the presence of the pest cannot be detected by visual inspection and thus the introduction of infested tissue is very likely to occur. Subsequent internal movement of plant material is likely to result in spread to new areas within the EU.

2.2.4. Uncertainties

Uncertainty for entry	**Description**
Moderate	Lack of information about the volume of plants moving along this pathway is a main source of uncertainty which will influence the conclusion given for the likelihood of entry.

2.3. Probability of establishment

2.3.1. Reports of *Dryocosmus kuriphilus* in Europe

See section 2.1.3.

2.3.2. Availability of suitable hosts in the risk assessment area

Sweet chestnut (*Castanea sativa*) is grown widely in Europe. Fig. 3 shows the distribution of *C. sativa* nut and timber production in Europe. This map was obtained from the European Forest Genetic Resources Programme (EUFORGEN) website (http://www.euforgen.org/distribution_maps.html) and summarises the detailed map provided by Conedera et al. (2004a). However, maps of *C. sativa* distribution in Europe produced by the Global Biodiversity Information Facility (GBIF: http://www.gbif.org) and for the British and Irish flora (http://www.bsbimaps.org.uk/atlas/) show that the species is grown as an ornamental as far north as northern Scotland, southern Norway and southern Sweden.

In the Mediterranean region, chestnut grows at a wide range of altitudes, from sea level to over 1,000 m (1,500 m in Spain and in Sicily) (Fernández-López and Alía, 2003). Limiting factors are represented by soil pH (chestnut tree dislikes limestone) and the amount of precipitation that should be at least 600 mm per year without long drought periods, especially in summer. An oceanic climate is preferred with a mean annual temperature of 8 °C (Bernetti 1995; Fenaroli 1945). The Plants For A Future database (http://www.pfaf.org/database/index.php) states that *C. sativa* is hardy to zone 5 (average annual minimum temperature of -29° to -23 °C) (although http://www.floridata.com/ref/C/cast_sat.cfm gives the hardiness zone for *C. sativa* as 5-7).

In Europe, chestnuts have been planted for timber, fruit, landscape conservation and as ornamentals. They are found in a variety of situations: as forests, mixed stands, orchards, coppices and single trees. Some countries have a strong tradition of chestnut production (e.g. Italy, France, Greece) while some have little production due to climate (United Kingdom). In other countries the chestnut only occurs sporadically (e.g. Hungary, Belgium) or has been recently introduced (eg. Slovakia, Netherlands) (Conedera et al., 2004b).

Sweet chestnut (*Castanea sativa*) is the only native species of Europe from the genus *Castanea* (Fagaceae), which contains up to 13 species distributed throughout the world (Martín et al., 2007). The Panel only took into consideration the distribution of this native species. Although other chestnut species are present in Europe and represent suitable hosts for *D. kuriphilus* these are only rarely planted as ornamentals.

Despite its wide range of distribution and its important role in many European countries, no official and coherent data on the distribution of this species exist up to date. Conedera et al. (2004a) considered that one of the main references for chestnut distribution was that represented by the maps from country reports by the Chestnut International Commission in 1958. The authors also provided updated quantitative data based on a survey held in 2000 as part of COST Action G4 “Multidisciplinary chestnut research”. However, these data are inconsistent due to different silvicultural approaches and classifications in chestnut stands throughout Europe. In Italy, for example, chestnut orchards are considered to cover 210,000 ha, but only 76,000 ha appear to be cultivated (Bounous, 2009). In addition, regional data vary between different sources, e.g. national agricultural censuses, regional authorities, mountain communities and other official sources (Bounous, 2002).

The Panel considers the table compiled by Conedera et al. (2004a) as the most up-to-date and harmonised collection of data at a European level and provides the basis for Table 2. Minor amendments to this table were added where new or more complete data were found (as indicated by specific footnotes) and data collected from other official sources were added below, in order to show gaps, differences, and inconsistencies between different sources. Appendix D provides additional detail.

Table 2: The main chestnut-growing areas in Europe (largely based on Conedera et al., 2004a)

Country	Total country area[8]	Total forest area[6]	**CHESTNUT FORESTS (chestnut > 50 %)**											MIXED FORESTS (chestnut < 50 %)	**Remarks**
			TIMBER PRODUCTION			**FRUIT PRODUCTION**			Irregular structure	**CHESTNUT AREA**			chestnut forests *vs.* total forest area		
			Coppices	High forests	*TOTAL*	Orchards	High forests	*TOTAL*							
	‘000 ha	‘000 ha	ha	ha	ha	ha	ha	ha	ha	ha	%	ha – from FVO survey 2009	%	ha	
EU countries															
Austria	8273	3886										3960000			Only one data from FVO: total forest area of whole Austria
Belgium	3025	620	750	300	1050					**1050**	0.0	1055	0.2	4450	In mixed forests chestnut covers about 30 % of the basal area.
Bulgaria	11055	3690	2000	100	2100		720	720	140	**2804**[9]	0.1	not received	0.1	480	Distribution between coppice and high forest estimated.
Czech Republic	7728	2632										300*			*Estimated number of places, mostly single trees in public greens, few small plantations and mixtures of chestnut and other deciduous trees in forest sites

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[8] FAO, 2003. State of the World's Forests (SOFO), Rome, XIV, 151 p. Land area refers to the total area, excluding areas under inland water bodies. The source of these data is FAO (2001); they may differ slightly from those in the State of the World's Forests 2001, which used a different source. The forest cover figure for each country has been calibrated to the country's land area.

[9] Glushkova M, 2004. Genetic resources of sweet chestnut (*Castanea sativa* Mill.) in Bulgaria. Forest Science 4: 13-25.

Denmark	4243	455										*			**Castanea sativa* are not native to Danish forests or grown in orchards. Out of about 450 nurseries/ garden centers *Castanea sativa* was found in 70.
Estonia	4227	2060										*			*Chestnuts (*Castanea* spp.) are not grown or cultivated in Estonia.
Finland	30459	21935										*			Chestnut, *Castanea*, is not grown in Finland.
France[10]	544000	157100	478000	262000	740000	1500	4500	6000		**746000**		780000	4.7	509000	coppice includes coppice with standards.
Germany	34927	10740	4400		4400					**7.500**[11]	0.2	13377.76	0.0	1600	Only total area available, including avenue and solitary trees; coppice stands are assumed to be prevalent.
Greece	12890	3599	33051		33051	10000[8]	600	600		**33651**	1.5	90392 (trees)	0.9		
Hungary	9234	1840	300	800	1100	900		900		**2000**	0.1	500*	0.1	650	Data refer to a mixture of chestnut - oak and other forest sites
Ireland	6889	659										58			Total forest area, excluding privately owned forests.

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[10] Breisch Henry, C.T.I.F.L.(Centre Technique Interprofessionnel des Fruits et Légumes) – Direction Scientifique et Technique Fruits et Légumes; Personal communication, 8-15 April 2010.

[11] Avanzato D, 2009. (ed) Following Chestnut Footprints (*Castanea* spp.). Cultivation and Culture, Folklore and History, Traditions and Uses. Scripta Horticulturae, 9.

Italy	29406	10003	385000[8]	15119	497870	210000 but only 76000 are cultivated[8]	65000[8]	235620	32347	**765837**	34.0	640800	7.7		Irregular structure intended as forest without a codified management
Latvia	6205	2923										*			*Only few plants of *Castanea* spp. growing in the territory of Latvia.
Lithuania	6258	1994										*			*Only a few trees of *Castanea sativa* are cultivated in Lithuania, as exotic plants.
Malta	32	n.s.										*			*Chestnut species are not grown in Malta
Netherlands	3392	375	50		50					**50**	0.0	~2200*	0.0	250	*0.6 % of total forestry area in the Netherlands according to estimates of experts
Poland	30442	9047										66*			*total number of production sites.
Portugal	9150	3666		33900	33900	19609		19609		**30000[8]**	2.4	not received	1.5	21400	Coppice are included in the high forest area
Romania	23034	6448		2890	2890	100		100		**2990**	0.1	1343.7	0.0	200	
Slovak Republic	4808	2177	16	1302	1318	92		92	95	**1505**	0.1	1459	0.1	45	
Slovenia	2012	1107		30000	30000	185		185		**30185**	1.3	~361000	2.7	202308	No detailed information on the special distribution of the different silvicultural systems

Spain	49945	14370	49909	50039	99948	37679		37679		**137627**	6.1	646342*	1.0		Confusion between high forests and orchards may exist; single or dispersed orchard trees are not included *Sum of 253439 ha with chestnut as main species and 392903 ha as secondary species
Sweden	41162	27134										*			Only 4 nurseries handle *Castanea*
United Kingdom	24160	2794	7913	10875	18788					**18788**	0.8	12000	0.7	10871	
Non-EU countries															
Switzerland	3955	1199	19000	4700	23700	3400		3400		**27100**	1.2		2.3	6800	Mixed forests intended as chestnut presence less then 25 % of the basal area

Other sources were also consulted: EUROSTAT, FAOSTAT and, for Italy, ISTAT: see Appendix D. However, the information they provide is widely conflicting, as illustrated by Table 2, which considers only areas of fruit production.

Table 3: Comparison of data (fruit production areas – ha) obtained respectively from Conedera et al. (2004a), Eurostat, Faostat and Istat

Countries	Conedera et al. (2004a)	Eurostat 2003	FAOSTAT 2003	ISTAT 2004	ISTAT 2005	FVO survey 2009[12]
Austria	0	-				
Belgium	0	-				
Bulgaria	720	0	35			
Czech Republic		-				
France	100000	7300	7264			10000
Germany	0	-				6500
Greece	600	10700	8760			90392 trees
Hungary	900	600	641			
Italy	235620	-	23500	209290	104721	147500
Netherlands	0	-				
Portugal	19609	30200	29885			
Romania	100	0	20			0
Slovakia	92	0				35-37000 trees
Slovenia	185	0	10			~70
Spain	37679	-	11237			
United Kingdom	0	-				

2.3.3. Suitability of environment

The suitability of the European climate for the establishment of *D. kuriphilus* in the EU is discussed in detail in Appendix B. The current presence of *D. kuriphilus* in the EU (Fig. 2) shows that the climate is highly suitable for establishment in Italy and other southern EU countries with a similar Mediterranean climate. To assess the climatic suitability of other areas of the EU where *C. sativa* is present but the summers and winters are cooler we have taken into account (a) the distribution and climatic responses of the hosts in eastern Asia and (b) the minimum threshold for *D. kuriphilus* development of 10 °C reported by Japanese studies (Oho and Shimura, 1970). Global climate databases such as the Köppen-Geiger climate zones (Kottek et al., 2006), world hardiness zones (Magarey et al., 2008) and degree day maps based on global gridded climatic datasets (New et al., 2002) have been used to compare locations where *D. kuriphilus* is present in eastern Asia with the EU.

In eastern Asia, the distribution of *D. kuriphilus* is similar to that of its *Castanea* hosts which can survive much colder winters than *C. sativa*, the principal host in Europe, and so it is expected that *D. kuriphilus* can successfully overwinter wherever *C. sativa* is grown. Despite information that the minimum threshold for development is 10 °C (Oho and Shimura, 1970), we cannot accurately map areas with summer temperatures suitable for development in Europe due to (a) lack of knowledge of

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[12] Based on reports from Member States, as provided on request by FVO on 22 February 2010.

the degree days required to complete development, (b) our imprecise knowledge of the northern limits of *Castanea* distribution in China and (c) the difficulty of relating the distribution of *Castanea* and *D. kuriphilus* to weather stations that accurately record temperature accumulation in mountainous areas. Nevertheless, its wide distribution in Italy, covering the major areas of *C. sativa* fruit production and the mountainous areas of northern Italy suggests that it can establish wherever *C. sativa* is grown throughout southern, central and western Europe. To answer question 1.19 in the risk assessment scheme, the EU can thus be considered to have largely similar climatic conditions to those in the current area of distribution with medium uncertainty.

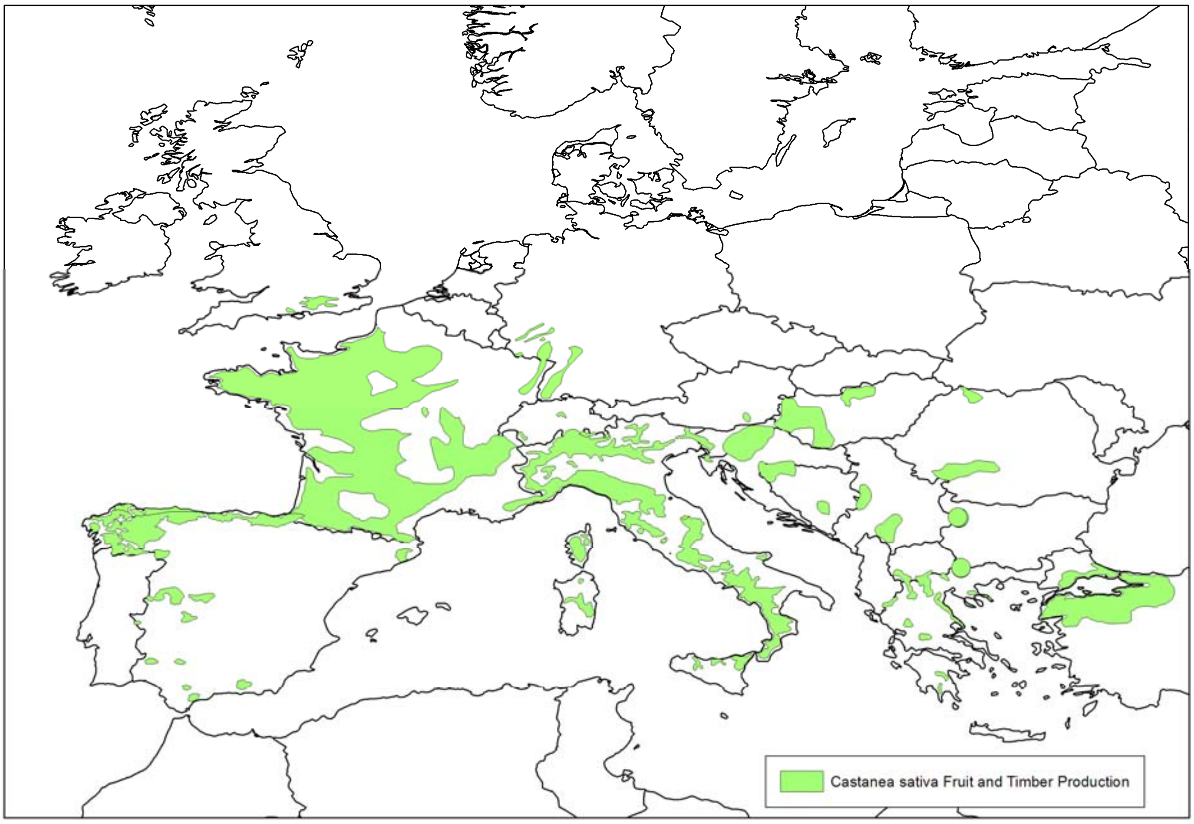

Figure 3: Distribution of *Castanea sativa* in Europe for fruit and timber production (data from EUFORGEN (European Forest Genetic Resources Programme), based on Conedera et al., (2004a), and the information from Bulgaria (Dimitrova, 2008; Glushkova, 2004, 2007)

Apart from climate, other abiotic factors, e.g. soils, are similar to those in its current area of distribution and are not likely to affect establishment.

Competition from existing species in the risk assessment area is very unlikely to prevent establishment with low uncertainty because *D. kuriphilus* is the only palearctic species of gall wasp affecting *Castanea* spp. (Ács et al., 2007).

Existing natural enemies in the EU are not likely to prevent *D. kuriphilus* establishment on a short term, as it is highly specialised as the only Palaearctic gall wasp species to be found on chestnut. This is also supported by the history of establishment following introduction of *D. kuriphilus* to Japan and US. Sixteen parasitoid species have so far parasitized *D. kuriphilus* in Italy, but their attack rates of infested shoots remain low (< 2 %) (Aebi et al., 2007; Stone et al., 2002; see Appendix E). Most of the species have more than one generation per year and thus need alternative hosts. According to Bosio et al. (2010) these indigenous parasitoids, often shifting from oak cynipids, show a low rate of parasitism on *D. kuriphilus*.

2.3.4. Cultural practices and control measures

Cultivation practices and conditions vary locally within and between Italy, Slovenia and France and do not seem so far to prevent wide establishment in Italy, a steadily increasing colonization in Slovenia and the establishment of the pest at least in one valley in the French Alps. The growing of resistant varieties is the only management practice identified to prevent establishment in commercial orchards (Botta et al., 2008; Moriya et al., 2003).

There are presently no existing management practices that could prevent establishment of *D. kuriphilus* in *Castanea* forest areas as the species is very cryptic during a large part of the year, from egg-laying in buds in June-July to budburst in the following spring and symptoms are not visible until the following season (Rieske, 2007) and insecticide treatment to prevent dispersal of the adult stages is not considered to be a feasible option in forest areas.

2.3.5. Other characteristics of the pest affecting the probability of establishment

The reproductive strategy and ecological niche of *D. kuriphilus* are likely to aid establishment. The pest has only one generation per year, but it is a thelytokous species, i.e. unfertilized eggs develop into diploid females (Zhu et al., 2007). Each female may lay more than 100 eggs, with 20-30 eggs found in one bud (Ôtake, 1980, 1989; Tamura, 1960). One female is thus sufficient for founding a new population.

2.3.6. Conclusion

Conclusion on the probability of establishment	**Description**
Very likely	*D. kuriphilus* has successfully established in parts of the PRA area and further establishment is very likely due to the availability of *Castanea* spp.and climatic suitability wherever *C. sativa* is grown in southern, central and western Europe.

2.3.7. Uncertainties

Uncertainty for establishment	**Description**
Low	There is uncertainty relating to the data on the occurence of *Castanea* species throughout the EU territory and in determining the northern limit for establishment of *D. kuriphilus*. However, this does not affect the overall conclusions regarding the very high likelihood of establishment.

2.4. Probability of spread after establishment

2.4.1. Spread by natural means

According to Payne (1981), the adults of *D. kuriphilus* can spread by natural means (active and wind-assisted flight) at an approximate rate of 15 miles (24.1 km) per year. Rieske (2007) presents a map illustrating the dispersal pattern of the gall wasp in North America from 1974 to 2006. He establishes that the distance at which *D. kuriphilus* disperses naturally varies in different years, with the maximum distance recorded being 25 km per year. Graziosi and Santi (2008) have observed a similar rate of natural expansion of the gall wasp in Italy, reaching 25 km per year. For the period 2002–2008, the pest has spread in 12 Italian regions both through active flight of adults and extensive transferral and exchange of infested nursery plant material. Oho and Shimura (1970) review the colonization of Japan by *D. kuriphilus* and show that since its first establishment in 1941 until 1965 it spread throughout the whole territory of the country. But they added also important information on the biological characteristics of the pest determining its spread capability. The adults do not fly well, and mainly rely on the wind to move from place to place. Their direction of dispersal is consistent with the direction of the prevailing wind: wind speeds of 0,15 to 0,45 m/s induce the adults to fly, and they are then carried by the wind, whereas they cease activity at wind speeds of 0,73 m/s or higher, but at wind speeds of 2,15 m/s or higher they are blown off the trees without the need to fly (Oho and Shimura, 1970). These findings suggest that adult dispersal is due to stimulation of flight by very low wind speeds, followed by their being blown in the direction of the wind. On 24 July 2009, the Slovenian NPPO published information on the spread of *D. kuriphilus* in the country on their web site. The published table reports 15 new instances of infestation on Slovenian territory. There is an increase in the number of infestations compared to previous years (2007: 4 reported infestations; 2008: 11 reported infestations; 2009: 15 reported infestation) after the establishment of the gall wasp in Slovenia in 2005. The table is accompanied by a map, showing the infested sites by years. The distances between zones infested in 2008 and 2009 are in the margins of 6–18 km, except for one point of infestation which is further away to the East, Delenji Novaki. It is located 33 km away from the nearest point of infestation, established in 2008, Lig. All points of infestation are situated near the border with Italy and most of them are located around roads and highways, suggesting passive transportation of adult wasps by vehicles.

In order to analyse the potential for spread of *D. kuriphilus*, a spread model was developed by the Panel and is presented in detail in Appendix C. The model considers both the natural and the human-assisted spread and transposes the spread mechanisms, which are described at an individual level (microscopic level) into a mechanistic representation of the spread at the population level (macroscopic level).

At the population level a stratified dispersal comprises two components: (i) a Short Distance Dispersal (SDD), which mainly includes the continuous dispersal of individual at low spatial scale due to the natural random movement of adults and the dispersal caused by natural (e.g. wind) or artificial driving forces (direct human transportation), (ii) a Long Distance Dispersal (LDD), due to discrete events that lead to the establishment of new infestation foci separated from the closest infested area by a non-infested zone. LDD events are mainly caused by artificial dispersal due to the transportation of biological material, but a possible contribution of the two other mechanisms cannot be excluded.

One of the main results of simulations of stratified dispersal in *D. kuriphilus* was to revise the estimates for average spread distance of this pest. The mean rate of spread of the invasion front is estimated as about 8 km/year (Appendix C). This is remarkably smaller than the values reported in literature (i.e. 25 km/yr) which acknowledges that movement of infested planting material is likely to contribute to the spread rates observed.

Uncertainties:

- The presence of the pest in natural forests may be under-reported particularly in less accessible habitats. In many cases the presence of *D. kuriphilus* is reported some years after the colonisation event;

- No information on population abundance which may clarify the dynamics of population growth as a function of local environmental conditions are reported;

- Heterogeneity in data collection and representation in different locations produces uncertainties, the most important source of uncertainty is the low spatial resolution of infestation data;

- The SDD model outputs are considered to be affected by a low level of uncertainty because of the large dataset used for parameter estimation and good results obtained in model validation (see Fig. 14. in Appendix C);

- The range of variation for continuous short distance dispersal of *D. kuriphilus* is 3-12 km/year, and properties of the truncated normal distribution describing the mean distance traveled in a year by the diffusion front allow higher values of continuous rate of diffusion on the right tail of the curve, even if with low probability. This calls for caution when setting buffers for demarcation zones.

2.4.2. Spread by human assistance

The history of this pest's spread shows that long distance dispersal has always been caused by human assistance (see e.g. Graziosi and Santi, 2008; Oho and Shimura, 1970; Rieske, 2007) and, considering the present distribution of *D. kuriphilus* and the number of countries that it has invaded, human assisted spread can be considered to be very likely.

In accordance with Oho and Shimura (1970), the example of spread to and within Korea shows that the wasps' natural tendency to spread is probably greatly increased by people transporting infested saplings for planting.

In Nepal, June-July 1999, galls of *D. kuriphilus* were found only on the cultivated Japanese chestnut *C. crenata* and the Chinese chestnut *C. mollissima*, while none were found on the native chestnut species, suggesting that the pest was introduced to Nepal with planting material of the Japanese and Chinese chestnut trees, even if its origin is unknown (Abe et al., 2007).

D. kuriphilus has been introduced to distant continents as North America and Europe (Zhang et al., 2009). Its presence in Europe was first officially communicated in 2002 (Brussino et al., 2002) when galls were already present on plants of two municipalities of the Cuneo province (Piemonte, Italy).

It spread quickly in the Italian peninsula from region to region through planting material (Graziosi and Santi, 2008) until it arrived also, via infested *Castanea* plants intended for planting, to France (first in 2005 in Valdeblore; EPPO Rse, 2007/086), Slovenia (first in 2005; EPPO Rse, 2006/101). In Slovenia evidence of spread is associated with roads and parking etc. The last new countries where the pest entered in Europe are Switzerland (at Mendrisio, 2009; EPPO Rse, 2009/107) and Hungary in May 2009, but in the second case it was only a single young chestnut tree in Budapest, originating from Northern Italy (Csóka et al., 2009), that was subsequently eradicated.

The model in Appendix C has also been applied to investigate the contribution of human-assisted diffusion on *D. kuriphilus* spread. Model simulation highlights the role of long distance dispersal, in particular through planting material, in explaining the rate and the pattern of colonization. The LDD was considered responsible for the exponential increase in the infested area observed in the period 2002-2009. A critical role was assigned to the number of LDD events per year that can be related to the movement of infested planting material. In most of the cases LDD events that were the source of new infested areas are unknown. The role of such dispersal events can only been reconstructed according to a set of hypotheses. The average number of LDD events and the distribution of distance covered by infested material were estimated based on the introduction history in Italy and these parameters allowed a good interpretation of *D. kuriphilus* spread.

According to expectation on the future pattern of LDD, model projections produce different scenarios of *D. kuriphilus* spread across Europe. A minimum rate of colonization is obtained under the assumption of SDD only (see. Fig. 17. and 18., Appendix C), with a front of colonization traveling at 8 km/year on average. The rate of colonization increases assuming an augmentation in the contribution of human assisted spread (see Fig. 20., 21., 22., Appendix C). A high rate of colonization is expected in Italy if the pattern of LDD does not undergo a significant reduction. (see Fig. 15., Appendix C). Model projection for Italy and the entire Europe under different assumptions on the role of long distance dispersal are reported and further discussed in Appendix C.

2.4.3. Conclusion

Conclusion on spread	**Description**
Likely	*D. kuriphilus* is likely to spread by adult flight and by the movement of infested planting material of *Castanea* spp., where immature stages are present, undetected in bud tissue. The mean rate of spread of the invasion front in Italy is estimated to be about 8 km/year. This is smaller than the value of 25 km/yr attributed to natural spread in the literature. The main means of long distance dispersal is the movement of infested planting material.

2.4.4. Uncertainties

Uncertainty for spread	**Description**
Low	There is some uncertainty relating to the natural dispersal capability due to the difficulty of excluding the contribution of human-assisted spread through movement of infested plant material. However, this does not affect the overall conclusions regarding the high likelihood of spread. To reduce uncertainty, an additional analysis was conducted to model the short distance dispersal based on detailed records of local spread in the first years following introduction in the Cuneo province. The analysis is documented in Appendix C.

2.4.5. Endangered areas

Based on its wide distribution in Italy, all areas of *C. sativa* fruit and timber production in southern Europe, particularly the Mediterranean, are endangered. The areas of the EU where *D. kuriphilus* is currently absent which have the highest degree day accumulations and the largest areas of chestnut production, e.g. in northern Portugal, northern Spain and south-west France (Conedera et al., 2004a) must be considered to be at the greatest risk. Precise limits to its distribution cannot be estimated because of a lack of information on the degree days required to complete its life cycle above the threshold of 10 °C (Oho and Shimura, 1970) and the difficulty of obtaining representative weather data in the mountainous areas of chestnut production in China and Italy.

To provide a more precise indication of the endangered area, the northern limits to the distribution of *D. kuriphilus* in Europe need to be predicted. However, this cannot be determined with great accuracy due to our incomplete knowledge of the climatic responses for *D. kuriphilus* and the difficulty of extrapolating from its current distribution in eastern Asia and the EU (see Appendix B). Nevertheless, we have shown that *D. kuriphilus* is likely to survive winters wherever *C. sativa* is present in the EU since it is present in China wherever the eastern Asian *Castanea*, which are much more cold-hardy than *C. sativa*, are grown. Although winter temperatures are therefore not likely to limit its northernmost distribution in the EU, summer degree day accumulation above its known minimum development threshold of 10 °C may prevent successful development and reproduction. We have therefore mapped annual degree days base 10 °C in the EU as an indicator of potential establishment.

Figure 4 overlays the EUFORGEN summary of the *C. sativa* fruit and timber production map from Conedera et al. (2004a) onto the annual degree days base 10 °C for 1961-90 at 10 minute resolution in Italy. It highlights how, in Italy, *C. sativa* is not grown in the hottest areas and is found particularly in hilly or mountainous areas where, according to the 10 minute resolution maps of degree days base 10 °C, the annual temperature accumulation is between 750 and 1500.

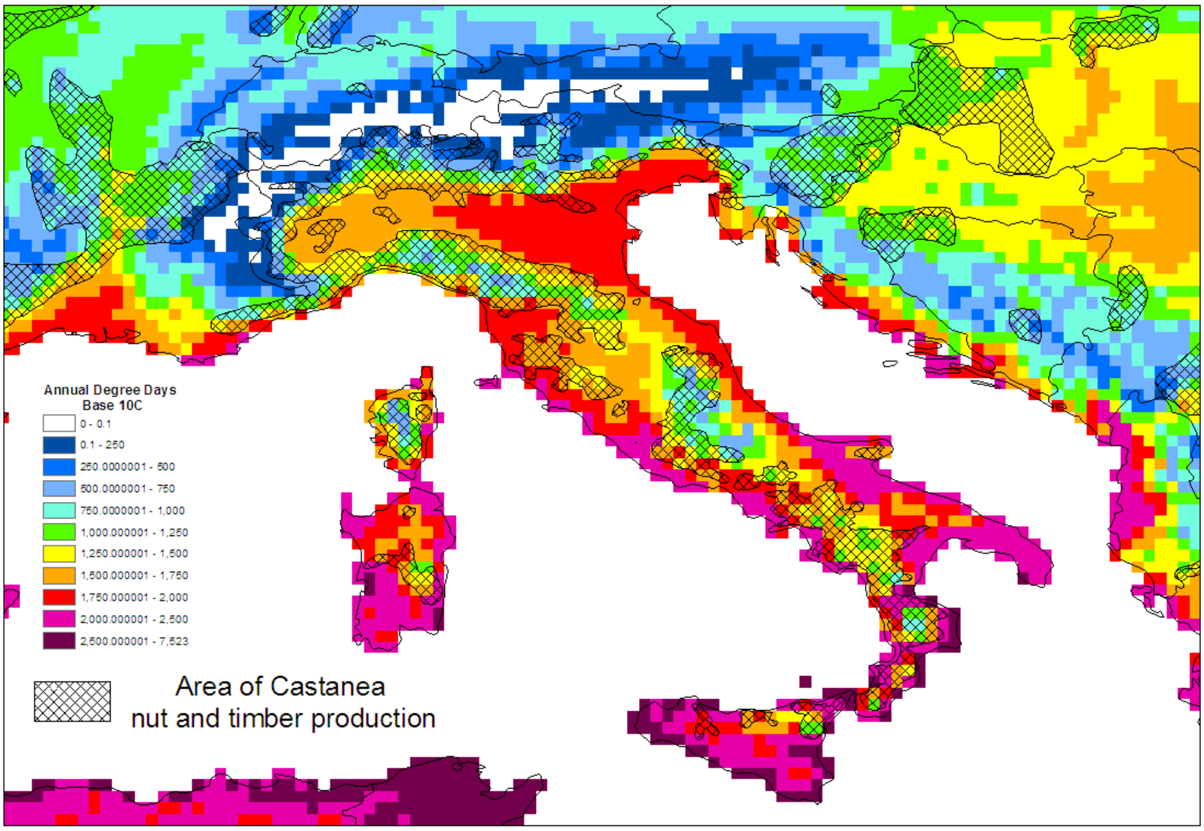

Figure 4: Annual degree days base 10 °C for 1961-90 (New et al., 2002) and the area of *Castanea sativa* nut and timber production in Italy from EUFORGEN

Figure 5 expands Fig. 4 to the area of the EU where *C. sativa* is grown for fruit and timber production, showing that almost all of this area also has an annual temperature accumulation within this range. This indicates that almost the whole area of *C. sativa* fruit and timber production in the EU is therefore at risk from *D. kuriphilus*. The areas where *D. kuriphilus* is currently absent which have the highest degree day accumulations and the largest areas of chestnut production, e.g. in northern Portugal, northern Spain and south-west France are considered to be at the greatest risk.

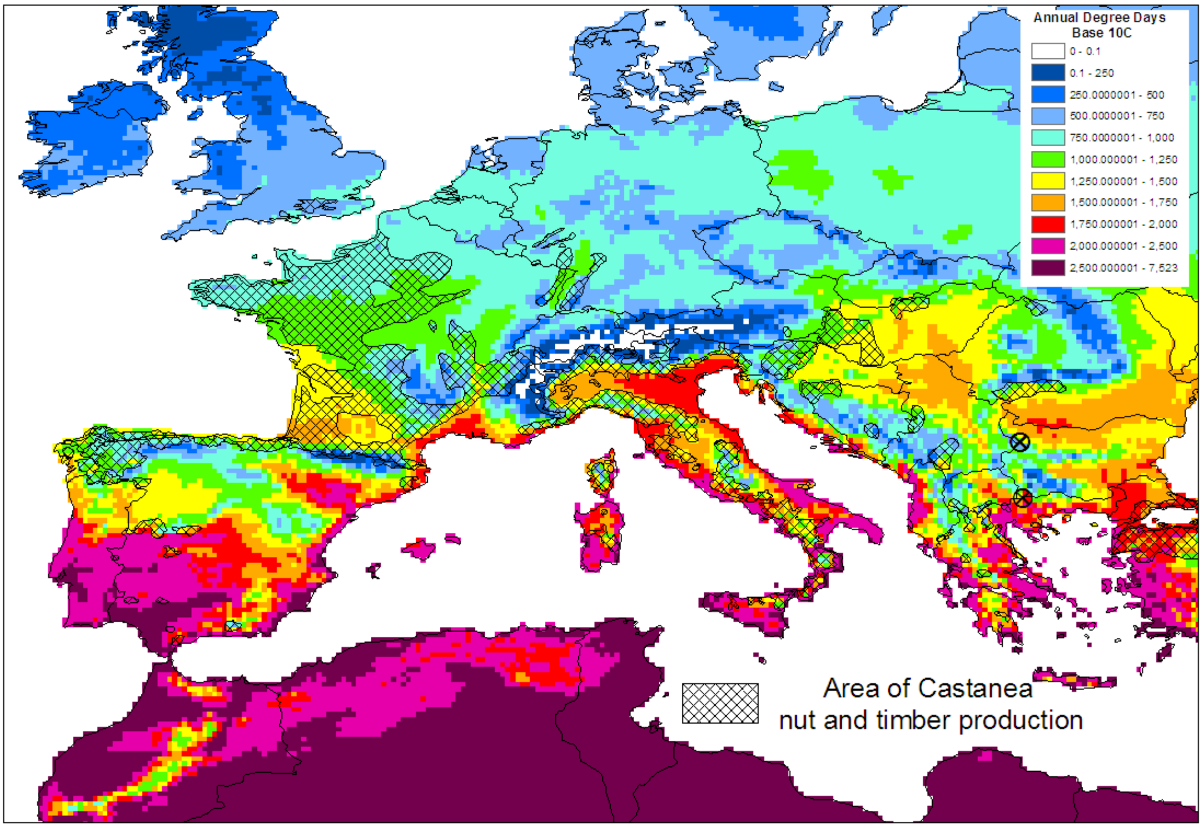

Figure 5: Annual degree days base 10 °C for 1961-90 (New et al., 2002) and the area of *Castanea sativa* nut and timber production in Europe from EUFORGEN

2.5. Assessment of potential consequences

2.5.1. Pest effects

2.5.1.1. Direct pest effects

Dryocosmus kuriphilus attacks vegetative buds and forms a gall, disrupts twig growth and reduces fruiting. Severe infestations may result in decline and death of chestnut trees (Payne, 1978; Payne et al., 1975, 1983). *D. kuriphilus* is reported to be the most severe insect pest worldwide on chestnuts and can eliminate nut production and even kill trees (Dixon et al., 1986). However, a corroboration of the statement that *D. kuriphilus* can kill trees was not found in the literature and not confirmed by experts, and attempts to quantify fruit yield losses due to insect attacks in Italy have so far not been conclusive (Roberto Botta, pers. com., Ljubljana 24 November 2009), although Breisch and Streito (2004) noted a 60 to 80 % reduction in yield in Italy but did not provide data in support of this statement.

China: Yield loss in some years over 80 % on Chinese chestnut (*Castanea mollissima*); in 1998, 96 % of trees and 70 % of chestnut branches were damaged in Pinggu (Beijing), with 30 % yield loss. In 2004 chestnut yield in Shennongjia (Hubei Province) was only 20 % of that in former years (Zhang, 2009). Occurrence and damage activities of *D. kuriphilus* are closely related to chestnut phenological phases. Pest occurrence is observed cyclically and regionally throughout mainland of China. Heavy damage is observed for 2-3 years, followed by only mild damage for approximately the next 10 years due to the regulating effect of parasitoids (Zhang, 2009).

Japan: *D. kuriphilus* was characterised by Yasumatsu (1951) as one of the most destructive insects in all important chestnut (*C. crenata*) producing areas of Japan. Kato and Hijii (1997) showed strong negative effects of *D. kuriphilus* on Japanese chestnut growth, with studies demonstrating the mean leaf area on galled shoots was half that recorded on healthy, ungalled shoots leading to a reduction in photosynthetic production. Galled shoots were lower in leaf/shoot biomass ratio and in the mean number of winter buds produced. Total biomass production in the following year suggested that there may be little compensatory growth for reduction in biomass leading to gradual decline in vigour of long-lived and slow-growing chestnut trees (Kato and Hijii, 1997). The higher the weight of the galls, the higher the rate of injury to the chestnut tree (Shimura, 1973). A damage threshold of 30 % galling in all buds surveyed is referred to in the literature (Gyoutoku and Uemura, 1985), but the Panel found no quantitative data to confirm this threshold.

USA: There are a few large chestnut groves in the US, and several small plantings in the Midwest, East and Southeast (Jaynes, 1975, cited by Payne, 1978). American chestnut (*Castanea dentata*) is susceptible to *D. kuriphilus*. Yield reductions of 50–75 % were indicated in the U.S.A. (Payne et al., 1983). The Panel found no quantitative information in the literature to confirm damage estimates and no report of tree mortality was confirmed.

Europe: Chestnut production for food in the EU in 1999 is presented in Table 4 below (FAO, 2002), indicating Italy, Spain and Portugal as the Member States with greatest production.

Table 4: Chestnut production for food in the EU in the year 1999 (FAO, 2002[13])

Member State	**Production (t)**
Italy	78432
Spain	20000
Portugal	19728
France	12745
Greece	11000
Hungary	973
Romania	900
Slovenia	500
Bulgaria	300
Total	144578

2.5.1.2. Environmental effects on forest systems

It is stated that where chestnut (*C. sativa* and other susceptible species) is planted in Europe for timber and to stabilize slopes, *D. kuriphilus* could cause serious decline (EPPO, 2005). However, no evidence was found by the Panel to confirm tree mortality. A gradual reduction in vigour in the longer term is likely to be a consequence of annual parasitism by *D. kuriphilus* causing a gradual reduction in biomass. However, the environmental consequences are considered by the Panel to be low, as the effects of *D. kuriphilus* are unlikely to adversely affect provisioning, regulating or sustaining ecosystem services provided by *Castanea* spp., although some loss of aesthetic quality and amenity value is identified with regard to cultural services. Abandonment of traditional chestnut cultivation in the Cévennes (France) is reported as leading to a reduction of diversity in the local annual flora (Gondard et al., 2001; Romane et al., 2001), but abandonment of orchards is attributed to changes in

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[13] Available from: http://www.fao.org/DOCREP/006/AD235E/ad235e04.htm

agricultural practices and rural depopulation starting at the end of the 19th century (O'Rourke, 2006) and had no relationship with chestnut mortality.

Regarding the environmental impact of potential control measures, a preliminary environmental risk assessment has been conducted by the Panel (Appendix E) to consider potential non-target effects of the introduction from Japan of the parasitoid, *Torymus sinensis* for biological control of *D. kuriphilus.*

2.5.2. Conclusion of the assessment of consequences

Conclusion of impact	Description
Moderate	No evidence of tree mortality but yield reductions of up to 80 % are reported, without quantitative studies confirming these estimates. A damage threshold of 30 % branches galled is recorded in Japan where effective control is achieved by the introduction of the biological control agent *T. sinensis* or with the use of resistant varieties of *Castanea* spp. Studies in Japan demonstrated the mean leaf area on galled shoots was half of that recorded on ungalled shoots reducing photosynthesis, biomass ratio and winter bud production. Continuous parasitism by *D. kuriphilus* can result in a gradual decline in vigour of long-lived and slow-growing chestnut trees but unlikely to adversely affect provisioning, regulating or sustaining ecosystem services provided by *Castanea* spp.

2.5.3. Uncertainties

Uncertainty	Description
High	Lack of evidence on yield loss directly attributed to *D. kuriphilus* on *C. sativae* in Italy. Further data confirming reduction in yield directly attributed to *D. kuriphilus* may influence the conclusion and could increase the rating given.

2.5.4. Conclusion regarding endangered areas

Almost all of the EU area where *C. sativa* is grown for fruit and timber production also has an annual temperature accumulation which is suitable for the pest development. However, the areas where *D. kuriphilus* is currently absent which have the highest degree day accumulations and the largest areas of chestnut fruit production, e.g. in northern Portugal, northern Spain and south-west France must be considered to be at the greatest risk. These areas are highlighted in Figure 6 which compares the distribution of *D. kuriphilus* with the orchards mapped by Conedera et al. (2004a). A 5 km buffer has been drawn around the orchards to enhance their visibility.

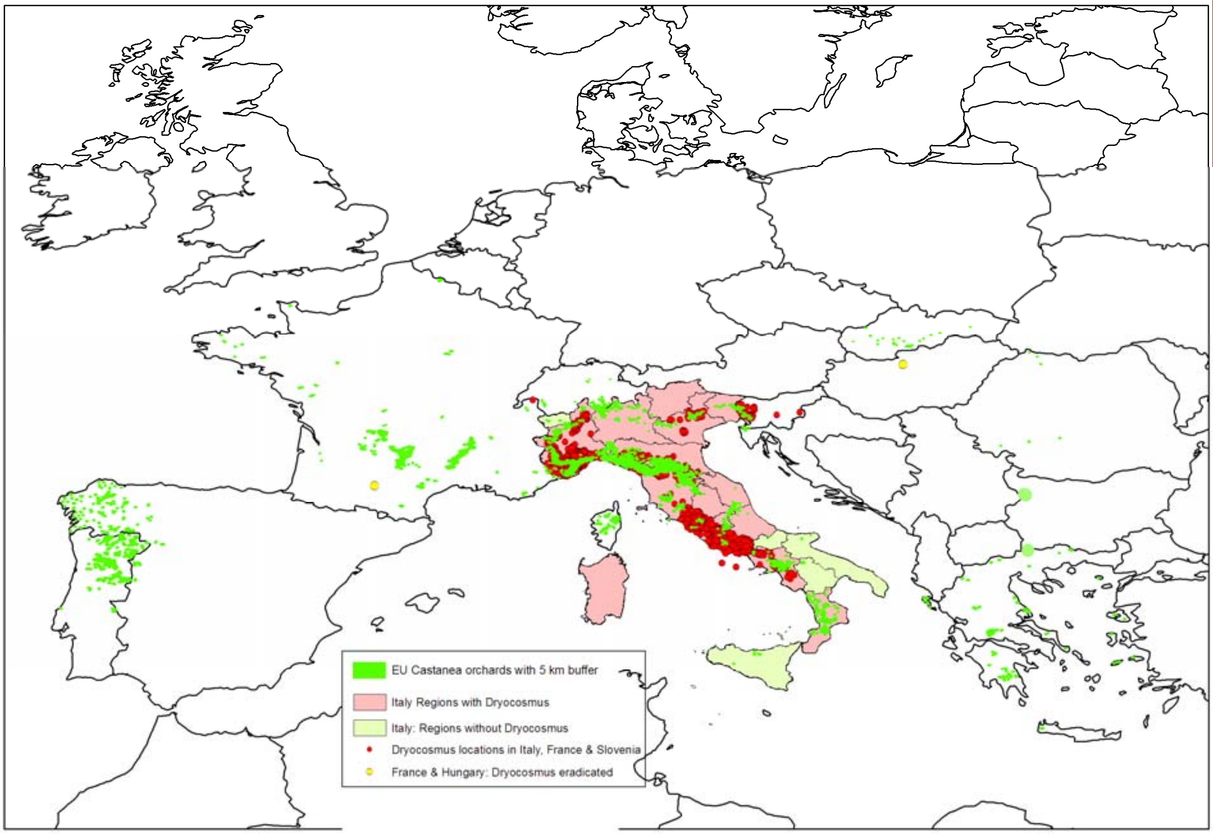

Figure 6: The distribution of *Castanea sativa* nut orchards in Europe based on Conedera et al. (2004a) and information from Bulgaria (Dimitrova, 2008; Glushkova, 2004, 2007) in relation to the presence of *Dryocosmus kuriphilus* in the EU. A buffer of 5 km has been drawn around the orchards to enhance visibility

2.6. Conclusion on risk assessment

ENTRY: The main entry pathway is identified as plants intended for planting, and demonstrated by the history of introductions of *D. kuriphilus* to new areas. Entry into the EU from third countries outside the PRA area may have been due to a low number of entry events and therefore considered to be unlikely. However, due to the presence of the pest within the bud tissue, the pest is very likely to escape detection by visual inspection of plant material which is dormant and free from leaves as required by existing risk management measures for plants of *Castanea* spp. under 2000/29/EC to ensure freedom from signs or symptoms of harmful insects.

ESTABLISHMENT:The establishment is very likely due to the proven successful establishment in the PRA area in Italy, and availability of *Castanea* and suitable climate.

SPREAD: The pest is likely to spread by natural means (adult flight, wind and human-assisted) and by the movement of infested *Castanea* planting material, where immature stages are present in bud tissue and cannot be detected. The mean rate of spread of the invasion front in Italy due to the continuous short distance dispersal is estimated to be about 8 km/year. This is smaller than the value of 25 km/yr attributed to natural spread in the literature. The main means of long distance dispersal is the movement of infested planting material.

IMPACT: No evidence of tree mortality was confirmed. Yield reductions of up to 80 % are reported, although there are no quantitative studies to confirm these estimates. A damage threshold of 30 % branches galled is referred to in Japan where control is reported as effective by introduction of the biological control agent *T. sinensis* at this threshold or by the use of resistant varieties of *Castanea* spp. Studies in Japan demonstrated the mean leaf area on galled shoots was only half of that recorded on ungalled shoots, reducing photosynthesis, biomass ratio and winter bud production. Continuous parasitism by *D. kuriphilus* can result in a gradual decline in vigour of long-lived and slow-growing chestnut trees but is unlikely to adversely affect provisioning, regulating or sustaining services provided by *Castanea* spp.

Almost all of the EU area where *C. sativa* is grown for fruit and timber production also has an annual temperature accumulation which is suitable for the pest development. However, the areas where *D. kuriphilus* is currently absent which have the highest degree day accumulations and the largest areas of chestnut fruit production, e.g. in northern Portugal, northern Spain and south-west France are considered to be at greatest risk.

3. Identification of risk management options and evaluation of their effectiveness in reducing the level of risk

Risk management options are identified according to the following categories:

- options to reduce likelihood of introduction on plant consignments;
- options to reduce likelihood of spread;
- options to reduce infestation and magnitude of impact in the crop.

The Panel evaluates the risk management options identified with respect to their effectiveness and technical feasibility, i.e. the level to which the risk is reduced by the risk management option and consideration of technical aspects which influence their practical application.

Movement of plants (and parts of plants) of *Castanea* spp. intended for planting is identified as the main pathway for introduction of *D. kuriphilus* into new areas, as illustrated by the history of *D. kuriphilus* introductions in the USA (Rieske, 2007), Italy (Graziosi and Santi, 2008), France (Saint-Dalmas-Valdéblore) in 2005 (EPPO Rse, 2007/086), Western Slovenia in 2004 (EPPO Rse 2006/101) and Hungary in 2009 (Csóka et al., 2009).

The existing protective measures for *Castanea* spp in Directive 2000/29/EC and the provisional emergency measures outlined in Decision 2006/464/EC are presented.

3.1. Options to reduce likelihood of introduction on plant consignments

3.1.1. Options for plant consignments

3.1.1.1. Evaluation of existing measures in 2000/29/EC

The following requirements are listed in 2000/29/EC:

- *Castanea* spp Mill. with leaves, other than fruit and seeds, from non-European countries are prohibited (Annex III(A)(2));
- Annex IVA1(39): Trees and shrubs intended for planting, other than seeds and plants in tissue culture, originating in third countries other than European and Mediterranean countries – where appropriate official statement [have been provided to the effect] that the plants a) are clean (free from plant debris) and free from flowers and fruits b) have been grown in nurseries c) have been inspected at appropriate times and prior to export and found free from symptoms of harmful bacteria, viruses and virus-like organisms, and either found free from signs or symptoms of

harmful insects, mites and fungi, or have been subjected to appropriate treatment to eliminate such organisms;

- Annex IVA1(40): Deciduous trees and shrubs intended for planting, other than seeds and plants in tissue culture, originating in third countries other than European and Mediterranean countries - where appropriate official statement [have been provided to the effect] that the plants are dormant and free from leaves;

- Annex IVA1(43): Naturally or artificially dwarfed plants intended for planting other than seeds, originating in non-European countries – where appropriate official statement [have been provided to the effect] that a) plants shall have been grown, held and trained for at least 2 consecutive years prior to despatch in officially registered nurseries subject to an officially supervised control regime.

The Panel considers that the requirement for plants to be dormant and free from leaves does not provide an effective measure to prevent the introduction of *D. kuriphilus* as egg and immature stages are present in the dormant buds. The effectiveness of the general requirement for trees and shrubs to have been inspected at appropriate times and prior to export and found free from symptoms of harmful insects is dependent on the plants being inspected during the previous year of growth when visible symptoms are present, and even this does not preclude infestation occurring after inspection on the previous year. There is no known treatment of plants intended for planting to eliminate *D. kuriphilus* in the bud tissue. The requirement for dwarfed plants to be grown for 2 consecutive years in officially registered nurseries subject to an officially supervised control regime allows opportunity for detection of symptoms on *Castanea* spp.

3.1.1.2. Provisional measures under Decision 2006/464/EC

Commission Decision 2006/464/EC of 27 June 2006 requires that:

(a) the plants have been grown throughout their life (or since their importation/introduction to the Community) in places of production in countries where the organism is not known to occur; or

(b) the plants have been grown throughout their life or since their introduction into the Community in places of production in a pest-free area, established by the national plant protection organisation in the country of origin in accordance with relevant International Standards for Phytosanitary Measures and under the rubric ‘place of origin’ the name of the pest-free area.

The Decision further requires the establishment of demarcated zones following introduction of the pest. Measures in demarcated zones include the prohibition of movement of plants out of or within these zones. In cases where the presence of the organism has been confirmed on the plants at a place of production, appropriate measures aiming at eradicating the harmful organism, consist of at least destruction of the infested plants, all those plants showing symptoms caused by the organism and, where appropriate, all such plants belonging to the same lot at the time of planting and a monitoring of the presence of the organism through appropriate inspections during the period of potential presence of the inhabited galls.

The demarcated zones consist of the following:

(c) an infested zone where the presence of the organism has been confirmed and which includes all plants showing symptoms caused by the organism, and, where appropriate, all plants belonging to the same lot at the time of planting;

(d) a focus zone with a boundary at least 5 km beyond the boundary of the infested zone, and

(e) a buffer zone with a boundary at least 10 km beyond the boundary of the focus zone.

Options relating to the place of production of *Castanea* spp. to reduce the likelihood of introduction of *D. kuriphilus* are discussed in 3.2.2. below. Demarcated zones are discussed in section 3.3.1 taking into account the results of an additional analysis undertaken by the Panel (detailed in Appendix C) to investigate the dispersal and spread of *D. kuriphilus.*

3.1.1.3. Detection of the pest in consignments by inspection or testing

The transportation of plants intended for planting usually takes place when plants are dormant and before bud flush, i.e. during the autumn, winter or early spring. At this time, the pest cannot be reliably detected by a visual inspection of a consignment at the time of export, during transport/storage or at import, because the eggs or young larvae of *D. kuriphilus* are undetectable in the dormant buds. Galls are only visible on plant growth following infection the preceding year. Detection by inspection of the consignment during the dormant period is therefore not considered by the Panel to be effective.

3.1.1.4. Treatment of consignments

There is no known treatment to eliminate *D. kuriphilus* in the bud tissue of *Castanea* spp. host plants.

3.1.1.5. Post-entry quarantine period

Dormant plants may be held (maintained at the place of production) until buds have developed, to allow galls arising from the presence of *D. kuriphilus* to develop. Visible symptoms are readily detected following bud burst and infested plants can be destroyed before the emergence of mobile adult wasps (occurring from May, depending on temperature).

This option is more practical for small quantities of plants or parts of *Castanea* plants including galls of *D. kuriphilus* imported for research purposes e.g. biological control.

3.1.2. Options at places of plant production

To reduce the risk of introduction of *D. kuriphilus*, plants of *Castanea* spp. may be produced in a pest-free area (ISPM No.4, IPPC, 1995) i.e. where *D. kuriphilus* is not present.

D. kuriphilus is established in China Japan, Korea, the United States, Nepal and Italy, and in parts of France and Slovenia. Where plants are produced in areas where *D. kuriphilus* is known to be present, there is a risk of contamination of planting material with *D. kuriphilus*. Plants should be grown in a pest-free place of production confirmed through targetted surveillance for *D. kuriphilus*, in line with International Standards for Phytosanitary Measures (ISPM No.10, IPPC, 1999) which outlines the requirements for establishment of pest free places and sites of production states in broad terms. It suggests that the extent of the buffer zone surrounding the production site should be based on the distance over which the pest is likely to spread naturally during the course of the growing season. The provisional emergency measures against *D. kuriphilus* (Decision 2006/464/EC) include establishment of demarcated zones with boundaries 5 km (“focus zone”) +10 km (“buffer zone”) beyond an infestation.

Graziosi and Santi (2008), Payne (1981) and Rieske (2007) suggest a rate of spread for *D. kuriphilus* as 25 km per year, but acknowledge that human-assisted movement cannot be excluded from this estimate. Results of a more detailed analysis conducted by the Panel regarding dispersal of the pest in Europe based on findings in Italy (see Appendix C), suggest that the current focus zone of 5 km required by Decision 2006/464/EC is insufficient for pest surveillance but that inclusion of the extended 10 km buffer zone area also currently required would support a 15 km demarcated area based on the short distance dispersal analysis outlined in detail in Appendix C and which suggests an annual diffusion rate of 8-12 km per year. Additional surveillance within an extended area would increase the confidence in confirming absence of the pest in or around a specified location. Appropriate surveillance would include identification and inspection of *Castanea* spp. during the previous growing season prior to shipment to ensure freedom from visual symptoms i.e. galls of *D. kuriphilus*. Inspection should be carried out at appropriate times (after May-June, when the galls of the buds infested the previous year have started to appear) to confirm the presence of the organism.

The plants could be considered pest-free when they have been grown in a place of production with complete physical protection against the introduction of *D. kuriphilus,* and have been surrounded by a buffer zone with a radius of at least 15 km where official surveys for the presence or signs of *D. kuriphilus* are carried out annually at appropriate times. Where signs of *D. kuriphilus* are found in the buffer zone, an increase in intensity of surveillance of *Castanea* spp. for symptoms of the pest is necessary to confirm the level of infestation in the surrounding area. Physical measures e.g. insect screening and/or insecticide treatment and restrictions on movement during the period of adult emergence (June-July) may mitigate the risk of contamination. However, the technical feasibility of insect screening is considered to be very low due to the small size of the insect. There is also no evidence to confirm the effectiveness of insecticide treatments which may be applied against the adult which would require repeated applications over the potential flight period.

Similarly, the technical feasibility of surveillance based solely on visual inspection of *Castanea* spp. within a 15 km radius appears questionable, particularly in mature chestnut forests with a high density of trees in the area. Therefore, the feasibility of ensuring freedom from the pest at places of production is dependent on the density of *Castanea* spp. in the surrounding which influences the level of inspection required to ensure detection of the pest at low population densities.

3.2. Options to reduce likelihood of spread following introduction to the EU

Human-assisted movement via plants intended for planting is identified as the main means of long-distance dispersal and spread of the pest and options on this pathway are presented in 3.1 above. Options to reduce the risk of natural spread are evaluated in this section.

3.2.1. Establishment of demarcated zones

Annex II of the provisional emergency measures (Decision 2006/464/EC) introduced for *D. kuriphilus* describes a 5 km wide focus zone around new infestation foci, and a 10 km buffer zone around the focus zone. The purpose of the two zones is not elaborated further in the Decision but allow for differentiation in the risk management options to be applied.

Based on the underlying mechanisms of spread at the population level, the Panel consider two demarcated zones only: (i) infested zone is where the presence of the organism has been confirmed and is the minimum area which includes all plants showing symptoms caused by the organism, and, where appropriate, all plants belonging to the same lot at the time of planting; (ii) buffer zone is an area surrounding or adjacent to an area officially delimited for phytosanitary purposes (i.e. equivalent to the focus zone in Decision 2006/464/EC) 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 as defined in ISPM No. 5, (IPPC, 2007).

Results obtained by the model outlined in detail in Appendix C suggest that the organism can disperse randomly and continuously in space from the infested zone into the surrounding area at an average rate of 8 km/year, with a variation comprised in a range of 3-12 km/year. Due to human-aided dispersal and movement of planting material the pest could create a new infested zone separated by a pest free area. This kind of long distance dispersal is potentially unbounded (see section 3.3. and Fig. 13. in Appendix C) and therefore should not be considered in determining the size of a demarcated zone. Management options in this case comprise the options to reduce risk of introduction on plant consignments. The Panel proposes:

- A single buffer zone of 15 km allowing for surveillance within an area based on an estimate of the active and passive short distance dispersal capability of *D. kuriphilus* (see section 3.2. in Appendix C).

- Surveillance within this area based on targeted inspection of *Castanea* for galling symptoms in April-June allowing for early detection and destruction of affected plants before the emergence of adult dispersal stages (occuring from May-July).

- Restrictions on movement within the period of adult activity (May to July), where feasible, may minimise the risk of human-assisted transfer.

However, analysis of the experience in Italy, France and Slovenia (see 1.2) suggests that, if the *Castanea* forest coverage in the focus or buffer zone is extensive, surveillance and destruction of the infested trees is impractical and there is a very high likelihood of spread following introduction of *D. kuriphilus* into areas in the vicinity of chestnut forests despite risk management measures undertaken (intensive surveillance activity and removal and destruction of affected trees in demarcated zones). Once introduced into *Castanea* forests, the Panel identified no management options to prevent further spread of *D. kuriphilus*.

3.3. Options to reduce the magnitude of impact in the crop

There are a limited number of management options identified for *D. kuriphilus* (Moriya et al., 2003; Murakami et al., 1977; Zhang, 2009). Conventional chemical control is hard to apply against the gall wasp, because eggs, larval and pupal stages are embedded in plant tissues and protected within the galls formed by this organism (CABI, 2007; Bosio et al., 2010). Host-plant resistance, and biological control using natural enemies are identified as the most effective means of reducing pest populations to reduce the magnitude of impact.

3.3.1. Resistant varieties

Growing of resistant varieties of *Castanea* spp. is identified by the Panel as a potential management option for reducing the magnitude of impact of *D. kuriphilus* in *Castanea* orchards. Since the introduction of *D. kuriphilus* to Japan in 1940's, selection programmes have been carried out to identify resistant varieties of the Japanese chestnut *Castanea crenata* (Kotobuki et al., 1984). During the first programme, several cultivars of *C. crenata* were found to be resistant to the gall wasp and as a result, the area of *C. crenata* in Japan rapidly increased through planting of these resistant varieties (Shimura, 1972). However, during the early 70's, damage caused by the gall wasp was recorded on the resistant varieties in several regions of Japan indicating the possible break down of resistance (Murakami, 1981). The population densities and spread of the pest were higher compared to what has been observed in the past (Shimura, 1973). During the last of the four programmes for selection of *C. crenata*, which continued for 12 years, two parental forms, highly resistant to *D. kuriphilus* were selected, but the mode of inheritance of resistance remains unclear (Kotobuki et al., 1984). Thus, during the 40 years of selection of *C. crenata* in Japan, resistant varieties have been used successfully, but the mode of inheritance of resistance was not established, which limits the application of more rapid contemporary methods for selection.

Kim et al. (2008) report that in South Korea, during the period 1985–1999, a new variety of *C. crenata* resistant to *D. kuriphilus* was obtained. It was selected from wild plantings of the Japanese chestnut in the country. However, the authors do not clarify how they have established the existence of this resistance.

In the USA, the programmes for selection of *Castanea dentata* are directed mainly towards resistance to chestnut root rot (*Phytophthora cinnamoni*) and chestnut blight (*Cryphonectria parasitica*) (Agnostakis, 1998, 2001). Nevertheless, Payne (1978), observed that chinquapins (*Castanea pumila*

(L.) Mill. and *Castanea alnifolia* Nutt.), seem to be resistant or immune to the chestnut gall wasp, but it remains unclear whether they are a reliable source of resistance to *D. kuriphilus*.

In Italy, resistant rootstocks of the euro-japanese hybrids (*C. sativa* x *C. crenata*) are grown and can be completely effective in preventing impact by of *D. kuriphilus* in chestnut orchards (Botta et al., 2008) as galls do not develop. Currently, the most commonly used clonal rootstocks are the euro-japanese hybrids (*C. sativa* x *C. crenata*) Marsol and Maraval but their compability with *Castanea sativa* varieties requires a case by case evaluation (Botta et al., 2008).

A 5-year study of resistance of 64 chestnut cultivars to *D. kuriphilus* is currently in progress in Piemontee. The results show that the varieties Bouche de Bétizac (*C. sativa* x *C. crenata*), Idae (*C. mollissima* x *C. crenata)*, Muraie (*C. sativa*) and Vignols (*C. crenata* x *C. sativa*) exhibit lowest susceptibility to *D. kuriphilus* with no infestation observed during the experiments (Roberto Botta, pers. com., Ljubljana 24 November 2009).

However, the following limitations are noted:

- this measure is only effective for new orchards and replantings;
- the level of resistance of the majority of *C. sativa* and hybrid varieties is unknown as a limited number of varieties have been tested to date. Thus it may not be technically feasible to plant resistant varieties in some areas, where local conditions may not favour the growth of the limited number of varieties available;
- unclear mode of inheritance of resistance to *D. kuriphilus* slows the selection process which takes at least 6 years to develop;
- there is a risk of selection of *Dryocosmus* biotypes which may in future overcome plant resistance, as illustrated with previous experience in Japan, therefore there is uncertainty on the effectiveness in the longer term.

3.3.2. Biological control

In China, the country of origin of *D. kuriphilus*, this gall wasp is reported to be kept at low densities by naturally occurring biological control agents in several areas, but natural control is not equally effective everywhere, which results locally in pest damage (Zhang, 2009).

In Japan, South Korea, the USA and Europe, many indigenous parasitoids attack *D. kuriphilus*, but attack rates of infested shoots were usually below 2 %. The only exception is one North American species, the generalist parasitoid *Ormyrus labotus* which attacked a higher percentage of chestnut galls (Aebi et al., 2006, 2007; Cooper and Rieske, 2007a; Murakami et al., 1994, 1995; Ôtake et al., 1982; Payne, 1978; Stone et al., 2002). In Italy, sixteen parasitoid species have so far parasitized the newly appearing *D. kuriphilus*, but their attack rates of infested shoots remain low (< 2 %) (Aebi et al., 2007; Stone et al., 2002).

In Japan, releases of *T. sinensis* have been very successful. *T. sinensis* was selected because it was the only Chinese species with high host specificity and had a life-cycle matching that of *D. kuriphilus* (Moriya et al., 2003). The effectiveness of *Torymus sinensis* in reducing the number of shoots infested with *D. kuriphilus* is clearly demonstrated and described by Moriya et al. (2003) as illustrated in Figure 7 below. The Panel notes that the percentage of chestnut shoots parasitised by *T. sinensis* is used as a reference point. The percentage of *D. kuriphilus* larvae parasitised within each shoot may, however, be lower.

Similarly after releasing *T. sinensis* in Georgia USA in the late 1970s, gall wasp populations in central Georgia declined within a few years and the incidence of galling dropped to below damaging levels.

Later, *T. sinensis* has moved with expanding gall wasp populations in eastern North America and reportedly reduced pest levels (Cooper and Rieske, 2007a, b; Rieske, 2007).

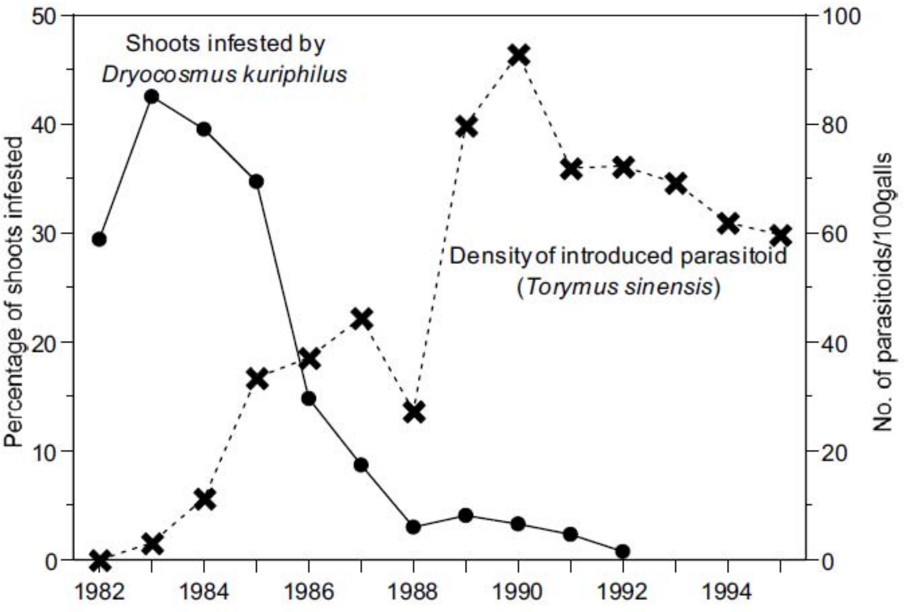

Figure 7: Changes in chestnut shoot infestation by *D. kuriphilus* and emergence of *T. sinensis* from the galls after its release at the National Institute of Fruit Tree Science. Source: Moriya et al. (2003)

Following the introduction and establishment of *D. kuriphilus* in Italy, *T. sinensis*, sourced from Japan, was first released in Italy in 2005 (Aebi et al., 2006). The rearing, release and potential establishment of this non-native parasitoid species in the province of Cuneo in the Piemonte region of Italy are described in detail by Quacchia et al. (2007).

The effectiveness of biological control by *T. sinensis* in reducing the impact of *D. kuriphilus* has not yet been demonstrated following the release of the parasitoid at selected sites in Italy. However, increased levels of parasitism have been recorded in 2009 which indicate the potential of biological control for effective long-term management of *D. kuriphilus* (Table 5).

Table 5: Monitoring results from Robilante experimental site showing percentage parasitism of chestnut shoots (Ambra Quacchia, pers. com., 2009)

			Emergence of *T. sinensis* adults				
	Pairs introduced	**Galls collected**	**Female**	**Males**	**Total**	**Sex ratio (M:F)**	**% parasitism of chestnut shoots**
2005	28	-					-
2006	123	-					-
2007	49	12000	3	2	5	0,67	0,04
2008	-	13200	79	34	113	0,43	0,86
2009	-	33080	5009	4701	9710	0,94	29,35

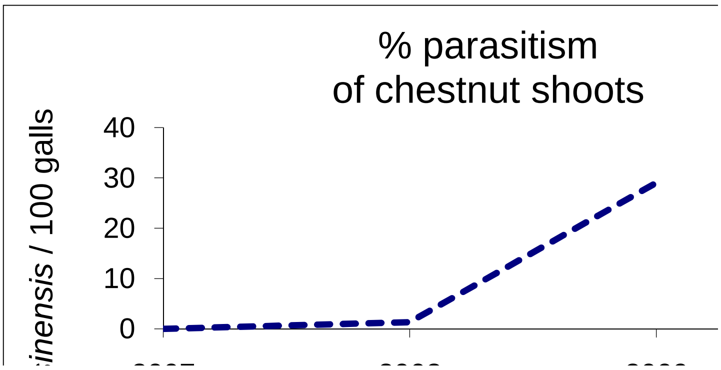

Figure 8: Results from the Robilante site on percentage parasitism of chestnut shoots (Ambra Quacchia, pers. com. 2009)

The effectiveness of *T. sinensis* in reducing pest infestation levels and thus the impact of *D. kuriphilus* is clearly demonstrated in Japan on *C. crenata* (Japanese chestnut), and reported as successful on *C. mollissima* (Chinese chestnut), *C. dentata* (American chestnut), and *C. sativa* (European chestnut) and their hybrids.

Following the introduction of *T. sinensis* in Italy, increasing levels of parasitism of chestnut shoots with *D. kuriphilus* have been recorded in 2009 which indicate the potential of biological control as a management option. However, a preliminary assessment of the environmental risks of introduction of *T. sinensis* conducted by the Panel (Appendix E) indicates that further research is needed, particularly on a) the host range of the parasitoid to determine the direct and indirect non-target effects on closely related oak gall wasps of the Cynipidae; b) the taxonomy and phylogenetic analysis of *T. sinensis* and closely related species and c) the potential of *T. sinensis* for hybridisation with other European *Torymus* species.

3.4. Conclusions on management options

The following options are identified by the Panel to reduce the likelihood of introduction and spread via planting material:

- certification of planting material as originating from pest free areas/places of production;
- inspection of consignments of *Castanea* spp, as living parts of plants, in particular bud-wood, cuttings and scions, and plants intended for planting, during the previous growing season prior to shipment to ensure freedom from visual symptoms i.e. galls of *D. kuriphilus*. Detection for the presence of the pest by visual inspection is only effective when carried out at appropriate times (after May-June, when visible galls appear as a result of larval feeding within the buds where eggs were laid the previous year). A post-entry quarantine period would also allow for symptom expression and increase the likelihood of detection;
- a single demarcated buffe zone of 15 km allows for surveillance in an area corresponding to the estimated short distance dispersal capability of *D. kuriphilus*;
- surveillance based on targeted inspection of *Castanea* for galling symptoms in April-June allows for early detection and destruction of affected plants before the emergence of the adult dispersal stage (occuring from May-July). Restrictions on movement during the adult emergence and flight period (May to July) may minimise the risk of human-assisted transfer, where feasible;
- no management options are identified to reduce the likelihood of spread following introduction to areas of *Castanea* woodland/forest.

The following options are identified for reducing the magnitude of impact:

- resistant varieties offer an effective management option which, however, is only applicable for new plantings. In addition, there are a limited number of resistant varieties available and these may not be suitable for all production systems;

- biological control using *T. sinensis* is a possible option for future sustainable management in locations within the EU territory where *D. kuriphilus* is established, subject to further studies of host specificity and of potential negative environmental impacts of this exotic species.

CONCLUSIONS

From its analysis of the evidence, the Panel reached the following conclusions:

- The movement of *Castanea* spp. as living parts of plants, in particular bud-wood, cuttings and scions, and plants intended for planting represents the main pathway for entry of *D. kuriphilus* to the EU territory. There is a very high likelihood of establishment of *D. kuriphilus* in the EU and the climate is suitable wherever *C. sativa* is grown in southern, central and western Europe;

- *D. kuriphilus* is widely established in Italy and the spread of *D. kuriphilus* follows a stratified dispersal pattern. Analysis of local random diffusion suggests an average rate of short distance dispersal as 8 km/year, which is significantly less than 25 km/year reported in the literature. The long distance dispersal component via the movement of planting material contributed to the rate of colonization in Italy, Slovenia and France;

- There is a high likelihood of spread within the EU territory due to the presence of eggs and larvae within the bud tissue, which cannot be detected by visual inspection, in the absence of symptoms during the dormant period. Movement of adult dispersal stages of *D. kuriphilus* by flight (natural and human assisted e.g. in vehicles or clothing) contributes to further spread within the EU;

- The potential for yield reduction in *Castanea* and negative effects on production is estimated as moderate. Although reported as high in the literature, there is a high level of uncertainty relating to this estimate in the absence of quantitative data confirming the yield reduction attributed directly to *D. kuriphilus*;

- All EU fruit production is endangered but the areas of *C. sativa* for fruit production with the highest degree day accumulations where *D. kuriphilus* is absent, e.g. in northern Portugal, northern Spain and south-west France, are particularly at risk;

- Management options to reduce the likelihood of introduction and spread are identified as certification of planting material as originating from areas/places of production free from *D. kuriphilus*;

- Management options to reduce the magnitude of impact are identified as plant varietal resistance and biological control.

Uncertainties were noted in particular with regard to:

a) the accuracy of data related to *Castanea* spp. distribution and use in the EU and the phenology of *D. kuriphilus* which may influence conclusions regarding the extent of the endangered area of the EU;

b) the absence of data on the effect of *D. kuriphilus* alone in reduction of yield in commercial orchards particularly of *C. sativa.* This may influence the conclusions regarding the magnitude of impact from this species.

DOCUMENTATION PROVIDED TO EFSA

1. Letter, 16 June 2009. Submitted by the European Commission, ref. SANCO E1/GC/svi D(2009) 510253

2. Commission Decision 2006/464/EC of 27 June 2006 on provisional emergency measures to prevent the introduction into and the spread within the Community of *Dryocosmus kuriphilus* Yasumatsu *(notified under document number C(2006) 2881)*. OJ L 183, 5.7.2006, p. 29-32.

3. EPPO (European and Mediterranean Plant Protection Organization), 2003. Pest risk assessment for *Dryocosmus kuriphilus* by Dr. Bosio, 17 pp.

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APPENDICES

APPENDIX A

Panel risk ratings for individual questions of the adapted EPPO scheme[14] used for *Dryososmus kuriphilus*

The Panel has used the EFSA-adapted EPPO risk assessment scheme which requires a choice of one of five levels of rating in response to a series of questions. The level of uncertainty is described as high, medium or low for each question.

The following table presents the ratings given by the Panel together with a short statement to provide supporting justification. The opinion text should be referred to for further detail.

Questions	**Rating**					**Level of uncertainty**			**Justification**
Identification of pathways									
1.2. Estimate the number of relevant pathways, of different commodities, from different origins, to different end uses.	very few **X**	few	moderate number	many	very many	low **X**	med	high	Only two pathways have been identified: movement of infested plant material (and parts of plants scions/budwood) of *Castanea* spp. (immature stages), and direct movement of adult stages by flight (natural and human assisted e.g in vehicles or clothing)
Probability of the pest being associated with the individual pathway at origin									

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[14] Adapted EPPO scheme based on Appendix C of “Guidance on a harmonised framework for pest risk assessment and the identification and evaluation of pest risk management options by EFSA” (EFSA, 2010)

1.4. How likely is the pest to be associated with the pathway at origin taking into account factors such as the occurrence of suitable life stages of the pest, the period of the year?	very unlikely	unlikely	mod. likely	likely	very likely **X**	low **X**	med	high	As the egg and early larval stage are present in the dormant buds of the year, the pest is very likely to be associated with the pathway at origin as it cannot be detected by visual inspection due to the absence of external symptoms. Vegetative propagation of *Castanea* and lack of treatment options for consignments lead to a high association of the pest with the pathway, in areas where the pest is present
1.5. How likely is the concentration of the pest on the pathway at origin to be high, taking into account factors like cultivation practices, treatment of consignments?	very unlikely	unlikely	mod. likely **X**	likely	very likely	low	med **X**	high	The pest is widespread but controlled by natural enemies on the pathway at origin; there is no evidence that the initial introduction into the EU arose from a high number of introduction events
1.6. How large is the volume of the movement along the pathway?	minimal	minor **X**	moderate	major	massive	low	med **X**	high	Although no data are available, the appearance of *Dryocosmus kuriphilus* in Italy suggests that limited, unregistered movements of plant material, possibly for breeding, has occurred in the past
1.7. How frequent is the movement of the pest along the pathway?	very rarely	rarely	occasion-ally **X**	often	very often	low	med **X**	high	Appendix C and the data on which it relies suggest that a single introduction point in Italy was sufficient to lead to the present widespread distribution
Probability of survival during transport or storage									
1.8. How likely is the pest to survive during transport /storage?	very unlikely	unlikely	mod. likely	likely	very likely **X**	low **X**	med	high	The immature stages are very secure in the dormant buds of the major pathway (plants intended for planting)

1.9. How likely is the pest to multiply/increase in prevalence during transport /storage?	very unlikely **X**	unlikely	mod. likely	likely	very likely	low **X**	med	high	Only immature stages are transported on plants intended for planting
Probability of the pest surviving existing pest management procedures									
1.10. How likely is the pest to survive or remain undetected during existing management procedures (including phytosanitary measures)?	very unlikely	unlikely	mod. likely	likely	very likely **X**	low **X**	med	high	Unless the buds on plants intended for planting are carefully dissected and submitted to close scrutiny, the presence of the insects inside is undetectable
1.11. In the case of a commodity pathway, how widely is the commodity to be distributed throughout the risk assessment area?	very limited	limited	mod. widely **X**	widely	very widely	low	med **X**	high	In theory, plants intended for planting could be introduced anywhere in the risk assessment area, but there are no data to document this possibility
1.12. In the case of a commodity pathway, do consignments arrive at a suitable time of year for pest establishment?	very unlikely	unlikely	mod. likely	likely	very likely **X**	low **X**	med	high	Plant consignments arrive at a suitable time of year for pest establishment as they are transported during the dormant season and are planted before the spring. Conditions are suitable for larval feeding within the host plant tissue and gall development. The presence of the pest in close association and protected within the host plant assures transfer to a suitable habitat

1.13. How likely is the pest to be able to transfer from the pathway to a suitable host or habitat?	very unlikely	unlikely	mod. likely	likely	very likely **X**	low	med **X**	high	Infested plants intended for planting guarantee a pathway
1.14. In the case of a commodity pathway, how likely is the intended use of the commodity to aid transfer to a suitable host or habitat?	very unlikely	unlikely	mod. likely	likely	very likely **X**	low **X**	med	high	Plants introduced for breeding purpose/for planting are very likely to be introduced in areas with high densities of *Castanea* spp
ENTRY (overall conclusions)	very unlikely	unlikely	mod. likely **X**	likely	very likely	low	med **X**	high	Although introduction to the EU appears to have been due to a low number of entry events, subsequent internal movement of plant material is very likely (and confirmed in practice by spread to new areas within the EU)
Availability of suitable hosts or suitable habitats, alternate hosts and vectors in the risk assessment area									
1.16. Estimate the number of host plant species or suitable habitats in the risk assessment area.	very few	few **X**	moderate number	many	very many	low **X**	med	high	There are only few species (*Castanea* spp) that are hosts of D. kuriphilus
1.17. How widespread are the host plants or suitable habitats in the risk assessment area?	very limited	limited	mod. widely	widely **X**	very widely	low **X**	med	high	*Castanea* spp. are widespread in the risk assessment area (see Appendix B)

1.18. If an alternate host or another species is needed to complete the life cycle […], how likely is the pest to come in contact with such species?	very unlikely	unlikely	mod. likely	likely	very likely	low	med	high	N/A
1.19. How similar are the climatic conditions that would affect pest establishment, in the risk assessment area and in the current area of distribution?	not similar	slightly similar	mod. similar	largely similar **X**	completely similar	low **X**	med	high	See Appendix B
1.20. How similar are other abiotic factors that would affect pest establishment, in the risk assessment area and in the current area of distribution?	not similar	slightly similar	mod. similar	largely similar **X**	completely similar	low **X**	med	high	Other abiotic factors, e.g. soils, are similar to those in its current area of distribution and are not likely to affect establishment.
1.21. If protected cultivation is important in the risk assessment area, how often has the pest been recorded on crops in protected cultivation elsewhere?	never	very rarely	rarely	occasion-ally	often	low	med	high	N/A

1.22. How likely is it that establishment will occur despite competition from existing species in the risk assessment area?	very unlikely	unlikely	mod. likely	likely	very likely **X**	low **X**	med	high	No species occupies this niche in the risk assessment area
1.23. How likely is it that establishment will occur despite natural enemies already present in the risk assessment area?	very unlikely	unlikely	mod. likely	likely	very likely **X**	low **X**	med	high	No specialised natural enemies occur in the risk assessment area, and the native natural enemies that attacked so far the pest in Italy only inflicted low damage to the pest
Cultural practices and control measures									
1.24. To what extent is the managed environment in the risk assessment area favourable for establishment?	not at all favourable	slightly favourable	mod. favourable	highly favourable **X**	very highly favourable	low **X**	med	high	According to the fast establishment of the pest in Italy, the managed environment in the risk assessment area is highly favourable for establishment
1.25. How likely is it that existing pest management practice will fail to prevent establishment of the pest?	very unlikely	unlikely	mod. likely	likely	very likely **X**	low **X**	med	high	The fast expansion of the pest's range in Italy shows that the existing pest management practices are inefficient to prevent establishment
1.26. Based on its biological characteristics, how likely is it that the pest could survive eradication programmes in the	very unlikely	unlikely	mod. likely	likely	very likely **X**	low **X**	med	high	The females are thelytokous and therefore one single individual is enough to establish a population. Furthermore, the eggs and larvae of the pest are very cryptic within the bud tissue and cannot be detected by visual inspection of plants which do not express symptoms during the dormant period.

risk assessment area?									
Other characteristics of the pest affecting the probability of establishment									
1.27. How likely is the reproductive strategy of the pest and the duration of its life cycle to aid establishment?	very unlikely	unlikely	mod. likely	likely	very likely **X**	low **X**	med	high	The females are thelytokous and therefore one single individual is enough to establish a population.
1.28. How likely are relatively small populations to become established?	very unlikely	unlikely	mod. likely	likely	very likely **X**	low **X**	med	high	See 1.27
1.29. How adaptable is the pest? Adaptability is:	very low	low	moderate	high **X**	very high	low	med **X**	high	The pest has successfully established in different countries (Japan, Korea, USA, Nepal and the EU), everytime shifting to the local host species (*Castanea crenata* in Japan, *C. dentata* in the US, *C. sativa* in Europe)
1.30. How often has the pest been introduced into new areas outside its original area of distribution?	never	rarely	occasion-ally **X**	often	very often	low **X**	med	high	The pest has successfully established in Japan, Korea, USA, Nepal and the EU
ESTABLISHMENT (overall conclusions)	very unlikely	unlikely	mod. likely	likely	very likely **X**	low **X**	med	high	The pest has already established almost in the whole of Italy and locally in neighbouring countries. *Castanea* is well available
Probability of spread									

1.32. How likely is the pest to spread rapidly in the risk assessment area by natural means?	very unlikely	unlikely	mod. likely	likely **X**	very likely	low **X**	med	high	*D. kuriphilus* is widely established in Italy and its spread follows a stratified dispersal pattern. Analysis of local random diffusion suggests an average rate of short distance dispersal as 8 km/year
1.33. How likely is the pest to spread rapidly in the risk assessment area by human assistance?	very unlikely	unlikely	mod. likely	likely	very likely **X**	low **X**	med	high	The long distance dispersal component of *D. kuriphilus*' spread via the movement of planting material is obviously important since it led to almost complete colonization of Italy between 2002 and 2009, and to the appearence of infestation foci in the neighbouring countries (Slovenia, France, and Switzerland)
1.34. Based on biological characteristics, how likely is it that the pest will not be contained within the risk assessment area?	very unlikely	unlikely	mod. likely	likely **X**	very likely	low **X**	med	high	There is a high likelihood of spread within the EU territory due to the cryptic nature of the eggs and larvae of the pest, which are found within the bud tissue and cannot be detected by visual inspection of plants which do not express symptoms during the dormant period
SPREAD (overall conclusions)	very unlikely	unlikely	mod. likely	likely **X**	very likely	low **X**	med	high	Since its discovery in Italy in 2002, the pest has spread over most of the country and also locally established in adjacent countries (France, Slovenia, and Switzerland)
Pest effects									

2.1. How great a negative effect does the pest have on crop yield and/or quality to cultivated plants or on control costs within its current area of distribution?	minimal	minor	moderate **X**	major	massive	low	med	high **X**	No evidence of tree mortality; major impacts on fruit yield reported but not documented; expected to reduce tree vigour through biomass reduction
2.2. How great a negative effect is the pest likely to have on crop yield and/or quality in the risk assessment area without any control measures?	minimal	minor	moderate **X**	major	massive	low	med	high **X**	No evidence of tree mortality; major impacts on fruit yield reported but not documented; expected to reduce tree vigour through biomass reduction
2.3. How easily can the pest be controlled in the risk assessment area without phytosanitary measures?	very easily	easily	with some difficulty	with much difficulty **X**	impossible	low **X**	med	high	Since its discovery in Italy in 2002, the pest has spread over most of the country and also locally established in adjacent countries (France, Slovenia, Switzerland)
2.4. How important are environmental consequences caused by the pest within its current area of distribution?	minimal	minor **X**	moderate	major	massive	low	med **X**	high	See 2.1. Continuous parasitism by *D. kuriphilus* can result in a gradual decline in vigour of long-lived and slow-growing chestnut trees but unlikely to adversely affect provisioning, regulating or sustining services provided by *Castanea* spp

2.5. How important are the environmental consequences likely to be in the risk assessment area?	minimal	minor **X**	moderate	major	massive	low	med **X**	high	See 2.1. Continuous parasitism by *D. kuriphilus* can result in a gradual decline in vigour of long-lived and slow-growing chestnut trees but unlikely to adversely affect provisioning, regulating or sustining services provided by *Castanea* spp
2.6. How likely is it that natural enemies, already present in the risk assessment area, will not reduce populations of the pest below the damage threshold?	very unlikely	unlikely	mod. likely	likely	very likely **X**	low **X**	med	high	Sixteen parasitoid species have so far parasitized *D. kuriphilus* in Italy, but their attack rates of infested shoots remain low (< 2 %) (see Appendix E). Most of the species have more than one generation per year and thus need alternative hosts
2.7. How likely are control measures to disrupt existing biological or integrated systems for control of other pests or to have negative effects on the environment, reduce population sizes, or increase their fragmentation ?	very unlikely	unlikely **X**	mod. likely	likely	very likely	low	med **X**	high	Resistant varieties would not disrupt existing biological or integrated systems for control of other pests inasmuch as they do not show increased susceptibility to major diseases (chestnut blight and ink disease). Biological control using Torymus sinensis is not very likely to affect any other organism than D. kuriphilus
2.8. How likely is the pest to cause a significant increase in the impact of other pests by acting as a vector or host for these pests?	very unlikely **X**	unlikely	mod. likely	likely	very likely	low **X**	med	high	The pest is not known to be a vector of any disease such as chestnut blight or ink disease

IMPACT (overall conclusions)	very low	low	moderate **X**	high	very high	low	med	high **X**	No evidence of tree mortality; major impacts on fruit yield reported but not documented; expected to reduce tree vigour through biomass reduction; likely to be controlled where biocontrol agent introduced or resistant varieties; low impact on timber and environment

APPENDIX B

ASSESSING THE EU'S CLIMATIC SUITABILITY AND ENDANGERED AREAS FOR *DRYOCOSMUS KURIPHILUS*

TABLE OF CONTENTS FOR APPENDIX B

1. Introduction

This Appendix provides supplementary information and discussion for two questions in the pest risk assessment scheme:

1.19 How similar are the climatic conditions that would affect pest establishment, in the risk assessment area and in the current area of distribution?

1.35. Based on the answers to questions 1.16 to 1.34 identify the part of the risk assessment area where presence of host plants or suitable habitats and ecological factors favour the establishment and spread of the pest to define the endangered area.

The climatic responses of *Dryocosmus kuriphilus* are not weel known. There are reports on the timing of the life cycle of *D. kuriphilus* at various locations, e.g. Zhang (2009) provides basic information on its life cycle in Henan Province, China. However, these are summaries for large regions and cannot be related to specific locations and weather stations. The most useful information is provided by Oho and Shimura (1970) in their summary of a large number of Japanese studies. They reported that larval development ceases below 10 °C, is optimal at 20 ºC, is intolerant of markedly higher temperatures, but, even after exposure to –5 ºC for 16 days, is able to resume normal growth when the temperature returns to 20 ºC. However, without access to the original Japanese studies, it is unclear whether this information has been obtained by laboratory experiments at constant temperatures, the standard method for obtaining temperature thresholds for development, or through field observations, which generally yield much more unreliable data. In addition, a key parameter, the number of degree days required for *D. kuriphilus* to complete its life cycle, has not been found in the literature.

While the information on climatic responses is valuable, to assess the potential distribution of *D. kuriphilus* in the pest risk assessment area, we also need to infer its responses to climate based on the climates in its current area of distribution. In order to do this as accurately as possible, the following conditions should be met: (a) there is sufficient detailed information on the locations where the species is established, particularly to define the core area where climate is optimal and the limits to the distribution where climate is limiting, (b) the species has reached the limits of its potential distribution in the areas used for climatic matching and (c) the limits to its distribution are based on climate and not on, for example, the presence of hosts or geographical barriers, such as the sea or mountains. Ideally, all three requirements should be met in the species' native range since it may still be spreading in invaded areas.

Unfortunately none of these conditions are met by the global distribution of *D. kuriphilus* (Fig. B1). The native range for *D. kuriphilus* is China but we have no detailed knowledge of its distribution apart from information on the provinces where it occurs and where most damage is caused (Zhang, 2009). We have a similar limited knowledge of distribution in Japan since we only know that *D. kuriphilus* was confirmed as established in the 1940's and had spread to all prefectures by 1965 (Oho and Shimura, 1970). South Korea was invaded in 1961 but the names of only a few locations are available (Oho and Shimura, 1970). In addition, the limits to the distribution of *D. kuriphilus* in eastern Asia are considered to be set by the distribution of its *Castanea* hosts rather than by climate (see section 2.1 below).

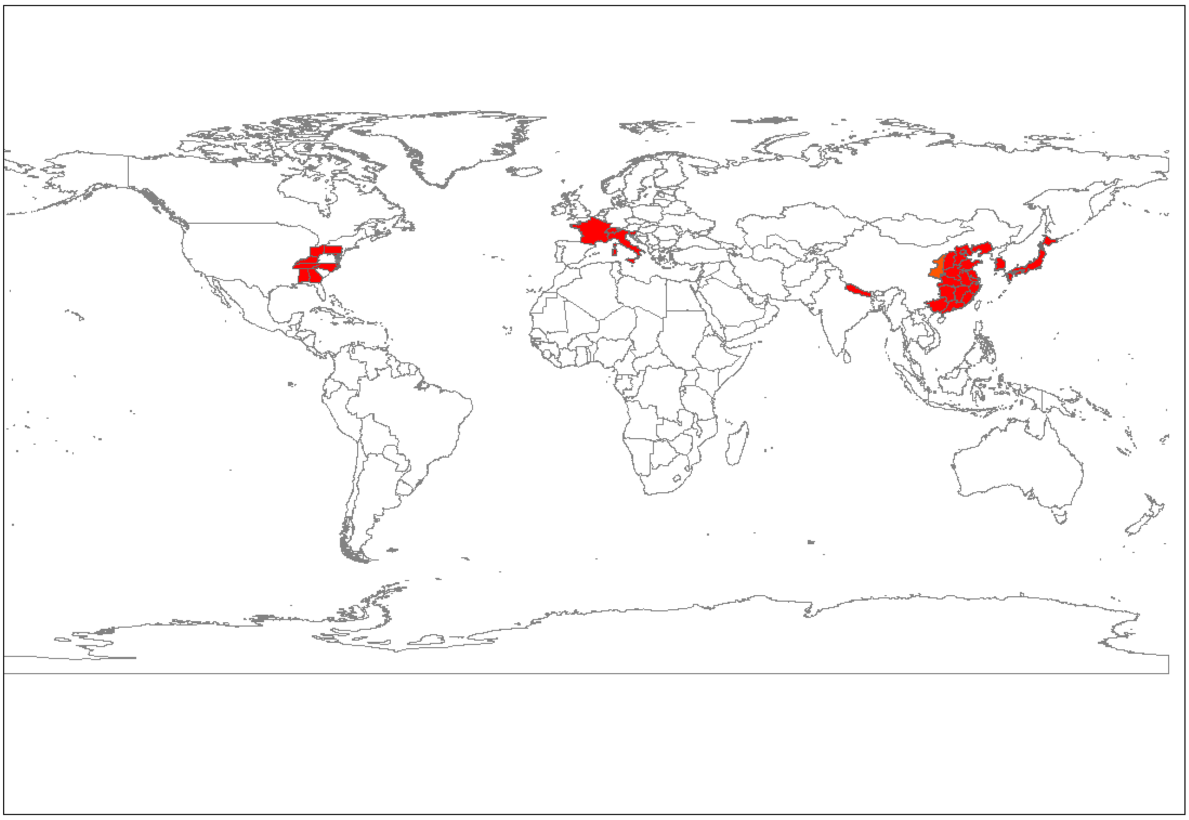

Figure B1: *D. kuriphilus* Global Distribution (for USA and China the states or provinces are given)

In the USA (Anagnostakis, 2001) and Europe (Bosio et al., 2010) (Fig. B2) the species is clearly still spreading and the locations cannot be used to infer climatic responses. When first discovered in Nepal in 1999, *D. kuriphilus* was recorded from eight locations between 800 and 2200 metres in altitude but there are no recent records of its distribution.

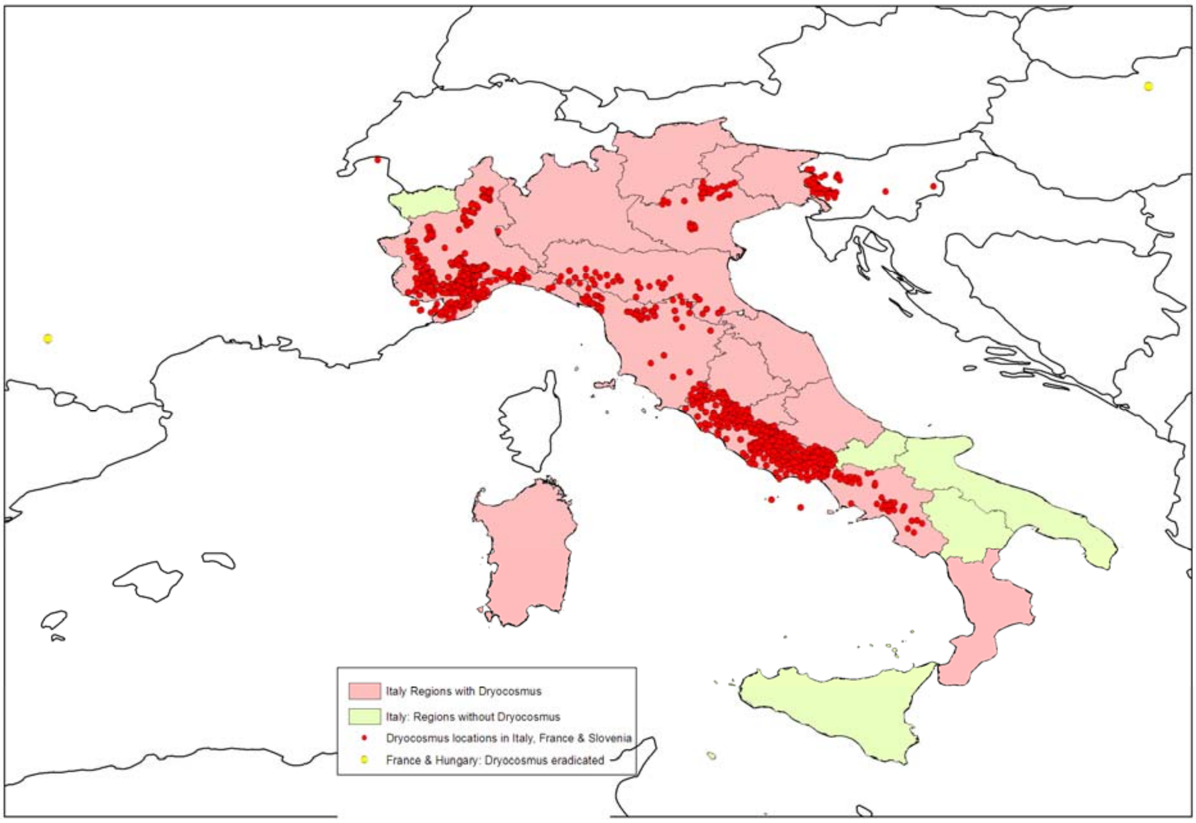

Figure B2: *D. kuriphilus* distribution in the EU

With such limited, host-constrained information on species distribution, it is not appropriate to utilise the techniques for predicting potential distribution based on climate such as regression models, e.g. Maxent and GARP, or combined deductive-inductive models, such as the compare locations component of CLIMEX. In these situations, all that is usually possible is to make general climatic inferences by comparing summer and winter temperatures in the native range and the pest risk assessment area, e.g. using the global Köppen-Geiger climate zones (Kottek et al., 2006), world hardiness zones based on average annual minimum temperatures (Magarey et al., 2008) and monthly climatic averages from weather station data or climatic data interpolated onto a grid. For *D. kuriphilus*, however, we have two advantages: (i) the pest distribution in its native range is observed to be similar to the host distribution. (ii) the pest is already present in the pest risk assessment area.

2. Climatic Suitability in the Pest Risk Assessment Area based on host distribution

In order to utilise the observation that *D. kuriphilus* and its *Castanea* hosts have a similar distribution in China to predict the potential distribution of *D. kuriphilus* in the EU, we need to:

- determine the distribution of the hosts in eastern Asia.
- obtain information on the climatic responses of the Asian host species.
- link knowledge of host distribution in Eastern Asia to global climate databases such as the Köppen-Geiger climate zones (Kottek et al., 2006), world hardiness zones (Magarey et al., 2008) and global gridded climatic datasets (CRU data) to compare these with the zones and gridded data for the EU.

2.1. The distribution of the *Castanea* hosts in China and Japan in relation to *D. kuriphilus*

In the Flora of China (Chengjiu, 1999), four *Castanea* species are listed (*C. mollissima*, *C. seguinii*, *C. crenata* and *C. henryi)*. The provinces and the altitudinal ranges where they are present are also included. Provincial maps for these species, based on these records, are provided by the Flora of China Check-List website (Tropicos.org, 2010) (Figs. B3, a–d). From these maps it is clear that *C. mollissima* and *C. crenata* are the most cold hardy, being recorded in Liaoning and Hebei, also the most northerly provinces where *D. kuriphilus* is present (Zhang, 2009) (Figs B4, a and b). *C. mollissima* is also found further north and inland in the province of Nei Mongol. *C. seguinii* and *C. henryi* have a more southerly distribution. The northern limit of *C. crenata* in Japan is in Southern Hokkaido (approximately 43 ^{o}N), and this is also the northern limit of the distribution of *D. kuriphilus* in Japan (Abe, pers. com., 2010). The information from China and Japan therefore indicates that the distribution of *D. kuriphilus* is closely related to that of its *Castanea* hosts.

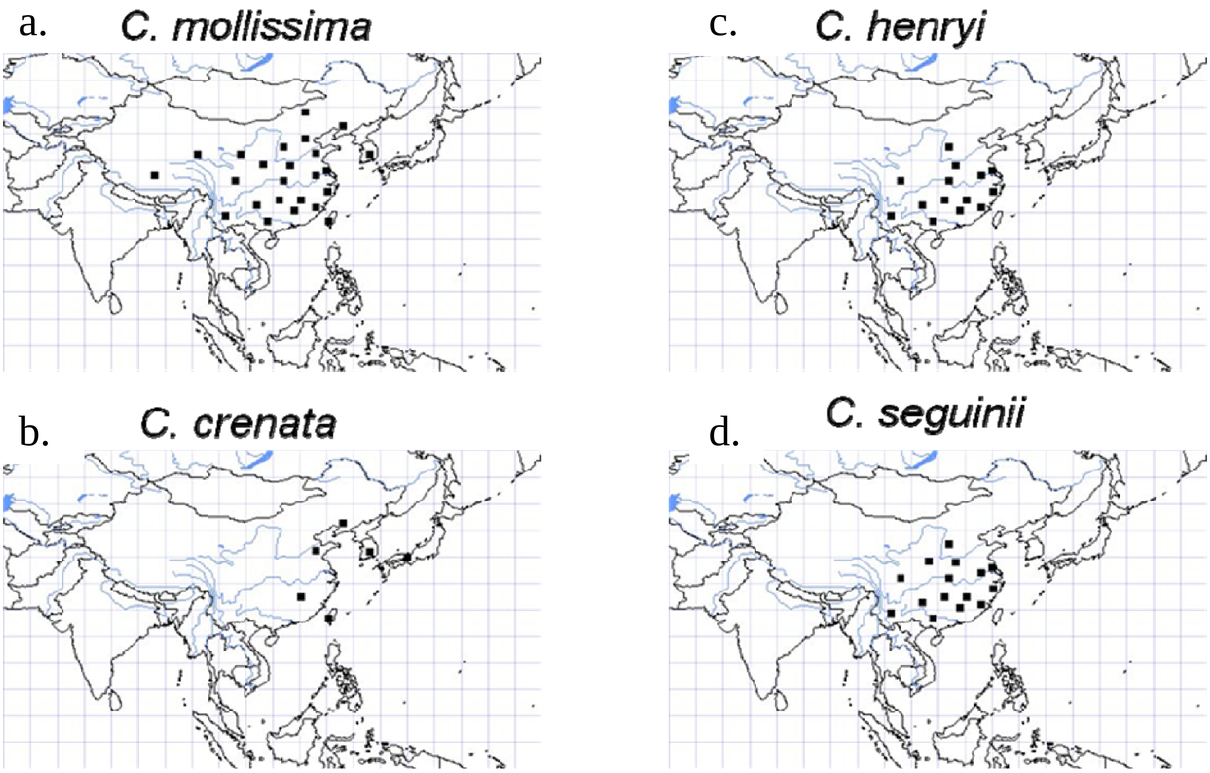

Figure B3: *Castanea* species in China (Tropicos.org, 2010)

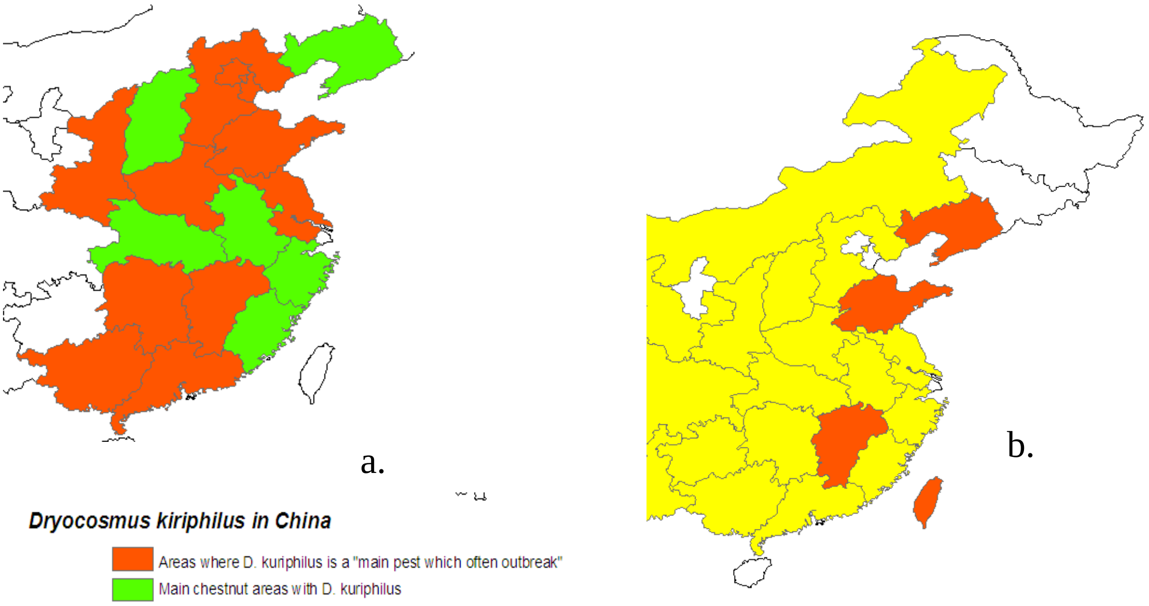

Figure B4: *Dryocosmus kuriphilus, Castanea mollissima* and *C. crenata* (Zhang, 2009)

2.2. Using knowledge of host distribution and plant hardiness to predict the potential distribution of *D. kuriphilus* in the EU

The "Plants For A Future" database (http://www.pfaf.org/database/index.php) states that *C. mollissima* and *C. crenata* are both hardy to zone 4 (average annual minimum temperature of -34 to -29 °C). However, *C. seguinii* and *C. henryi* are only hardy to zone 6 (average annual minimum temperature of -23 to -18 °C), suggesting that this is the reason for their more southerly distribution in China. The Plants For A Future database states that *C. sativa* is hardy to zone 5 (average annual minimum temperature of -29 to -23 °C) (although http://www.floridata.com/ref/C/cast_sat.cfm gives the hardiness zone for *C. sativa* as 5-7) and is therefore more frost sensitive than the two eastern Asian hosts with more northerly distributions, *C. mollissima* and *C. crenata*. The Dandong chestnut, a cross between *C. mollissima* and *C. crenata*, is even hardier, with the hybrid being planted north of a -12 °C line in the Dandong area of Liaoning province where the non-hybrids cannot survive (Ti-zhi and Rui, 2009). Assuming *D. kuriphilus* can establish in eastern Asia wherever *Castanea* is present and the most cold-hardy hosts, *C. mollissima* and *C. crenata*, are hardy to zone 4 then this implies that *D. kuriphilus* should be able to overwinter wherever *C. sativa* is present in the EU. Figs B5 and B6 provide maps of the hardiness zones in Eastern Asia and Europe.

Fig. B8 shows the distribution of *C. sativa* nut and timber production in Europe. This map was obtained from the European Forest Genetic Resources Programme (EUFORGEN) website (http://www.euforgen.org/distribution_maps.html) and summarises the detailed map provided by Conedera et al. (2004). However, maps of *C. sativa* distribution in Europe produced by the Global Biodiversity Information Facility (GBIF: http://www.gbif.org) and for the British and Irish flora (http://www.bsbimaps.org.uk/atlas/) show that the species is grown as an ornamental as far north as northern Scotland, southern Norway and southern Sweden.

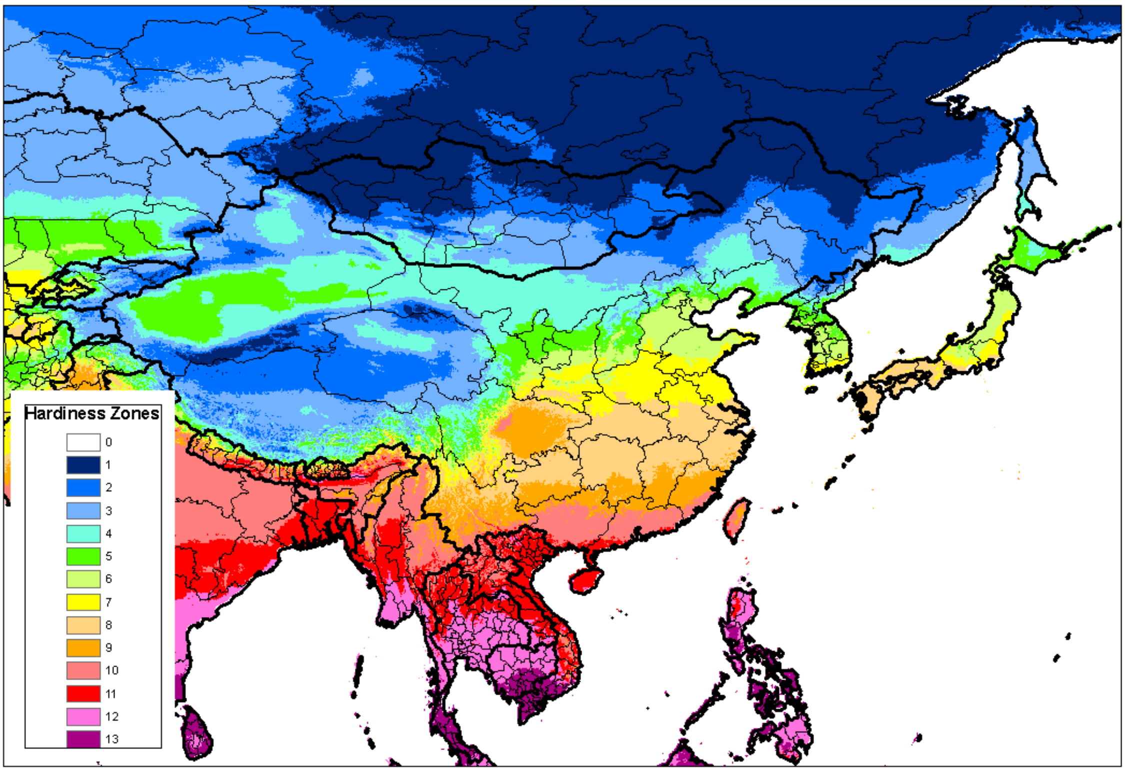

Figure B5: World hardiness zones for Eastern Asia (based on data from Magarey et al., 2008)

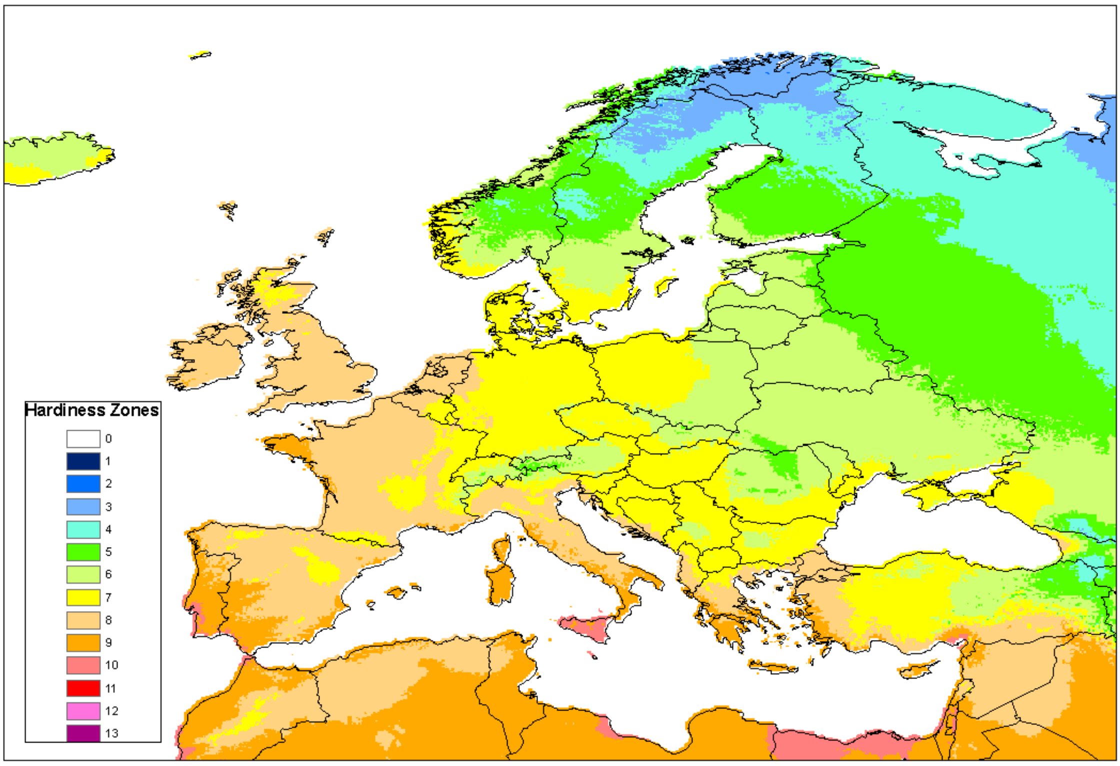

Figure B6: World hardiness zones for Europe (based on data from Magarey et al., 2008)

2.3. Using global climate zones and knowledge of temperature budgets to predict the potential distribution of *D. kuriphilus* in the EU

While hardiness zones are commonly used to determine whether plants can survive in particular areas, over-wintering survival is often of less importance when determining whether insects can establish than the amount of degree days available for development during the summer. The importance of temperature in the life cycle of *D. kuriphilus* is demonstrated by the different adult wasp emergence dates from galls at different sites in different areas related to the diversity of climatic conditions (Bosio et al., 2010; Ôtake, 1980). The review of Japanese studies by Oho and Shimura (1970) provides a minimum threshold for development of 10 °C and an optimum temperature of development of 20 °C. However, without information on the degree days needed to complete the life cycle of *D. kuriphilus* it is not possible to map areas in eastern Asia and the EU where temperature budgets are sufficient to enable development. We have therefore explored two approaches: (a) comparing the global Köppen-Geiger climate zones where *D. kuriphilus* is present in eastern Asia with those in the EU and (b) comparing the temperature budgets (annual degree days base 10 °C) in the northernmost province of China where *D. kuriphilus* is present (Liaoning) with the temperature budgets at its northernmost locations in Europe.

The global Köppen-Geiger climate zones (Kottek et al., 2006) take into account average minimum winter temperatures and summer maxima (as well as rainfall amount and pattern) and can therefore be considered to be more useful for predicting the potential distribution based on climate for insects than plant hardiness zones. However, apart from Tibet and the extreme north-west of China, only two EU Köppen-Geiger climate zones (“Bsk”: arid main climate, steppe precipitation, cool arid temperature and “Esk”: warm temperate main climate, fully humid precipitation, hot summer temperature) are found in China (Figs B7 and B8) and neither of these occurs in the northernmost part of the *Castanea* distribution. This is because, in locations with summer temperatures comparable to those in Europe, the winters in China are very much colder.

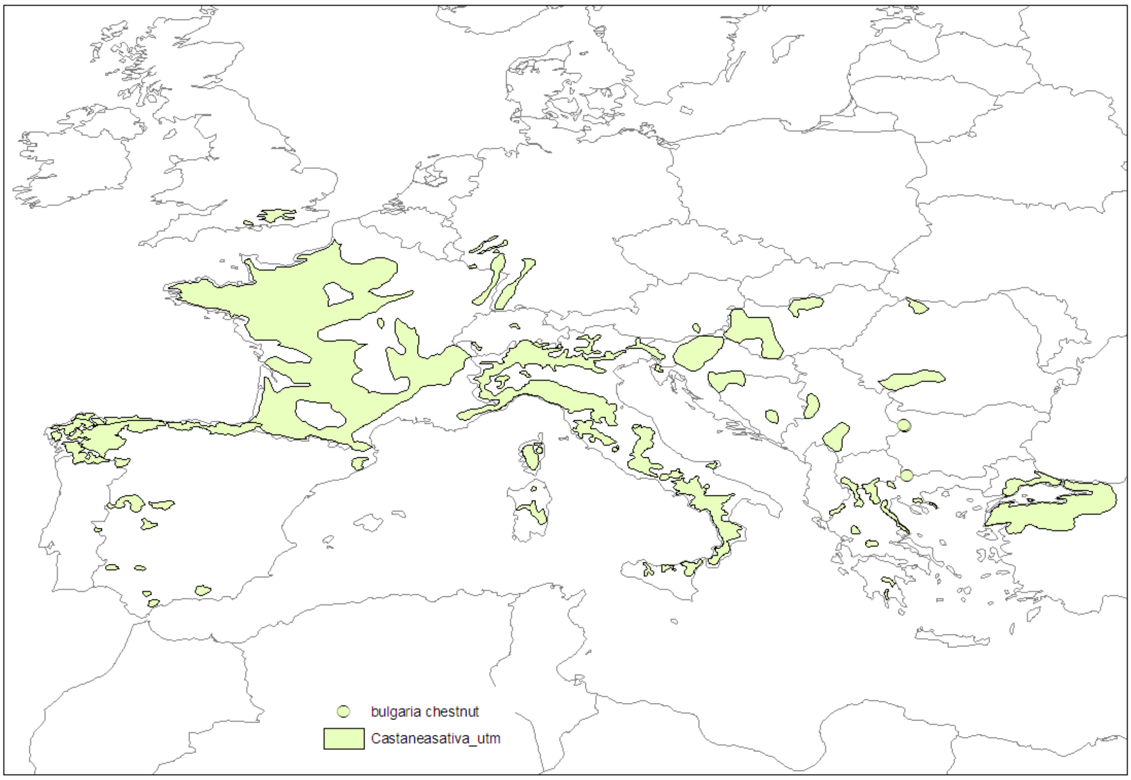

Figure B7: *Castanea sativa* fruit and timber production (EUFORGEN and Bulgaria)

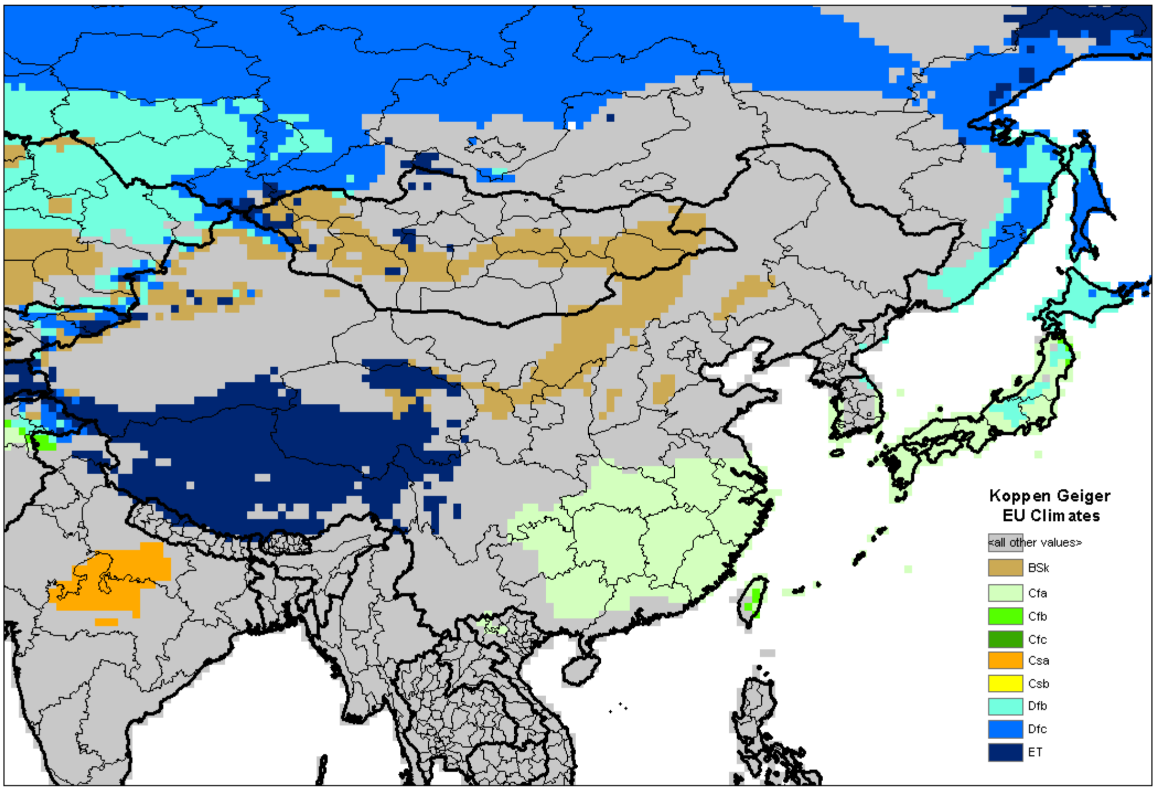

Figure B8: EU Köppen Climates in Eastern Asia (based on data from Kottek et al., 2006)

The World Wildlife Fund provides GIS data for terrestrial biomes (Olson et al., 2001). These show that the native woodland in Liaoning is made up of Northeast China Plain deciduous forests, Central China loess plateau mixed forests and Manchurian mixed forests (Fig. B9). However, the descriptions (PA0411, PA0426 and PA0430 in http://www.worldwildlife.org/wildworld/profiles/terrestrial_pa.html) do not indicate which, if any, of these biomes contain *Castanea*. Although we have no information on wild *Castanea* in Liaoning, Ti-zhi and Rui (2009) describe the Dandong region in the south-east of Liaoning close to the Korean border as the most northerly of the six main chestnut production areas in China. Eighty million trees from 100,000 hm^2 produce 40000 tons of chestnut a year. Most of the chestnut orchards are found in the mountains in sloping terrain. While this knowledge of the distribution of *Castanea* in Liaoning is useful, we have no information on *Castanea* distribution in Liaoning outside the Dandong region and we cannot relate the distribution directly to weather station data. We have therefore utilised climatic data from global gridded climate databases to derive approximate temperature budgets (annual degree days base 10 °C) for development. We used 1961-90 monthly average maximum and minimum temperatures taken from the 10 minute latitude and longitude Climatic Research Unit database (New et al., 2002). This database is the most commonly used global climate dataset for predicting potential species distributions based on current climate. Baker (2002) has already used this dataset to produce a map showing the annual degree days at a base of 10 °C throughout the terrestrial land surface of the world. Fig. B10 shows the annual degree days base 10 °C for the 10 minute 1961-90 latitude and longitude grid cells in Liaoning. The average for the 563 cells in Liaoning is 1475 (the minimum is 1057 and the maximum is 1817). The Dandong region has an annual degree total of approximately 1300-1500.

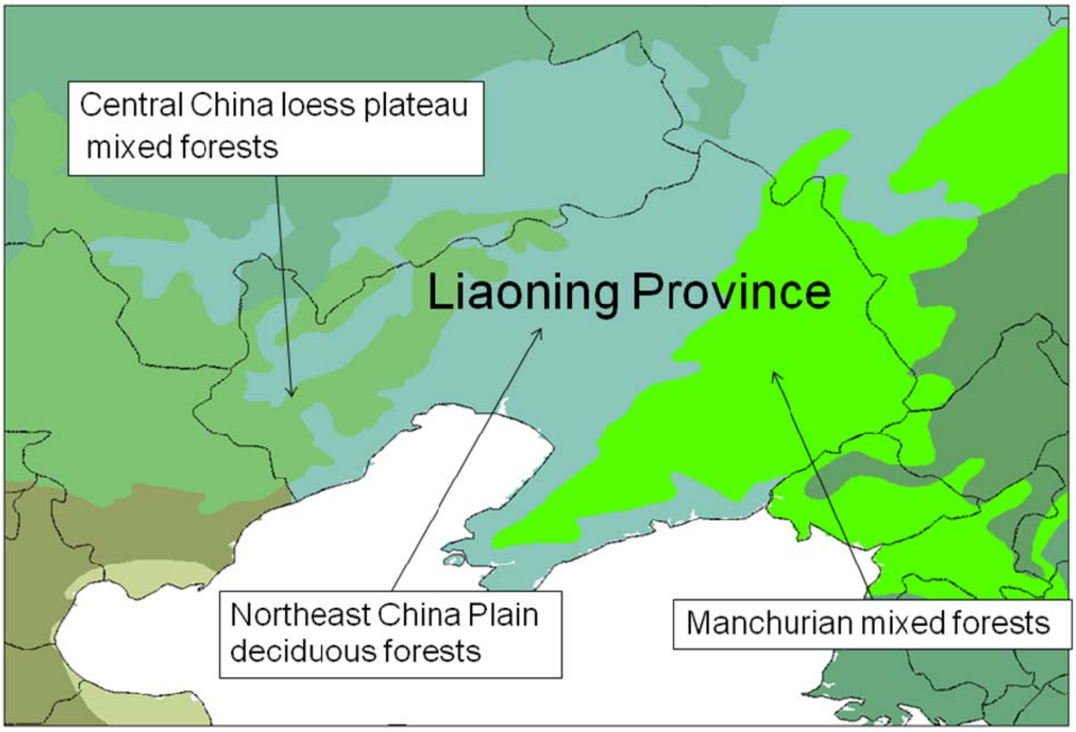

Figure B9: Terrestrial Biomes in Liaoning Province, China (based on data from Olson et al., 2001)

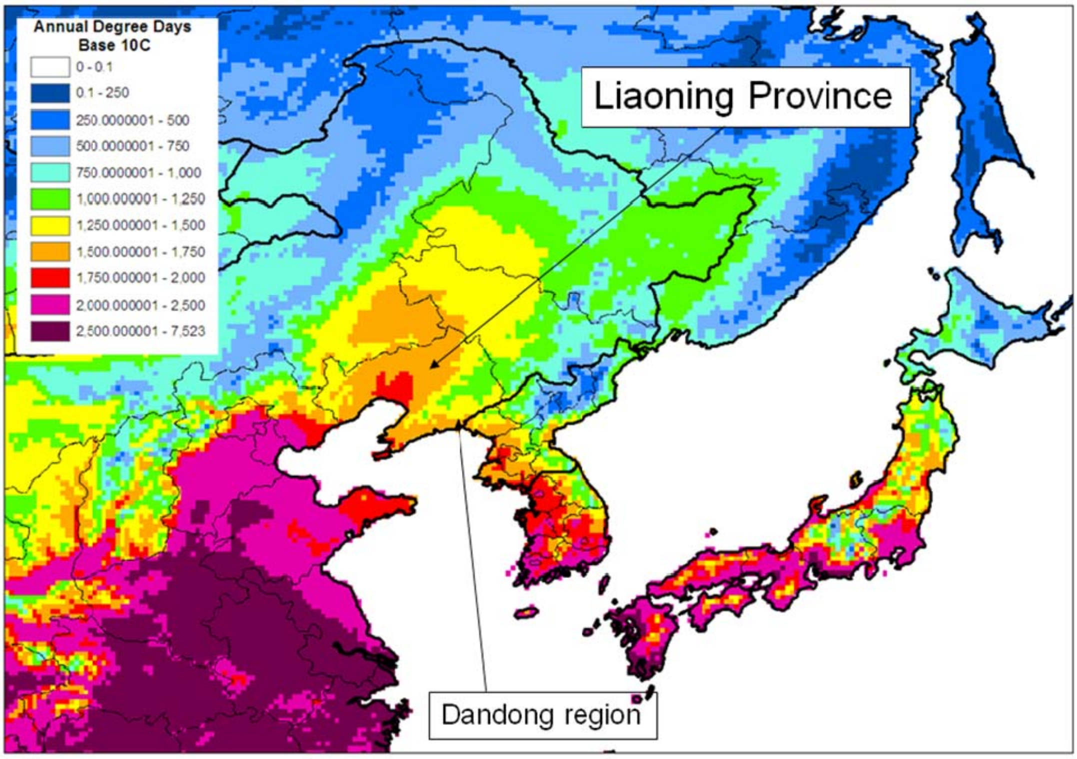

Figure B10: Annual degree days base 10 °C in Eastern Asia (based on data from New et al., 2002)

Fig. B11. compares the monthly minimum and maximum temperatures averaged for all 563 cells in Liaoning with the grid cell for Cuneo in Piemonte province, Northern Italy where *D. kuriphilus* is common and where the degree day total, based on the same global climate dataset, is 1371. Although annual degree day totals in Liaoning are similar to those in Cuneo, it is clear that the winters in Liaoning (average January mean maximum temperatures of -5,0 °C and mean minimum of -17,0 °C) are very much colder than those in Cuneo (average January mean maximum temperatures of 7,1 °C and mean minimum of 0,7 °C). Maps of the annual degree days base 10 °C for 1961-90 at 10 minute resolution are provided for Italy in Fig. B12 and for the whole of Europe in Fig. B13. Based on these maps, northern Italian locations where *D. kuriphilus* occurs can be considered to have an annual temperature budget within the 1,000-1,800 range observed throughout the Chinese province of Liaoning. However, if the degree totals for the Dandong Region (1,300-1,500) are considered to be more representative of the northernmost limits to the distribution of *D. kuriphilus* in China, then it appears that in northern Italy the species can establish in areas with cooler summers. Without more precise information on the locations of *Castanea* species in Liaoning, it is not possible to use the Chinese distribution to set a more precise threshold for the annual degree days base of 10 °C associated with *D. kuriphilus* presence. However, even with precise information on these locations and associated climatic data, since the limits to its distribution in China are considered to be based on host presence rather than climate, utilising the degree days from northern China to predict establishment in the EU could give an erroneous and too southerly a potential distribution for *D. kuriphilus* in the EU.

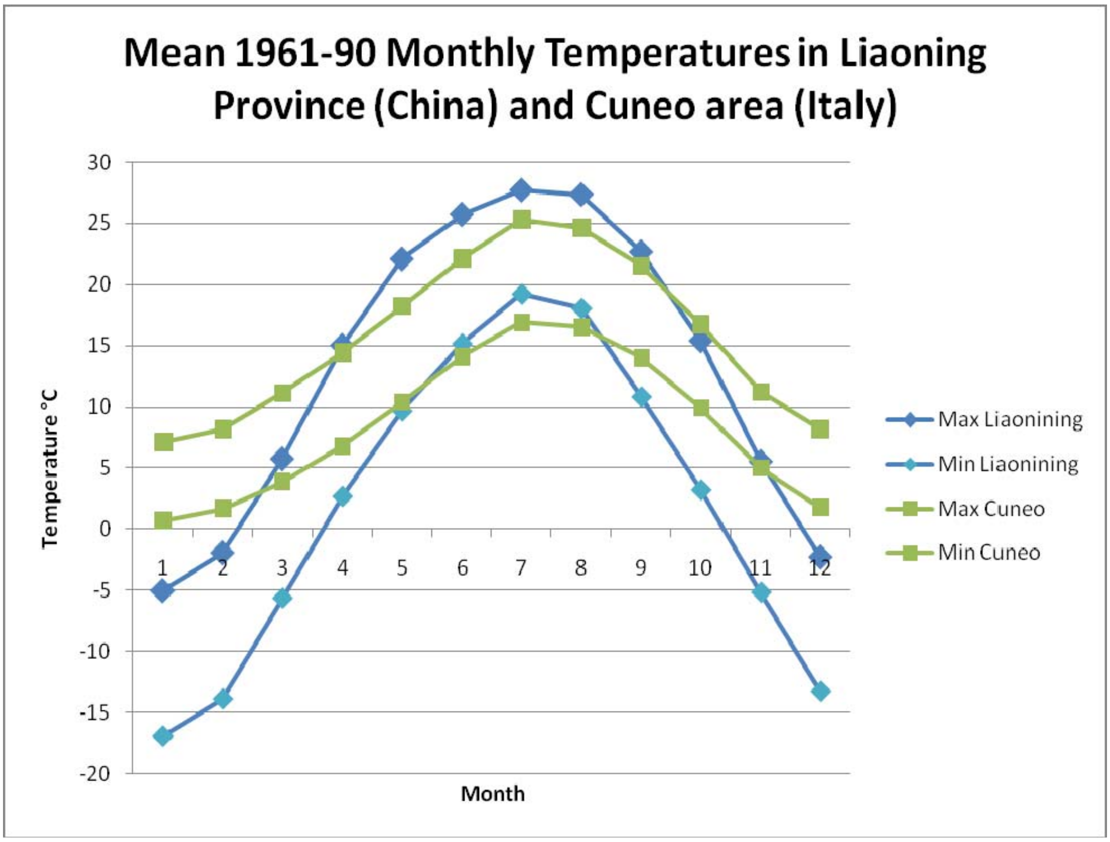

Figure B11: Comparison of monthly maximum and minimum temperature in northern China and northern Italy (based on data from New et al., 2002)

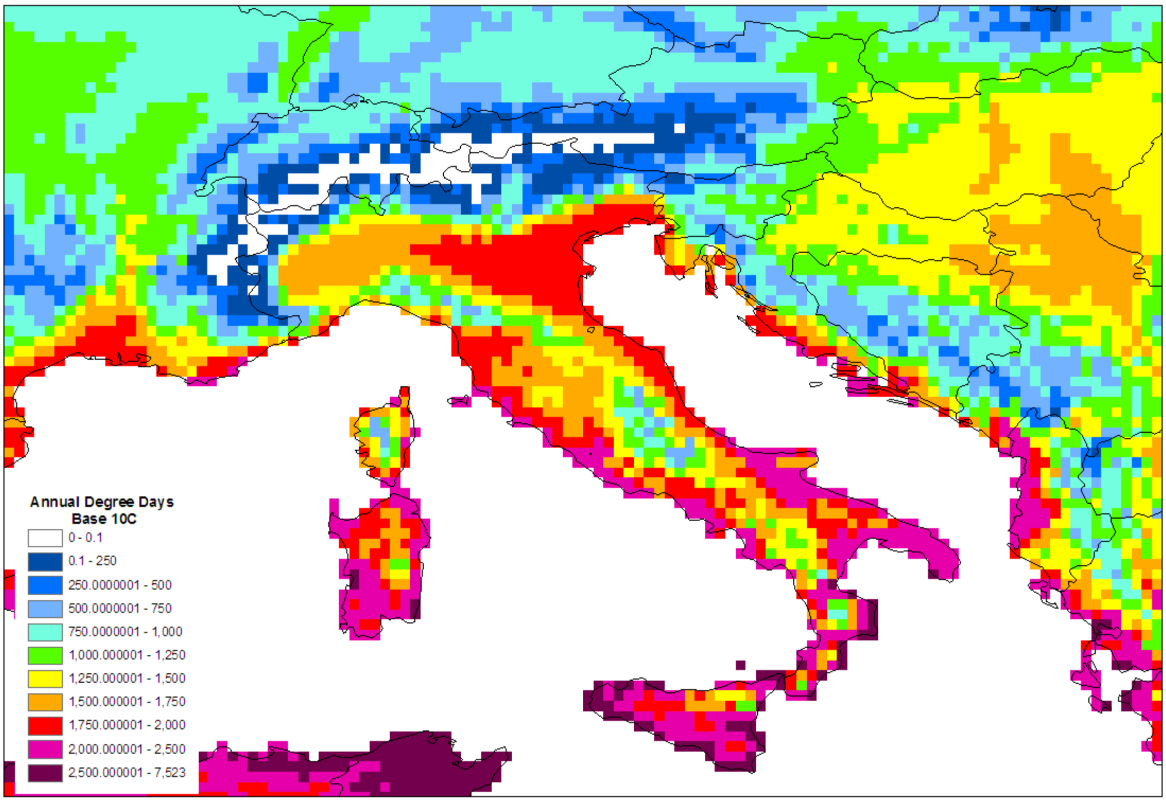

Figure B12: Annual degree days base 10 °C in Italy (based on data from New et al., 2002)

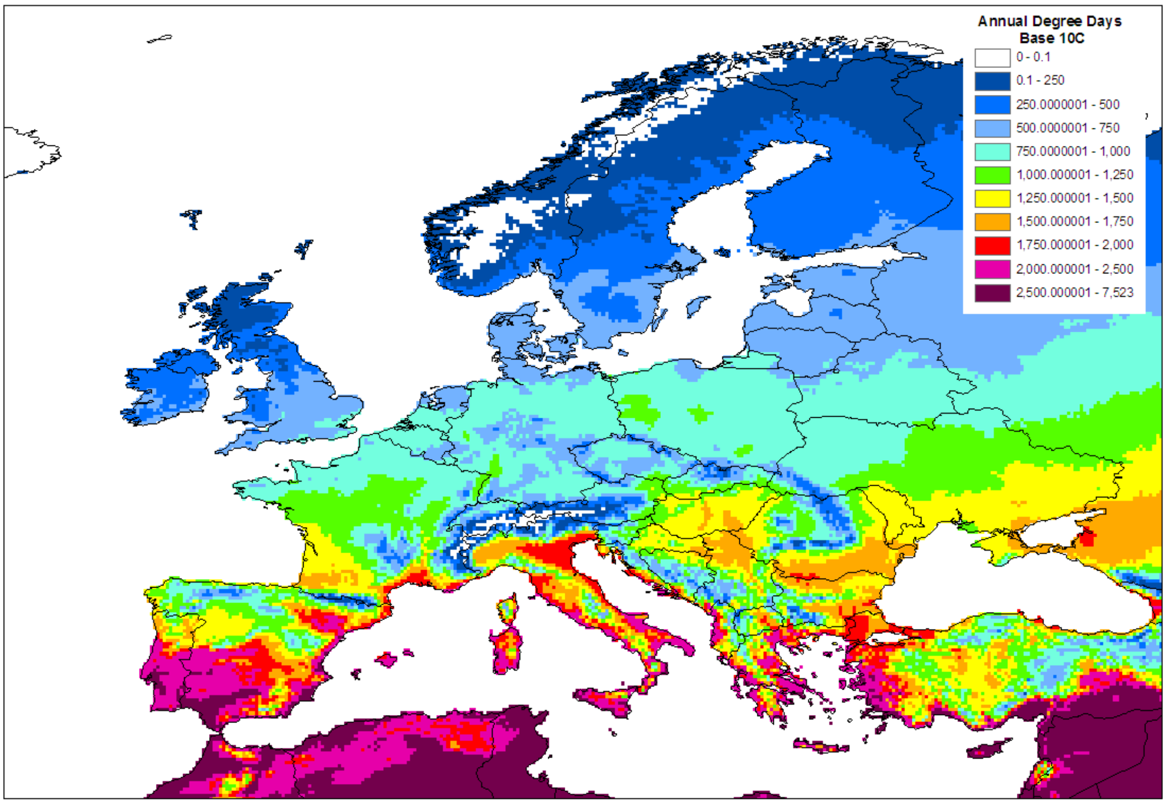

Figure B13: Annual degree days base 10 °C in Europe (based on data from New et al., 2002)

3. Climatic suitability in the pest risk assessment area related to the presence of *D. kuriphilus*

If *D. kuriphilus* was still absent from Europe, the potential for *D. kuriphilus* to establish in Europe would have had to be based solely on the knowledge that (a) in China and Japan *D. kuriphilus* occurs wherever *Castanea* species are present, (b) *C. sativa* is less cold-hardy than the Chinese *Castanea* species, (c) the minimum threshold for development of *D. kuriphilus* is 10 °C and (d) the northern limits of the Chinese distribution of *D. kuriphilus* have total annual degree days base 10 °C similar to large areas of southern Europe where *C. sativa* is grown. Given that *D. kuriphilus* has established in Europe, despite the fact that it is still spreading, can we use this information to assess the climatic suitability and endangered areas of the EU with more precision?

D. kuriphilus has been established in Italy since 2002 (Brussino et al., 2002), France since 2005, Slovenia since 2005 and Switzerland since 2009 (summarised by Bosio et al., 2010). Eradications have occurred in France and Hungary (Csóka et al., 2009; Zhang et al., 2009). In Italy, it has been reported from 15 of the 20 regions, dense populations have been observed in some places and it can be assumed that all the major areas of *C. sativa* production have been invaded (Graziosi and Santi, 2008). Fig B2 summarises the current distribution in Europe. Based on its presence throughout Italy, the climate in large parts of central southern EU, especially all the area defined by Metzger et al. (2005) as Mediterranean and at least part of the area given as Lusitanian (Fig B14), can be considered suitable for establishment and the need to determine “how similar are the climatic conditions that would affect pest establishment, in the risk assessment area and in the current area of distribution” is already partially answered.

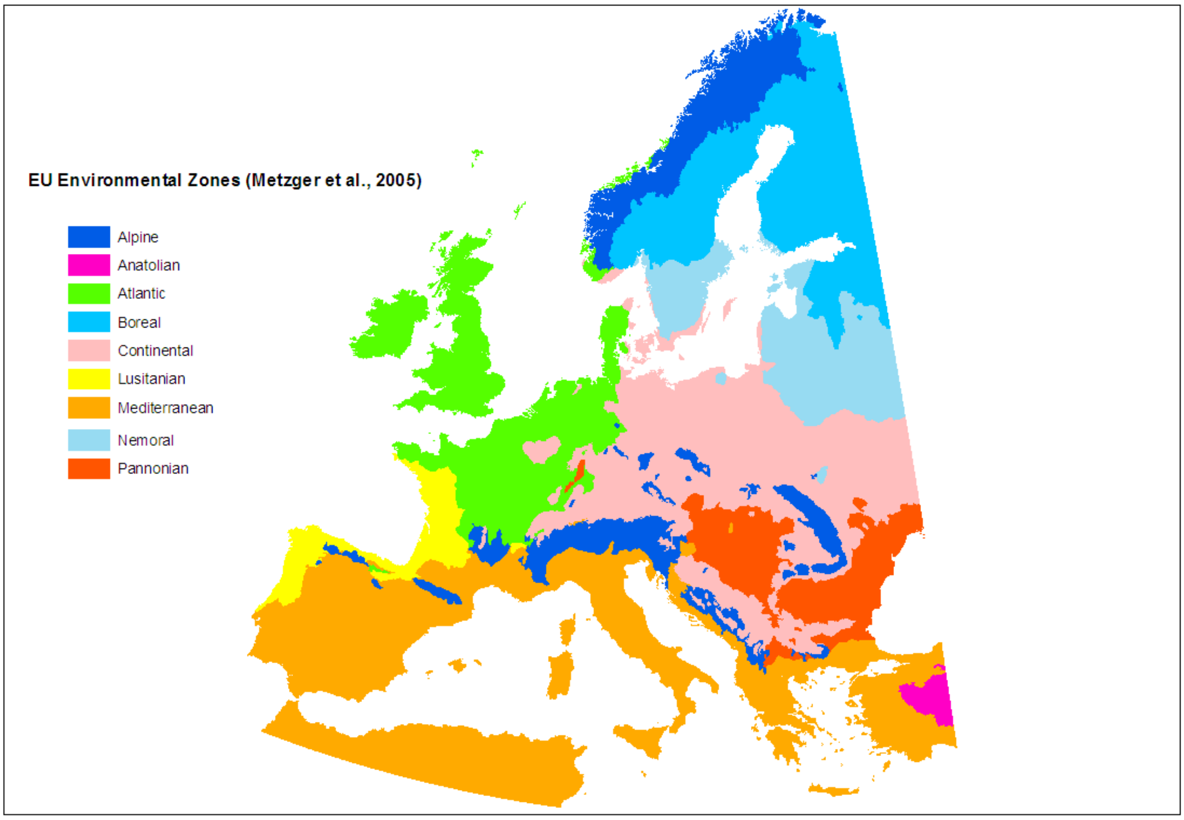

Figure B14: EU Environmental Zones based on climate (Metzger et al., 2005)

If we consider that the current wording of question 1.19 is an attempt at a simpler formulation of “How suitable is the climate for establishment in the risk assessment area” [Very unsuitable, unsuitable, moderately suitable, largely suitable, highly suitable] we can already state that the answer is not “very unsuitable” or “unsuitable” (equivalent to “not similar” or “slightly similar” in the current scheme). The climate is clearly highly suitable in Italy but, taking into account the likelihood that it may still be unsuitable in northern parts of the EU, it would be more appropriate for our answer to be either “moderately suitable or largely suitable” (equivalent to moderately similar or largely similar in the current scheme) with a low-medium uncertainty.

To provide a more definitive response to question 1.19 and a more precise indication of the endangered area (question 1.35), we need to predict the northern limits to the distribution of *D. kuriphilus* in Europe. It is clear that we cannot use our knowledge of the Chinese distribution to determine this with great accuracy. Fig. B15 overlays the EUFORGEN summary of the *C. sativa* fruit and timber production map from Conedera et al. (2004) onto the annual degree days base 10 °C for 1961-90 at 10 minute resolution in Italy. It is apparent that, in Italy, *C. sativa* is not grown in the hottest areas and is found particularly in hilly or mountainous areas where, according to the 10 minute resolution maps of degree days base 10 °C, the annual temperature accumulation is between 750 and 1500. Fig. B16 expands Fig. B15 to the area of the EU where *C. sativa* is grown for fruit and timber production showing that almost all of this area also has an annual temperature accumulation within this range. This indicates that almost the whole area of *C. sativa* fruit and timber production in the EU is therefore at risk from *D. kuriphilus*. The areas where *D. kuriphilus* is currently absent which have the highest degree day accumulations and the largest areas of chestnut production, e.g. in northern Portugal, northern Spain and south-west France must be considered to be at the greatest risk.

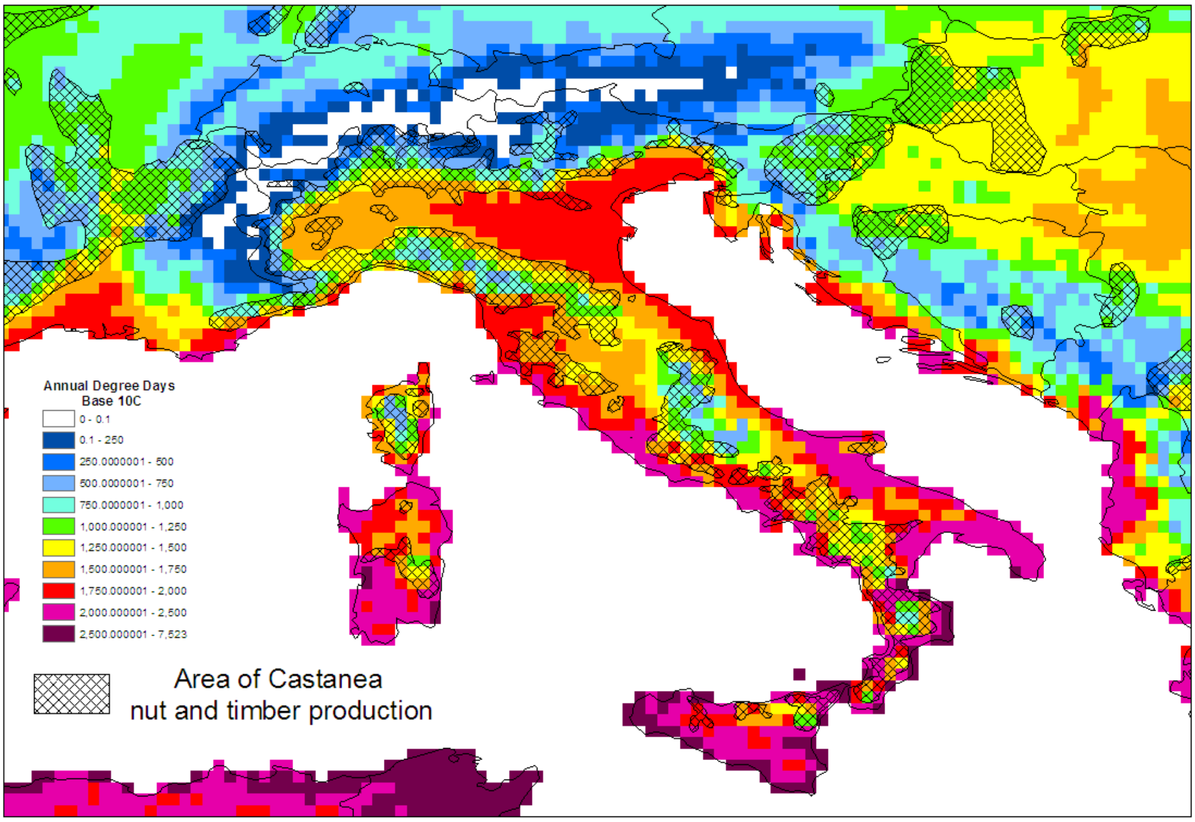

Figure B15: Annual degree days base 10 °C and the area of *C. sativa* nut and timber production in Italy (based on data from EUFORGEN and New et al., 2002)

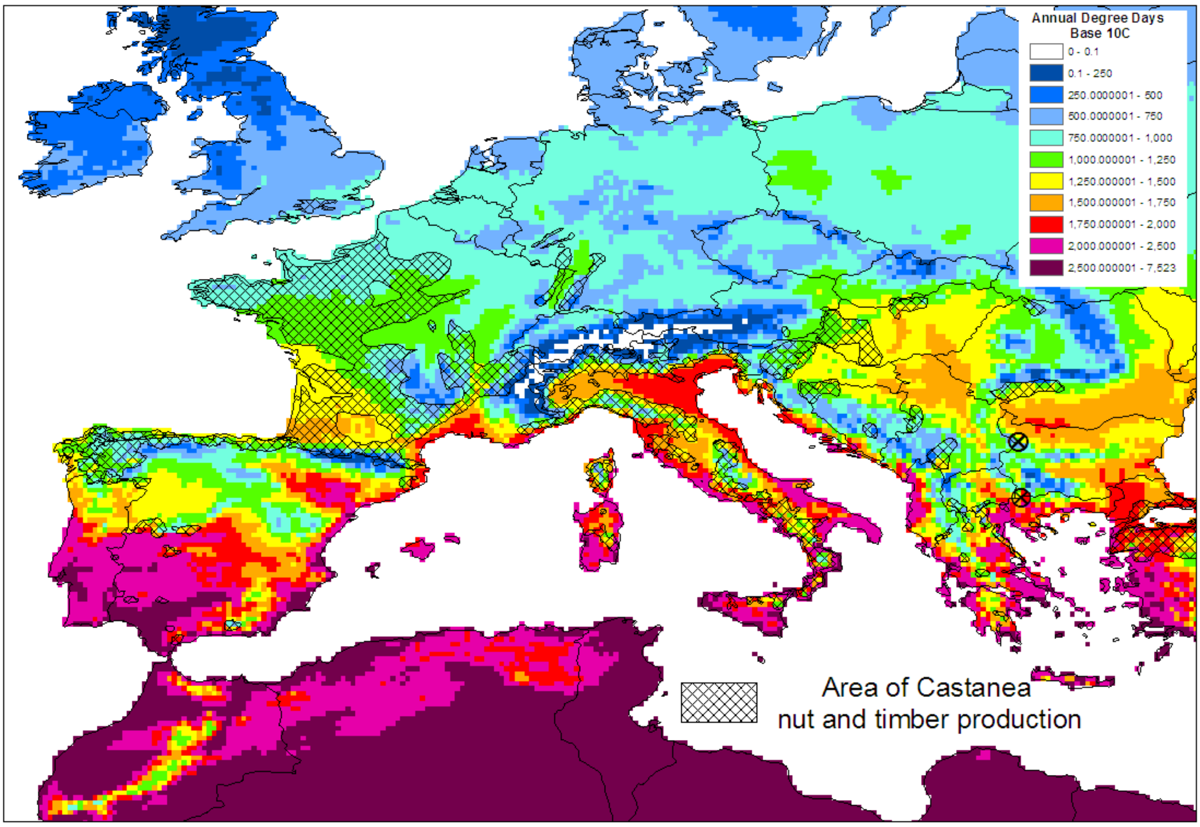

Figure B16: Annual degree days base 10 °C and the area of *C. sativa* nut and timber production in Europe (based on data from EUFORGEN and New et al., 2002)

However, there are a number of caveats:

- These conclusions are based on 30 year averages of climatic data from 1961-90 constructed by New et al. (2002). Although this dataset has been used to enable comparison with the Chinese *Castanea* distribution, they can be replaced with the more recent gridded climatic data prepared by the JRC to explore the potential distribution within Europe based on degree day accumulations.

- The 10 minute latitude-longitude resolution of the 1961-90 dataset provides grid cells with dimensions of approximately 17 x 17 km in northern Italy. However, they are likely to be based on climate interpolated from fewer stations and will be less accurate than the 25 x 25 km grid cells generated from the JRC climate database.

- Each grid cell provides one value for accumulated temperatures at mean altitude irrespective of the complexity of the terrain. In mountainous areas, e.g. those where *Castanea* tends to be grown for fruit production in China and Italy, temperatures are likely to vary significantly within each grid cell according to the altitude, slope, aspect, presence of water bodies and even the concavity and convexity of the landscape. Farmers will exploit the terrain to maximise production, e.g. by utilising south facing slopes with good cool air drainage. Grid cell data in mountainous areas are thus not likely to give values for maximum and minimum temperatures that are representative of temperature conditions in chestnut orchards and daily weather data collected from close to the *D. kuriphilus* outbreaks would be required to determine whether annual degree day accumulations throughout the area of *C. sativa* nut and timber production is sufficient for *D. kuriphilus* development.

- Annual degree days derived from the global 10 minute latitude-longitude 1961-90 database are based on monthly summaries and are therefore much more inaccurate than degree day accumulations calculated from daily measurements, e.g. by the JRC, that directly represent the diurnal variability of weather conditions.

4. Conclusions

1.19 How similar are the climatic conditions that would affect pest establishment, in the risk assessment area and in the current area of distribution?

Answer: largely similar

Level of Uncertainty: low

Part of the reason that this question is difficult to answer is because, in effect, two questions are being asked: (i) what proportion of the risk assessment area has a suitable climate for establishment and (ii) in the locations that have a suitable climate for establishment, to what extent does the climate enable development, reproduction and permit survival? Without additional information, based on the current presence of *D. kuriphilus* in the EU, we would probably answer question (i) as moderately suitable with medium uncertainty and question (ii) as highly suitable with low uncertainty. In eastern Asia, the distribution of *D. kuriphilus* is similar to that of its *Castanea* hosts which can survive much colder winters than *C. sativa*, the principal host in Europe, and so it is expected that *D. kuriphilus* can successfully overwinter wherever *C. sativa* is grown. Despite information that the minimum threshold for development is 10 °C, we cannot accurately map areas with summer temperatures suitable for development in Europe due to (a) lack of knowledge of the degree days required to complete development, (b) our imprecise knowledge of the northern limits of *Castanea* distribution in China and (c) the difficulty of relating the distribution of *Castanea* and *D. kuriphilus* to weather stations that accurately record temperature accumulation in mountainous areas. Nevertheless, its ubiquitous distribution in Italy, covering all the major areas of *C. sativa* fruit production and the mountainous areas of northern Italy suggests that it can establish wherever *C. sativa* is grown throughout southern, central and western Europe.

1.35. Based on the answers to questions 1.16 to 1.34 identify the part of the risk assessment area where presence of host plants or suitable habitats and ecological factors favour the establishment and spread of the pest to define the endangered area.

Answer (based solely on hosts and climate)

Based on its wide distribution in Italy, all areas of *C. sativa* fruit and timber production in southern Europe, particularly the Mediterranean, are endangered. The areas where *D. kuriphilus* is currently absent which have the highest degree day accumulations and the largest areas of chestnut production, e.g. in northern Portugal, northern Spain and south-west France must be considered to be at the greatest risk. Precise limits to its distribution cannot be estimated because of a lack of information on the degree days required to complete its life cycle above the threshold of 10 °C and the difficulty of obtaining representative weather data in the mountainous areas of chestnut production in China and Italy.

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APPENDIX C

MODELLING APPROACHES TO DETERMINE SPREAD POTENTIAL OF *DRYOCOSMUS KURIPHILUS*

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1. Introduction

Various estimates of the rate of dispersal of *Dryocosmus kuriphilus* are mentioned in the literature. Payne (1981) states that adults of *D. kuriphilus* can spread on average 15 miles (24.1 km) per year by natural means. Rieske (2007) provides maps illustrating the dispersal of *D. kuriphilus* in USA from 1974 to 2006. She concluded that natural dispersal of *D. kuriphilus* shows annual variation with a maximal recorded distant of 25 km per year. In Italy, Graziosi and Santi (2008) have observed a similar rate of natural dispersal of *D. kuriphilus* in Italy: 25 km per year. The limited information provided on dispersal and spread of *D. kuriphilus* found in the literature leads to the following questions:

1) *Which definition of spread did the authors use, and how did they estimate the dispersal rate*? Probably, they divided the distance spread over time from the supposed site of introduction by the

number of years since introduction. A question is whether this approach is methodologically sound and if the estimates are realistic. In particular the use of the qualification as 'natural' for the dispersal is questioned, as it implies that human-assisted dispersal could apparently be excluded and (ii) that the same pattern of dispersal will be the same everywhere (as seems to be shown by the coincidence of three estimates).

2) *Is the spread really uniform and constant over time*? The answer to this question depends on the real pattern of spread by *D. kuriphilus*. A simple visual analysis of maps representing the spread of *D. kuriphilus* in Italy shows that a rate of 25 km/year does not account for the fast colonization of this country. Furthermore, the rate is not constant over time but tends to increase. Both these characteristics prove that dispersal is not random but stratified with a component of long-distance spread in which human transportation of *D. kuriphilus* plays a key role.

3) *Are these studies of some utility for management option evaluation*? The management problem is complex and in many respects dependent on assumptions and calculation of the intrinsic population growth rate, and the mechanisms and the rates of population dispersal.

The limited data available in literature on the *D. kuriphilus* population spatial-temporal dynamics and the lack of knowledge on the basic biology of this pest make it difficult to address the above issues. Considering these limitations it is of primary importance to develop a methodology that could:

(i) Provide tools able to summarize all the relevant information and knowledge to produce analysis of *D. kuriphilus* spread and allow us to reconstruct a realistic representation of past events and to provide valid projections on the likely course of future events based on appropriate assumptions and scenarios;

(ii) Produce guidance for the definition of criteria for the evaluation and comparison of management options.

The aim of this Appendix is to present a modelling approach that could provide a useful tool to support the analysis of *D. kuriphilus* spread and in doing so, provide guidance for the evaluation of management strategies. The essential elements that characterize the methodology adopted for development of the model are outlined below.

1) A general framework for a mechanistic approach is developed and applied to *D. kuriphilus* in order to analyze different aspects of the invasion. This approach is characterised by: (i) wide applicability, (ii) solid theoretical foundation, and (iii) realism in biological parameters. The approach to parameter estimation is based on a combination of top-down and bottom-up approaches, based on the use of biological data and information on population dynamics.

2) Biological assumptions are clearly expressed and realistic. The model is based on few general assumptions

- Population abundance increases at a constant rate with limitation due to over-crowding effects;
- The spread of individuals depends on both active and passive mechanisms. Migrating individuals, both adult and immature, leaving already infested areas and colonizing new contiguous or separated areas can establish new local population with a probability dependent on number of individuals arriving into the new area and the distance travelled;
- At population level the spread is characterized by a stratified pattern with a local random continuous dispersal (or short-distance dispersal-SDD) and discrete events of long distance dispersal (LDD);
- Mathematically the model is time-discrete, all biological processes occur once a year and are assumed to take place in discrete point in time. First, short and long-distance dispersal occurs,

then dispersing individuals establish in new areas they are colonizing, finally reproduction takes place;

- Population growth and spread are not limited by climatic factors. This limitation may occur moving northward into the potential area of colonization (most of southern and central Europe). However, under the hypothesis that the area of first colonization in Europe (i.e. Italy) provides favourable conditions, disregarding potential limitations of climate may lead to a more precautionary or over-estimation of colonisation potential;

- The landscape is continuous and subdivided intro 1x1 km cell characterized by presence or absence of *Castanea* spp., population development take places only where chestnut is available;

- Spatio-temporal dynamics can be represented by a reaction-diffusion model applied to the case of continuous space and discrete time.

Particular attention has been devoted to the mechanistic representation of dispersal

- At microscopic level (individual level) diffusion of *D. kuriphilus* occurs by means of three main processes:

    a) Natural dispersal (active flight of the adults and natural transportation, e.g. wind);

    b) Artificial dispersal due to direct human transportation of the adults;

    c) Artificial dispersal due to the transportation of infested biological material.

- At macroscopic level (population level) these three modalities have been grouped into two types of dispersal that can be interpreted within the typical pattern of the stratified dispersal:

    Type 1: SDD (Short Distance Dispersal), which mainly comprises the continuous dispersal of individuals at a low spatial scale due to the natural random movement of adults and the dispersal caused by natural (e.g. wind) or artificial driving forces (direct human transportation);

    Type 2: LDD (Long Distance Dispersal), due to discrete events that lead to the establishment of new infestation foci separated from the closest infested area by a non-infested zone. LDD events are mainly caused by artificial dispersal due to the transportation of biological material, but a possible contribution of the two other mechanisms cannot be excluded. Each new infestation centre is the origin of a SDD process that results into an infested area that expands over time.

3) A minimum set of mathematical tools are selected for the formal representation of bio-ecological processes related to invasion

- *Local population establishment*. Considering a population already established in a new territory, dispersal events can lead to the establishment of new expanding local populations. The process is highly stochastic and the probability of establishment depends on the distance from the core population. To describe this probability a model is derived from the formulation proposed by Jerde and Lewis (2007).

- *Population growth*. Temporal population dynamics are described by a discrete model with saturation. The Beverton-Holt model (Beverton and Holt, 1981), a discrete analogous of a logistic model, has been selected because of its simplicity, biological meaningfulness, and stability properties.

- *Population spread*. Local random and continuous dispersal is introduced considering a dispersal kernel that is the probability density function associated with the random dispersion of the population from two different points in the space in a single dispersal event. Population growth and continuous dispersal are modelled by an integro-difference equation. Long distance dispersal is represented by a stochastic process that creates new infestation centre (local expanding isolated population) from previous established infestation centre. Further details and assumption on the dispersal are given below.

2. Mathematical model

2.1. Probability of local population establishment

The spatial domain considered in the model is partitioned in a regular bidimensional grid defining a matrix of *I*x*J* cells. When we consider the movement of the individuals and population growth, we suppose that the population is concentrated in the centre of a cell.

Considering a population already established in a new territory, dispersal events can lead to the establishment of new expanding local populations. The process is highly stochastic and probability of establishment depends on the distance from the core population and the number of arriving individuals. To describe this probability a model derived from the formulation proposed by Jerde and Lewis (2007).

Let a_t^{ij} denotes the number of individuals arriving in the cell (i, j) at time *t* and p_s the survival probability of a single individual. We have that

$p_s\, a_t^{ij} =$ number of individuals establishing in the cell (i, j) at time *t*

and

$1-\exp\left(-p_s\, a_t^{ij}\right)=$ probability of observing at least one established individual in the cell (i, j) at time *t* (Jerde and Lewis, 2007).

2.2. Population growth

D. kuriphilus population develops in discrete time. For time discrete population dynamics we adopt the Beverton-Holt model (Beverton and Holt, 1981).

$$N_{t+1} = \frac{R_0 N_t}{1+\left[(R_0-1)/K\right]N_t} \qquad [2.1]$$

where N_t is the population abundance at time *t*, N_{t+1} is the population abundance at time *t*+1, R_0 is the net reproductive rate and *K* is the carrying capacity of the environment. Population abundance is normalized to the carrying capacity, then $K=1$.

2.3. Adding the random diffusion: the dispersal kernel

The model [2.1] can be summarized by the simplified formulation

$$N_{t+1} = f\left(N_t\right).$$

This equation does not take into account the dispersion. Following Kot et al. (1996) we denote by $N_t(x)$ the population density as a function of space at time *t* and by $k(x,y)$ the dispersal kernel, that is the probability density function associated with the dispersion of the population from a position *y* to a position *x* in the space, in a single dispersal event occurring at time *t*.

Growth and dispersal of the population can be described by the integro-difference equation

$$N_{t+1}(x) = \int_{\Re^2} k(x-y) f\left(N_t(y)\right) dy \,. \qquad [2.2]$$

From this formula we can see that the dispersal depends only on the distance $x-y$ so the dispersal properties are the same for all the points *x* in the space with the same distance from *y*.

In our case the dispersal kernel is a bivariate normal distribution

$$k(x-y) = \frac{1}{2\pi\sigma^2} \exp\left(-\frac{|x-y|^2}{2\sigma^2}\right)$$

where σ is the random diffusion parameter. It follows that equation [2.2] can be written in the form

$$N_{t+1}(\mathbf{x}) = \int_{\Re^2} \frac{1}{2\pi\sigma^2} \exp\left(-\frac{|\mathbf{x}-\mathbf{y}|^2}{2\sigma^2}\right) \cdot \frac{R_0 N_t(\mathbf{y})}{1+\left[(R_0-1)/K\right] N_t(\mathbf{y})} d\mathbf{y} \,. \qquad [2.3]$$

Equation [2.3] is an integro-difference equation representing population growth and short distance dispersal (SDD) due to random movement of individuals.

At the initial time, $t=0$, the population N_0 is concentrated in a single point (infestation centre). For example with infestation centre of coordinates $(0,0)$ in the plane x, y we have

$$N_0(\mathbf{x}) = n_0\, \delta(0,0).$$

From this point the population starts its dispersal in the surrounding environment. Then, for R_0 deterministic, the short-distance dispersal generates a circular colonized area expanding through time. In Fig. C1. is reported a section (a quadrant) of the spatio-temporal dynamics of the population in (0,0) expanding via random diffusion.

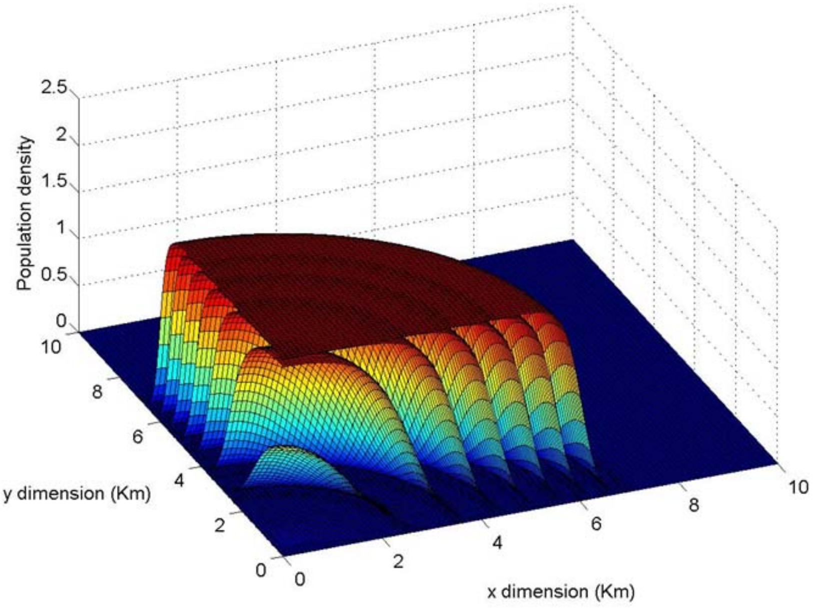

Figure C1: A section (a quadrant) of the spatio-temporal dynamics of the population in (0,0) expanding via random diffusion (SDD). Each surface represents the distribution of the population in a year

2.4. Adding the long distance dispersal: the stratified dispersal

At each time step the population $N_{0,0}(t)$ in the infestation centre (point (0,0) in Fig. C2.) is also supposed to generate new infestation centres (via long-distance dispersal, LDD). LDD is interpreted as the result of passive transport through human vehicles or trade of biological material. The resulting population dynamics pattern is depicted in Fig. C2.

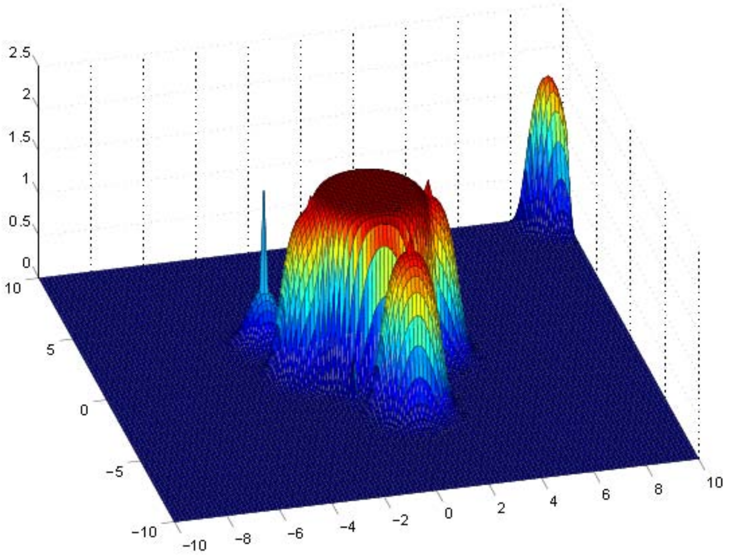

Figure C2: A representation of the spatio-temporal dynamics of the population in (0,0) expanding via random diffusion (SDD) and long distance dispersal (LDD) with the creation of new infestation centres

Considering long-distance dispersal, we hypothesise that the initial population at each time step generates a number M of new colonies.

In the absence of other information, the position of the new infestation centre is determined randomly. The model is also able to tackle specific information on the pathways followed by trading material. To determine the position where new infestation centre establishes, we generate a point from a uniform distribution on $[0,2\pi]$; this point determines the random direction of dispersion. Then, we determine the distance travelled by colonizing individuals from the front of dispersal in the generated direction. We draw a number from a Gamma distribution representing the probability density function of the travelled distance and calculate the coordinates of the new infestation centre. The possibility of establishment is determined by the probability of arrival and the presence of *Castanea sativa* in the cell, representing the surface cover by chestnut trees.

Assuming at each time step, local population (inhabiting an infestation centre) growth and random dispersal following equation [2.3] and generation of new colonies as indicated above, growth (SDD and LDD) is iteratively applied, resulting in continuous spread from the infestation centre and follow a multistage process of generation of new centres. The resulting pattern is illustrated in Fig. C3.

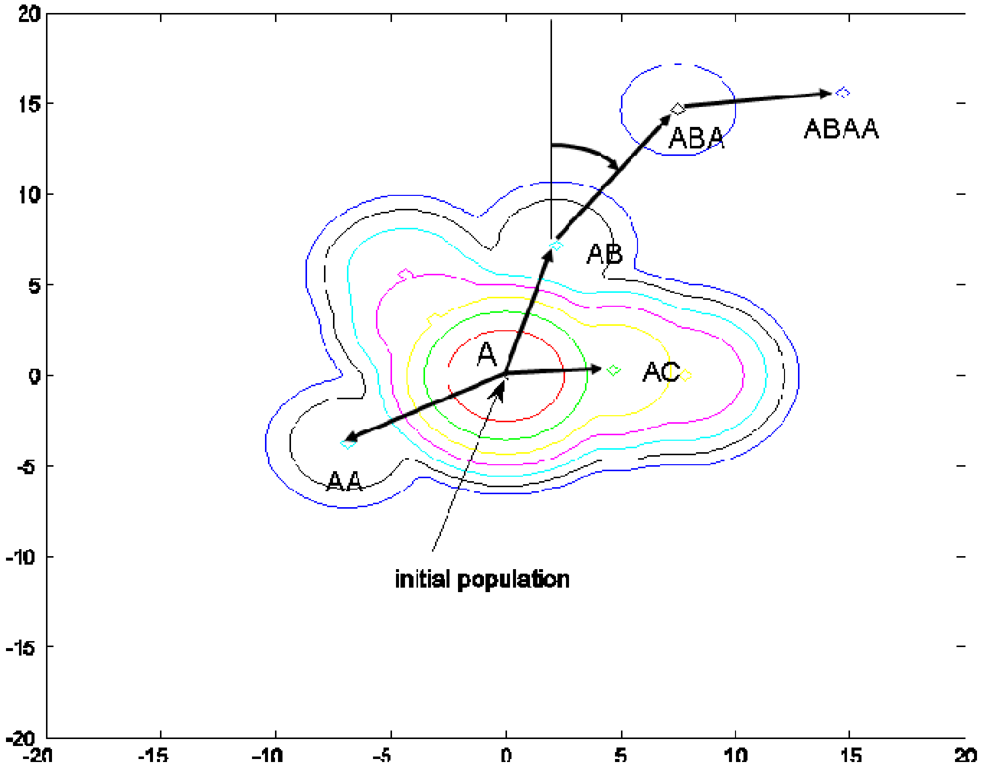

Figure C3: A schematic representation of population spread by means of short distance dispersal (SDD) that produces concentric diffusion front, and long distance dispersal (LDD) that produces new separate infestation centres following a multistage process separated by the centres of origin. The combination of SDD and LDD could lead to the coalescence of expanding populations in different infestation centres

3. Data and parameter estimation

3.1. Data

3.1.1. *Castanea* distribution

Two sources were available to represent the chestnut distribution area in Europe, the most detailed compiled by Conedera et al. (2004) which highlights the main areas of chestnut cultivation. In most cases (e.g. France, Italy, Portugal, Greece and Spain) they represent the updated and digitalised form of the original maps provided by the Chestnut Working Group in the 1950's (Groupe des Experts du Châtaignier, 1951).

A second chestnut distribution map was available through EUFORGEN (http://www.euforgen.org/). This distribution map, including both natural and naturalized occurrence, was compiled by members of the EUFORGEN Noble Hardwoods Network based on an earlier map published by Maurer and Fernández-López (2001) and Bounous (2002). This distribution includes also potential areas in addition to the core areas included in Conedera et al. 2004.

The reference chestnut distribution map used in this study is based on Conedera et al. (2004) chestnut distribution following this approach:

a) Chestnut areas detailed in the Conedera et al. (2004) distribution falling inside the EUFORGEN distribution area were buffered with a 5 km surrounding zone. The resulting areas were again intersected with the EUFORGEN distribution to include the latest estimates;

b) Chestnut areas detailed in the Conedera et al. (2004) distribution falling outside the EUFORGEN distribution were buffered with a 1 km surrounding zone (Fig. C4.).

The adopted *Castanea* cover is the best estimate from available data although there are uncertainties as it may exclude some *Castanea* areas and/or include areas where *Castanea* is not currently present. This could also affect the distribution of *D. kuriphilus*. At the time of this analysis, 5 % of the Italian municipalities (23 out of a total of 464 that have reported the presence of *D. kuriphilus*) are not included in the adopted *Castanea* covered, thus excluded from model parameter estimation.

The vector format distribution maps obtained with the above methodology were then converted to a raster format using a 1 km^2 cell size and finally to an ASCII grid to be used as input to the model (Fig. C3). As distance is an important parameter in this study the projection selected to represent the distribution areas is the Europe Equidistant Conic projection. Equidistance projections provide a more accurate estimate of the distances then other types of projections. It is important to select the most appropriate projection for each application as each projection affects negatively one or more spatial properties such as distances, shape and area. Equidistance projections offer the best compromise for maintaining accurate distances.

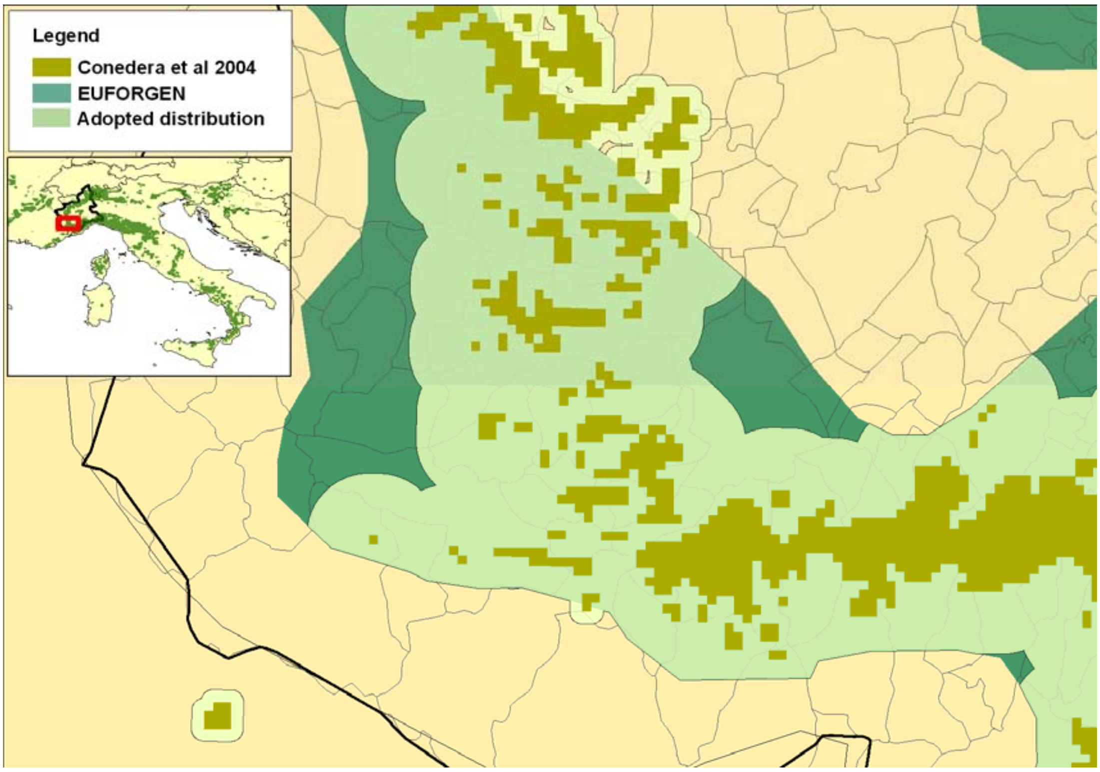

Figure C4: Comparison between the Conedera et al. 2004, EUFORGEN and the adopted chestnut distribution in a sample area located in the south of Piemonte Region. A buffer of 5 km was applied to Conedera et al. (2004) chestnut areas falling inside the EUFORGEN distribution area and then the resulting areas were clipped over the latest chestnut areas falling outside the EUFORGEN distribution were buffered with a 1 km zone

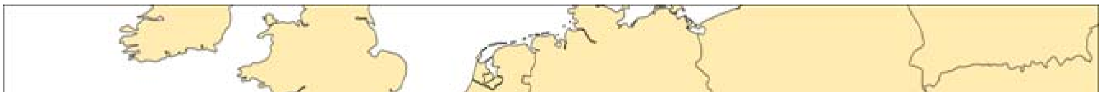

Figure C5: The distribution of *Castanea* in Europe obtained with the method described in section 3.1.1. and here adopted for model simulation

3.1.2. *D. kuriphilus* distribution

The collection of occurrence data[15] for *D. kuriphilus* was carried out from July 2009 to January 2010 and obtained directly from the regional phytosanitary services in Italy and from reports provided from phytosanitary services in France, Slovenia and Switzerland, on a national level.

The data obtained were highly heterogeneous in their format and quality. Information provided was also not harmonized in their spatial resolution. In most of the cases the presence of *D. kuriphilus* was reported at administrative level (municipality), in some cases occurrence was geo-referenced. In others, when only the place names and year of observation were available, they were converted to geographic areas, using the administrative boundaries at municipal level from the national cartographic archives (e.g. ISTAT).

Because exact geographic coordinates for all occurrences were not available, distribution maps of the presence of *D. kuriphilus* were based on the administrative areas identified by the municipality of occurrence (available in all cases) intersected with the distribution area of the chestnut (Fig. C5.).

The data were validated and standardized before importing into the GIS software. Some of the validation steps included:

- Organizing all data in a unique table format with fields such as Region, Municipality, Latitude, Longitude, Date, Source;
- Converting all data to the same geographic coordinate systems/projection;
- Correcting, where possible, obviously wrong coordinates;
- Standardizing names of places to municipality names included in the GIS dataset;
- Adding municipality name were only coordinates were available.

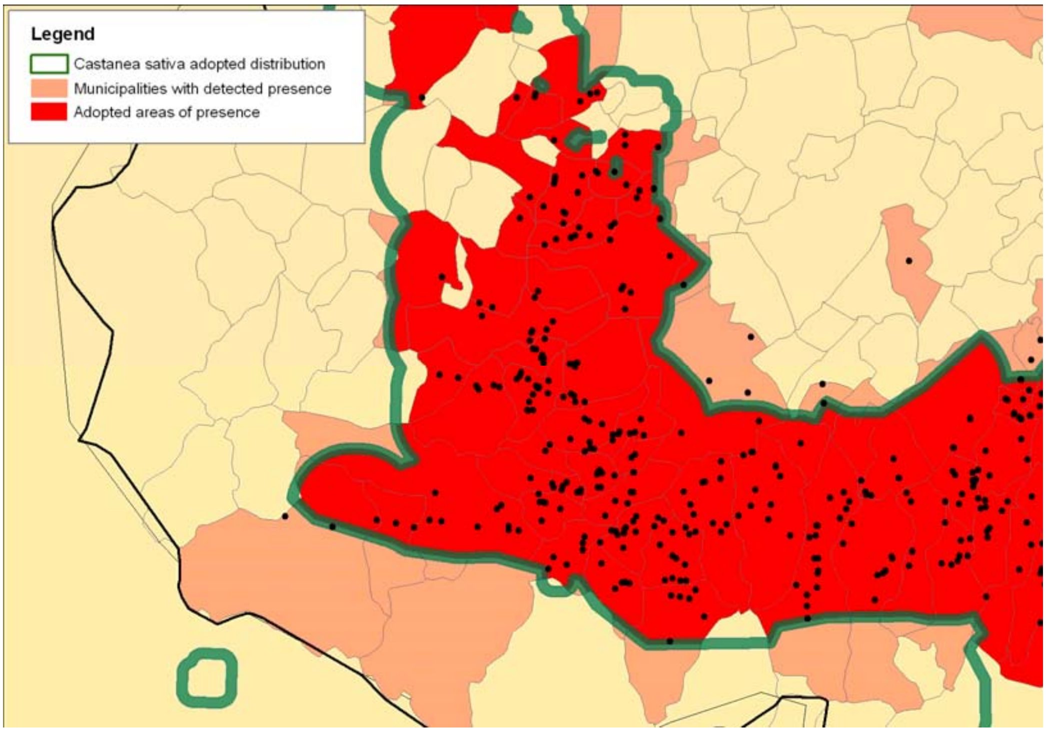

Figure C6: Distribution maps of the presence of *D. kuriphilus* were based on the administrative areas identified by the municipality of occurrence, intersected with the distribution area of the chestnut: example of the resulting map in an area located in the south of Piemonte Region

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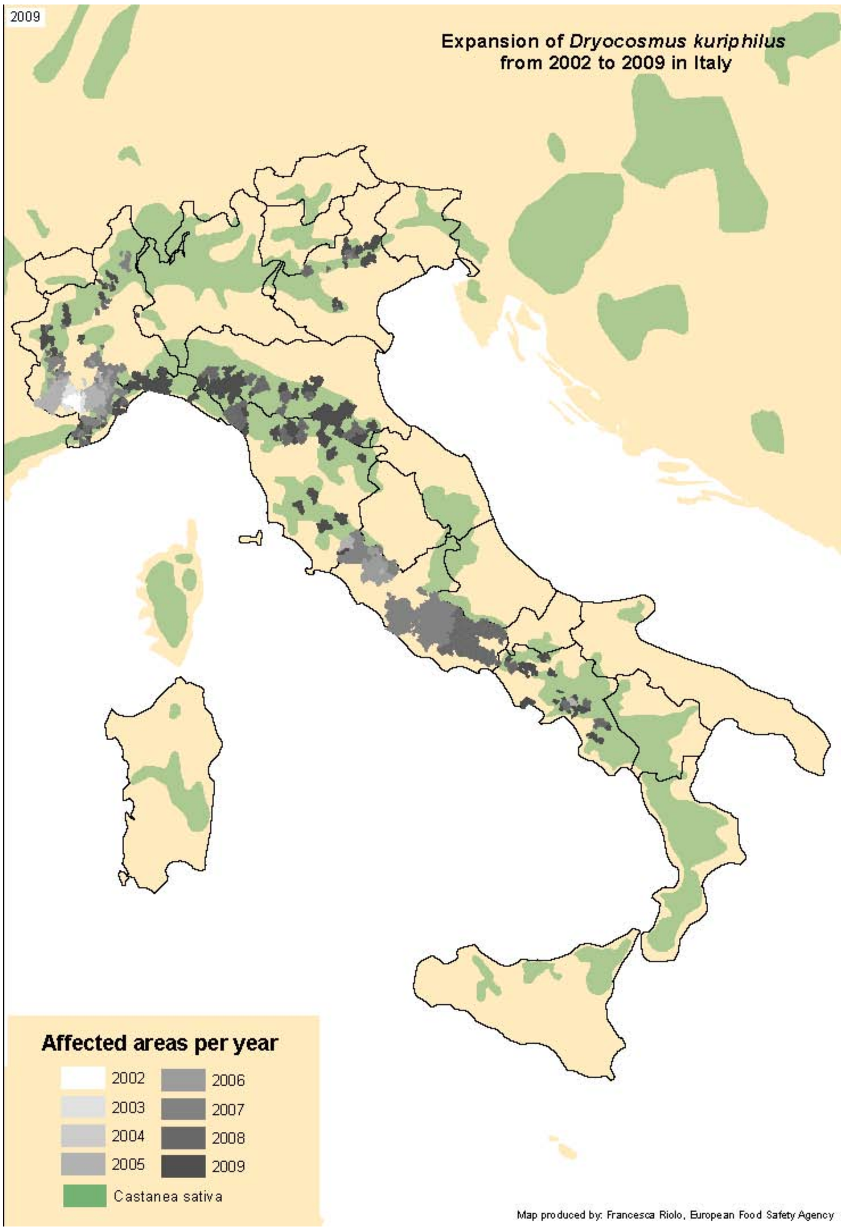
[15] The data are available from EFSA on request to plh.panel@efsa.europa.eu.

All data were imported and processed in the ESRI ArcGIS9.3 software with the Spatial Analyst Extension. Various GIS dataset for Europe, including the NUTS administrative boundaries, were available as base maps. The GIS dataset with the administrative boundaries at municipality level (corresponding to LUA2 level) was acquired for each country (maybe mention sources here, e.g. from ISTAT website for Italy).

For parameter estimation were considered all the data available in a suitable format on the February 28th, 2010. Because at that date only data from Italy were available at the selected spatial resolution only Italian records on *D. kuriphilus* distribution have been consider in parameter estimation. We suppose this does not affect estimation of SDD, while the estimation of LDD are expected to be much influenced by Italian records. However, LDD parameters can be considered as constant but they highly depend on cultural and geographical aspects of the territory we are dealing with, for such reason LDD parameters are considered as variables in the performed sensitivity analysis.



Map produced by: Francesca Riolo, European Food Safety Agency

Figure C7: Spatial distribution of *D. kuriphilus* in Italy in different years from early detection in 2002 to 2009

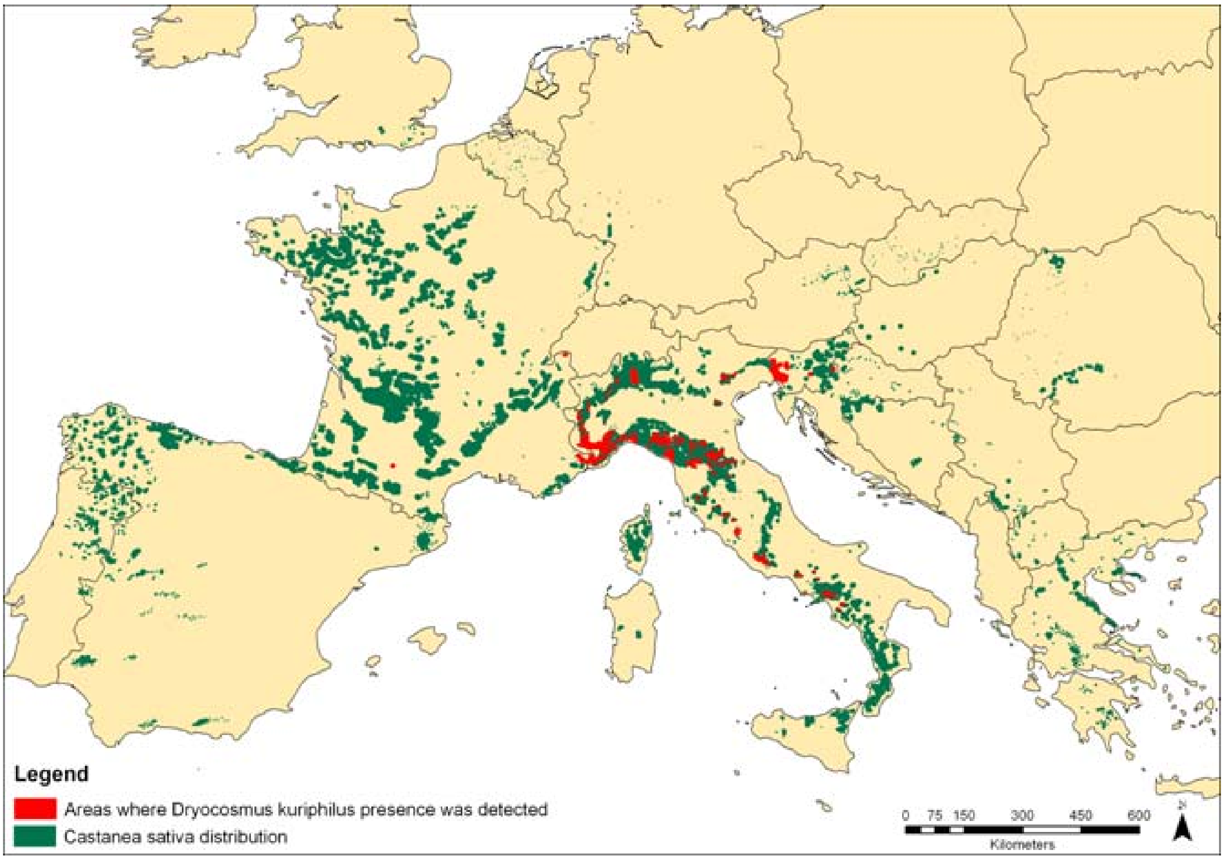


Figure C8: Spatial distribution of *D. kuriphilus* in Europe in 2009. Data from Italy are represented per administrative unit (municipality). Data from France, Switzerland and Slovenia are geo-referred point data, to make them more visible a buffer of 10 km was applied

3.2. Analysis of Short Distance Dispersal (SDD)

The proposed mechanistic interpretation of dispersal has been applied to the data available, recognising the limitations in data as described. Most of the data on *D. kuriphilus* distribution comes from surveys performed by the Italian extension (phytosanitary) services at a regional level. Field data generally does not allow accurate representation of the temporal and spatial patterns of colonization of new territories and are affected by some uncertainty, mainly due to the low spatial resolution. The discrimination of SDD and LDD based on the hypothesis of the underlying mechanism at individual level in most of the cases is impossible. Therefore, we rely on an operational definition of SDD and LDD. In particular we identify a LDD event when

> i) is well documented that a new established population has been founded by propagules associated to biological material coming from an infested zone;
>
> ii) we observe at time t+1 a new infested and isolated area that is completely separated from infested area at time t;

Where we observe an expansion of the infested area from time t to t+1that does not produce discontinuity, this expansion is interpreted as the effect of SDD irrespective of the distance travelled by the front of colonization.

From a quantitative point of view the estimation of SDD involves the measurement of the rate c at which the infestation front expands (units: km/year). To do this, for area of first establishment in Italy (Cuneo Province and surroundings, Piemonte), and for all other areas of expansion as a result of LDD events and formation of new infestation centres, the average rate of expansion in different directions and in different years has been estimated.

Coalescence between two infestation centres leads to the disappearance of individual borders between the two infested areas and stops the spread in the contact zone. Spatially more complex situations involving multiple centres are interpreted under suitable assumptions in order to attribute a given portion of the expansion front to a given centre.

An example of interpretation and measurement of an expansion front is shown in Fig. C9. for the Treviso Province in the Veneto Region (Italy).

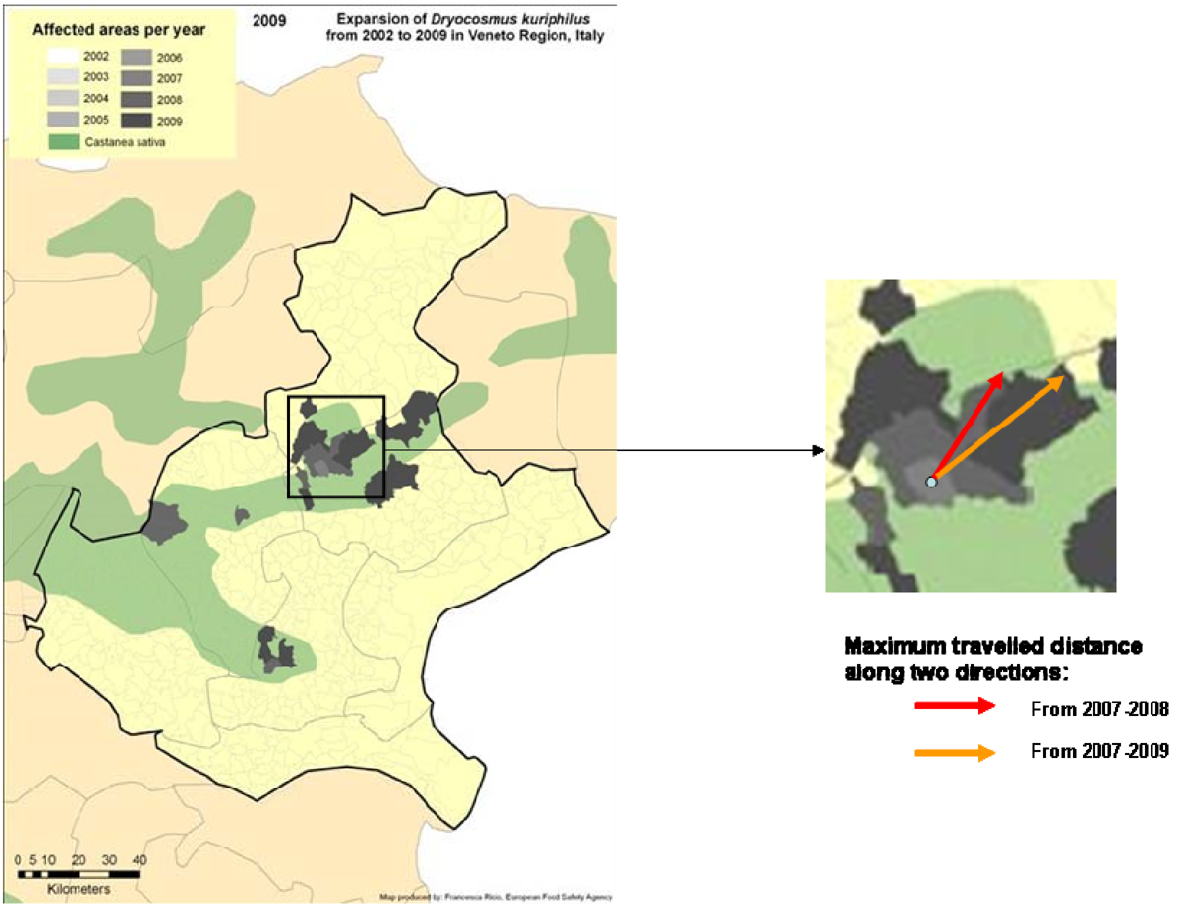


Figure C9: An example of the procedure followed in the estimation of the per-year distance travelled by the pest expansion front. The example refers to an infestation centre in the Treviso Province (Veneto Region)

For the estimation of the parameter *c* all the SDD processes occurred in the Italian Regions starting from 2002 have been considered. The initial expansion of *D. kuriphilus* in Italy in the municipalities of Boves e Pevaragno (Cuneo Province) has been also included in the estimation procedure.

Thirty three independent processes of local diffusion were considered, with a single per-year estimation provided in most cases. The mean value obtained is $c = 8.08$ km/year, which is significantly less than the values reported in literature. The variance is high as shown in the frequency distribution of speed of the reaction-diffusion front depicted in Fig. C10. Apart from few outlayers data probably a misinterpretation due to the quality of the available data and to the low spatial resolution, most of the values are distributed in a range of 3-12 km and seem to follow a normal distribution centred in the classes 5-6 and 7-8 km/year.

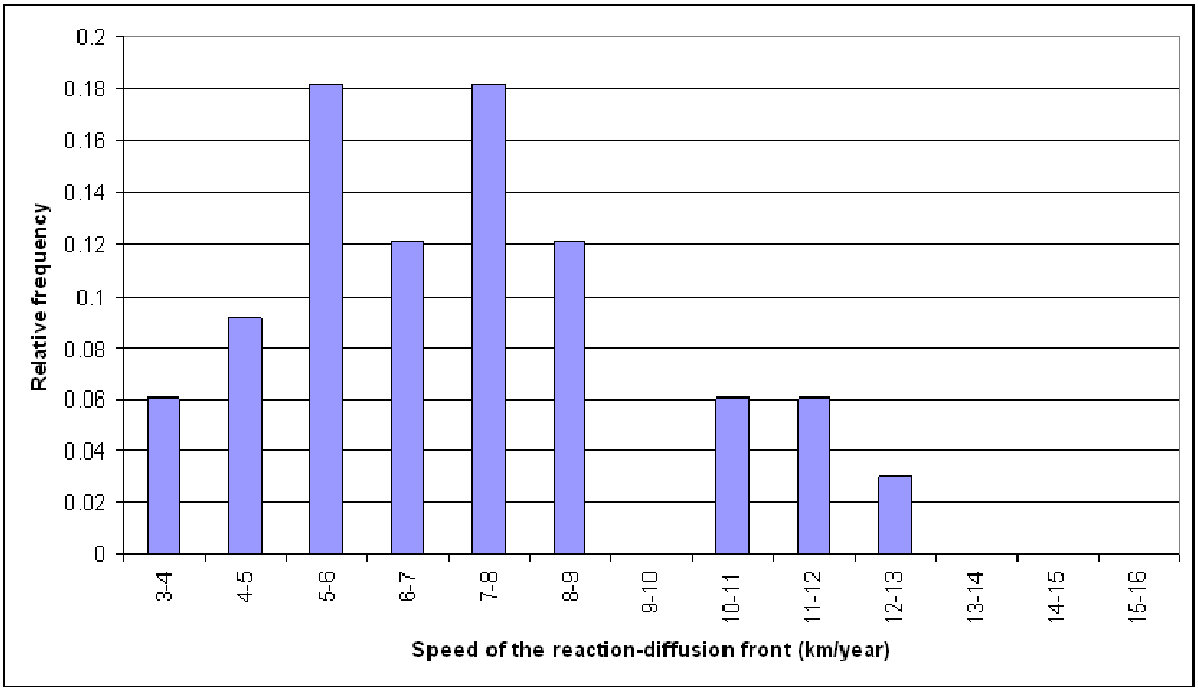


Figure C10: Frequency distribution of the parameter *c*, the speed (in km/year) of the reaction-diffusion front expansion

In the estimation of the parameter *c*, an average measure of the distance from the infestation centre is obtained for each area per year. A slightly different approach has been applied in the infested area around the municipalities of Boves e Pevaragno (Cuneo Province), the area where *D. kuriphilus* was detected for the first time in Italy in 2002. In this area the longer time series (7 years of spread) and the larger infested area allow opportunity to estimate the distance travelled per year along different transects. The mean distance travelled in different directions in each year is reported in Fig. C11. The distance from a hypothetical centroid of the infested area and the front in the year 2002 has been excluded given that no information on the date of the first release is reported in the literature. The mean distances travelled by the front are well interpolated by a linear function as expected in the case of SDD with constant *c,* as is believed to have occurred in this area. The slope of the line is 7.31 km/year, close to the value of 8.08 km/year estimated for the single-year analysis. This represents an important confirmation of the estimated value of the parameter *c*.

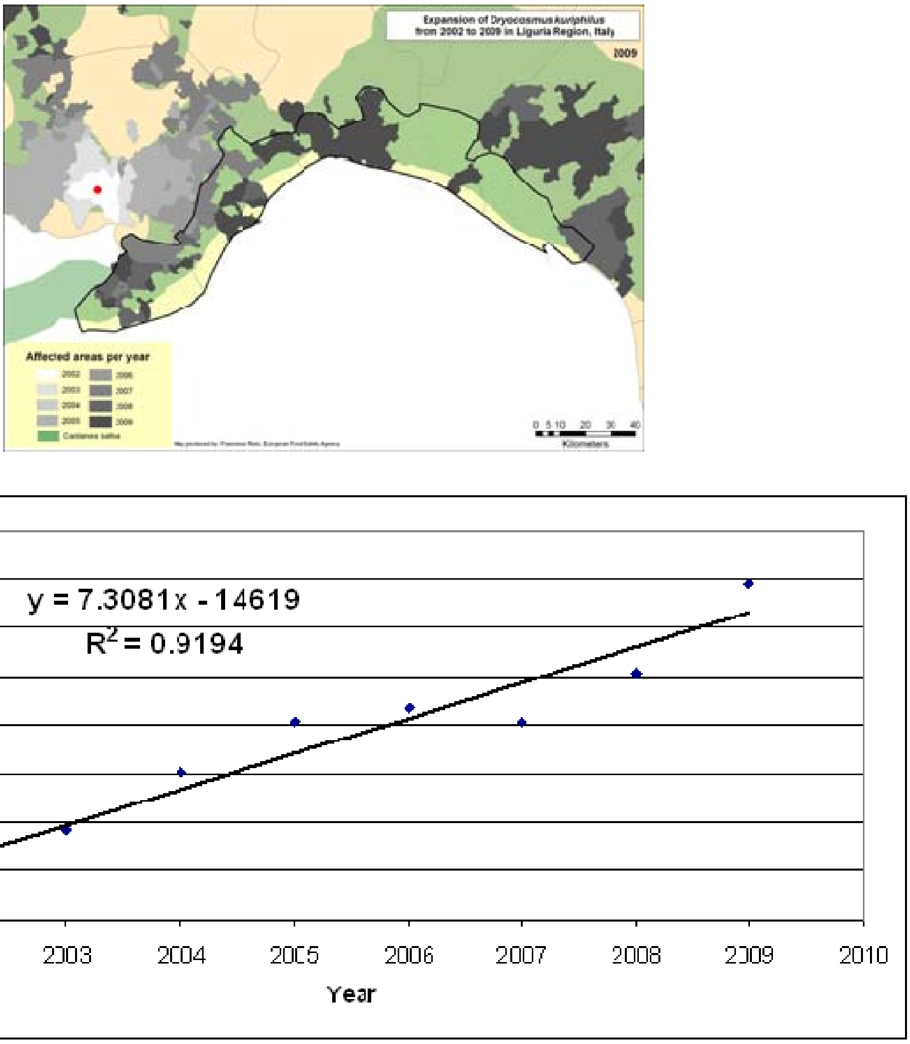


Figure C11: Expansion of *D. kuriphilus* in Piemonte and Liguria Regions starting from the area where *D. kuriphilus* was reported for the first time reported (the red dot represents the centroid of this area in the Cuneo Province, Piemonte). Below is represented the distance from the centroid covered the front of expansion by SDD from 2002 to 2009. The observations are linearly interpolated and the slope of the curve represents an estimation of the parameter *c*

3.3. Analysis of Long Distance Dispersal (LDD)

As mentioned above, few cases document events that gave rise to LDD. In most cases, we are forced to adopt the operational definition of LDD proposed here. Accordingly, a dispersal event at time *t* is considered LDD when results into a colonization of a new area at time *t* +1 through the formation of a new centre of infestation. The new area has to be completely separated from the source area (the centre originating the LDD event).

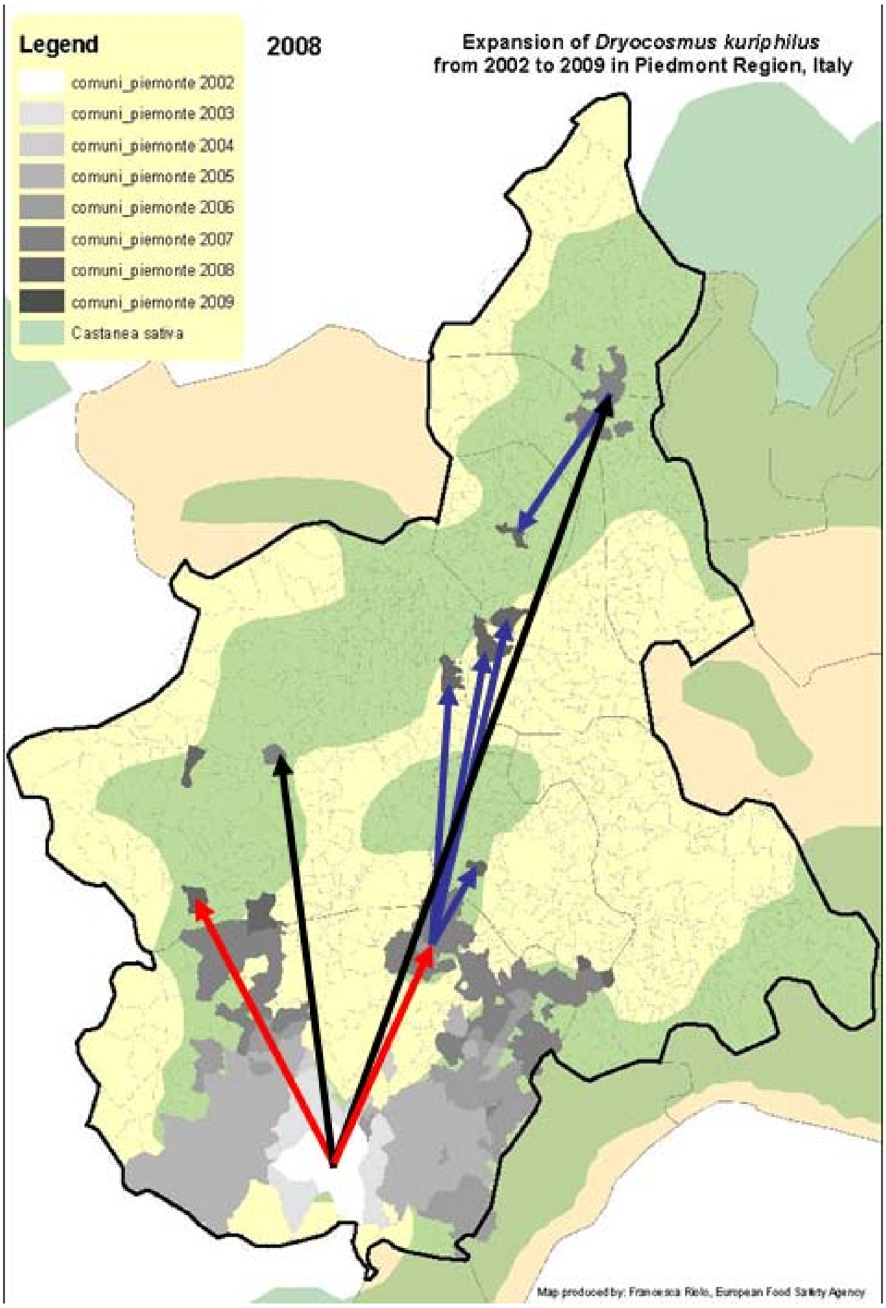


Figure C12: Characterization of LDD events. The method is based on a combination of information (black arrows) and a multi-stage process of dispersal (red and blue arrows). When no information is available, new infested centre (isolated patch at time t+1) are generated by the nearest colony established at least in the previous year (at time t). Each isolated colony becomes a centre for the origin of new LDD events and SDD

Information on the spatio-temporal distribution of *D. kuriphilus* in all the Italian Regions and the available knowledge on the origin of the colonizing individuals (normally associated to the movement of infested material) enabled the following analyses to be carried out.

1) The identification (discrimination) of the events interpreted as LDD and the measurements of the travelled distances per LDD event (Fig. C12.). The following procedures can be applied:

(i) Information on the origin of the infested material allows the direct measurement of travelled distance. This is measured on the segment that links the centroid of the source centre at time *t* with centroid of the new infestation centre appearing at time *t* +1. The travelled distance *d* (units: km) is measured between the front of the source and the centroid of the new centre;

(ii) If no information on the source of infested material is available, the process of LDD is interpreted as follows. The first centre of colonization in a Region is considered to be originated from infested material imported from Piemonte, by convention from the area of the first infestation in the province of Cuneo (where, among other, are the most chestnut nurseries in Italy). Subsequent LDD events in the same Region are assumed originating from the centre of the nearest infested area (not necessarily belonging to the same Region). The distance is measured as in (i).

2) The representation of the frequency distribution of the travelled distances per LDD event. This discrete data set (with classes of 50 km in dimension) is then interpolated by an empirical continuous frequency distribution of the lengths *d*;

3) The definition of the average number λ of LDD events per time unit per infestation centre (1/year).

A total number of 90 LDD events have been identified, although this probably represents an underestimation of the real number of LDD, as many events are probably not detected because of the low spatial resolution of the data.
The results obtained are reported in Fig. C13. The most frequent travelled distance is within 50 km, the mean distance is $d = 180.6$ km. The distribution is then interpolated by means of a Gamma distribution, in particular the distance of a new infestation centre is a random variable *D* with gamma density

$$f(d) = \frac{1}{\beta^{\alpha}\Gamma(\alpha)} d^{\alpha-1} e^{-\frac{\alpha}{\beta}} \qquad [3.1.]$$

where α is the shape parameter and β the scale parameter. In our case $\alpha = 1$ and $\beta = 60$. In the model LDD directions are generated randomly from uniformly distributed over $[0, 2\pi]$.

As for the frequency of LDD, an estimated number of 1.9 events per infestation centre per year is obtained considering long distance dispersal as a deterministic process. However, given that the LDD is highly stochastic and probably many LDD events were not detectable because of the spatial resolution of the data available, a different estimation procedure is followed. LDD are stochastic events described by a Poisson process, the number of LDD events generated from each infestation centre in a given year is a Poisson random variable with

$$P(M = m) = e^{-\lambda}\left(\frac{\lambda^{m}}{m!}\right) \qquad [3.2]$$

where λ is the mean number of LDD events per year. The value of $\lambda = 2.5$ is obtained as the one that minimize the difference between the colonized area reported by the extension services and the colonized area in the simulations.

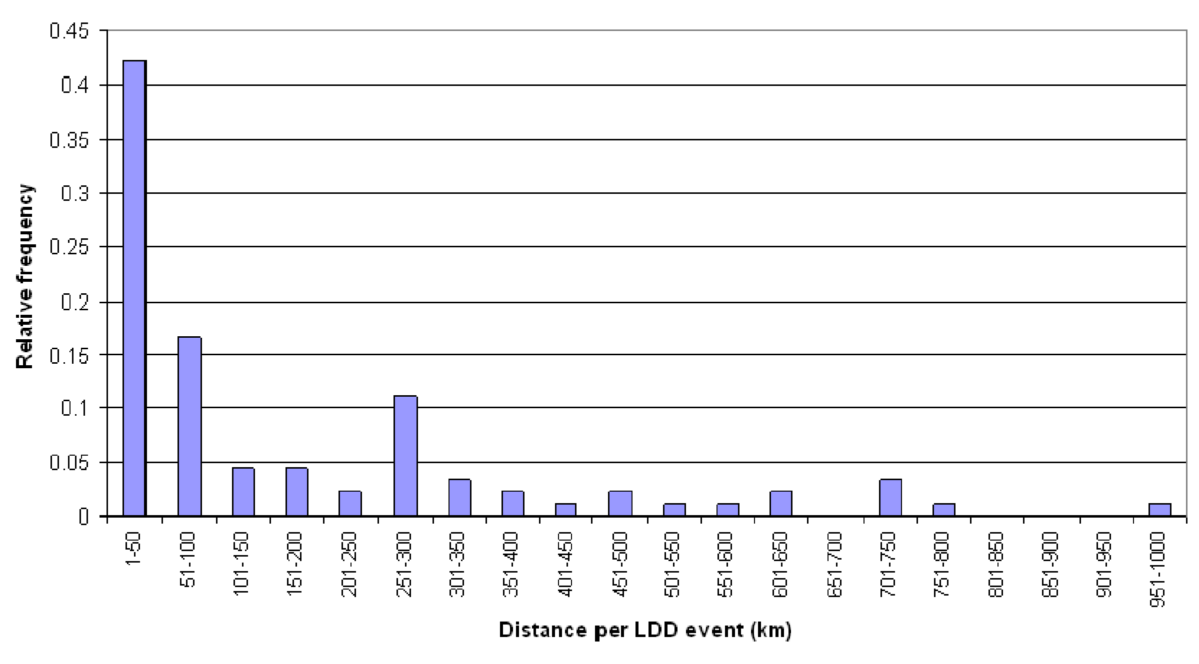


Figure C13: Frequency distribution of LDD events observed in Italy in the period 2002-2009 as function of discrete classes of travelled distance per event (the distances are grouped in 50 km class)

3.4. Estimation of other biological parameters

To apply the model described above, it is necessary to estimate the population finite growth rate R_0, the random diffusion parameter σ, the mean speed *c* of the travelling front of dispersal and the mean of the probability that the new colony establishes in the cell (that depends on parameter p_s).

The parameter σ can be obtained through the approximation formula for the speed of invasion (van den Bosch et al., 1990), suitable for small R_0 and, in case of a Gaussian contact distribution, also for large R_0:

$$c = \frac{\sigma}{\mu}\sqrt{2\ln\left(R_0\right)}\left\{1+\left[\left(\frac{v}{\mu}\right)^2 - \beta + \frac{1}{12}\frac{\gamma}{\sigma^4}\right]\ln\left(R_0\right)\right\} \qquad [3.3.]$$

where μ is the mean age at oviposition, v^2 is the variance in the age at oviposition, γ the kurtosis for the dispersal kernel and β a measure of the interaction between reproduction and dispersal (see also Hemerik et al., 2004). To estimate the parameters R_0 and *A*, we consider only the short distance dispersal. As in Hemerik et al. (2004) we adopt the simplifying assumption that $\beta = 0$.

Since *D. kuriphilus* is a semelparous species (i.e. oviposition occurs once in the life cycle), we suppose that $\mu = 1$, that is the mean age at oviposition is set equal to the duration of one generation. Moreover, due to the short reproductive period in the adults we assume the variance of the age at oviposition zero.

In the case of normal dispersal kernel $\gamma = 3\sigma^4$, therefore, equation [3.3.] can be rewritten as

$$c = \sigma\sqrt{2\ln(R_0)}\left\{1 + \frac{1}{4}\ln(R_0)\right\}. \qquad [3.4.]$$

Parameter R_0 can be estimated considering both an individual-based or life-history-based approach and a population-based approach (estimating model parameters via, for example, a non-linear fitting procedure).

At individual level R_0 can be interpreted as the product between the female fecundity, the finite egg survival rate and the juvenile finite survival rate. Data on survival and fecundity of *D. kuriphilus* are available in literature (Cooper and Rieske, 2007; Kato and Hijii, 1993, 1999, 2001). However many inconsistencies arise in the reported estimation, they mainly depend on the role assigned to parasitoid induced mortality in pre-imaginal stages and to the real fecundity of the female. In fact, in *D. kuriphilus* adult survival during migration would be relatively low because of predation or risk of dispersion from the host plant by the wind (Kato and Hijii, 1993). Considering a mean fecundity rate of 100 (Kato and Hijii, 1993) and a mean survival rate of immature of 0.5 (Cooper and Rieske, 2007) we obtain an estimation of $R_0 = 50$. At population level this value leads to an unrealistic and very fast population growth, local population with initial percentage of infestation of 0.01 % can reach the 92 % of infestation after only 2 years and the 99.8 % of infestation after 3 years. Considering different estimation obtained from different fecundity and survival data reported in literature R_0 is in the interval between 30 and 50.

Population approach is constrained by the very scarce population dynamics data availability. Data on population growth are reported by Gyoutoku and Uemura (1985) in two different Japanese regions lead to an estimation of $R_0 = 1.29$ and $R_0 = 1.53$ by means of a non-linear fitting procedure. Both the values are much less than the estimates obtained considering life history parameters, partially because the *D. kuriphilus* populations are under the parasitoids control in the area surveyed.

Many experiences on the population growth in newly colonized areas in Italy, where an important control by parasitoids can be excluded, seem to follow a common pattern than can be useful for obtaining more realistic estimation in condition of limited natural control. According to these observations made by personnel of regional extension services, the pest population reach considerable level of infestation in an average period of 4 years (Giovanni Bosio, personal communication, 2010). Starting from low level of infestation (conveniently set at 0.01 %) with $R_0 = 7.83$ the population reaches 75 % of infestation in 4 years and 95 % in 5 years. These infestation levels appear to be realistic and support an estimation of R_0 as the one previously calculated.

From the parameters $R_0 = 7.83$ and $c = 8.08$ and the eq. [3.4.] the value of $\sigma = 2.6$ is obtained.

The parameter p_s is expresses ad dependent on the distance travelled by dispersal individuals.

4. Model validation and projections

4.1. Model validation

To test the goodness of the model for the spatio-temporal dynamics of *D. kuriphilus*, numerical simulation of the expansion of *D. kuriphilus* in Italy have been performed. The model simulated the invasion starting from the initial condition in 2002 in Piemonte up to 2009. Model parameters have been estimated in sections 3.2, 3.3, and 3.4.

Due to the lack of information on the real pattern of LDD the formation of new infestation centres is considered as a random process in the model. This makes the comparison between the observed and simulated colonized area over time the most important indication of quality and reliability of the simulation. In the phase of expansion in a new territory the area occupied by an invasive species depends on the pattern of dispersal. In the case of stratified dispersal the typical pattern is an exponential growth of the area over time (Shigesada et al., 1995). As the area available decreases and approaches 0 the colonization rate (area/time) also diminishes and the colonized area reaches the maximum (with a logistic-like pattern).

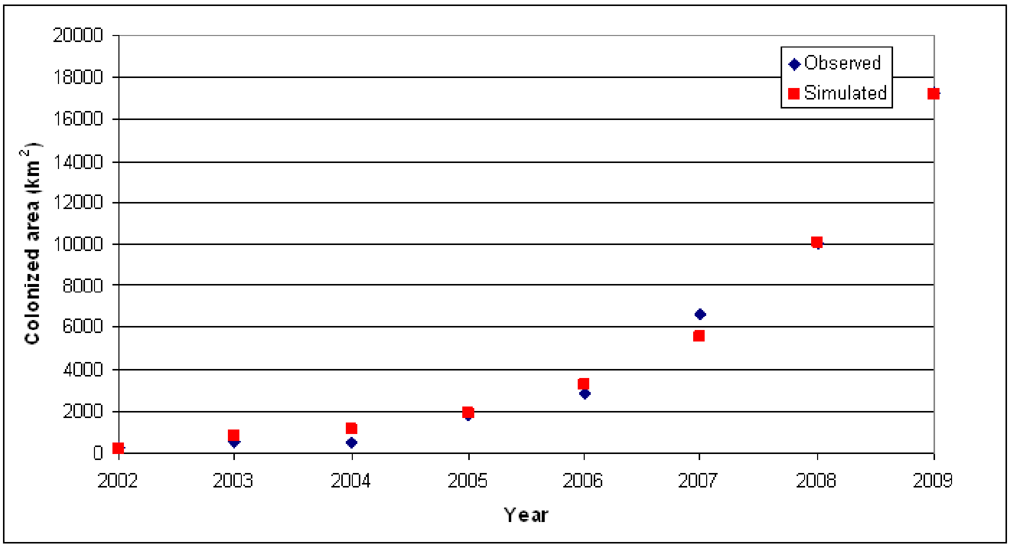


Figure C14: Observed (blue) and simulated (red) area colonized by *D. kuriphilus* in Italy from 2002 to 2009. Simulated data are obtained by model [2.3.] adding long distance dispersal. Initial condition corresponds to the area occupied by *D. kuriphilus* in 2002

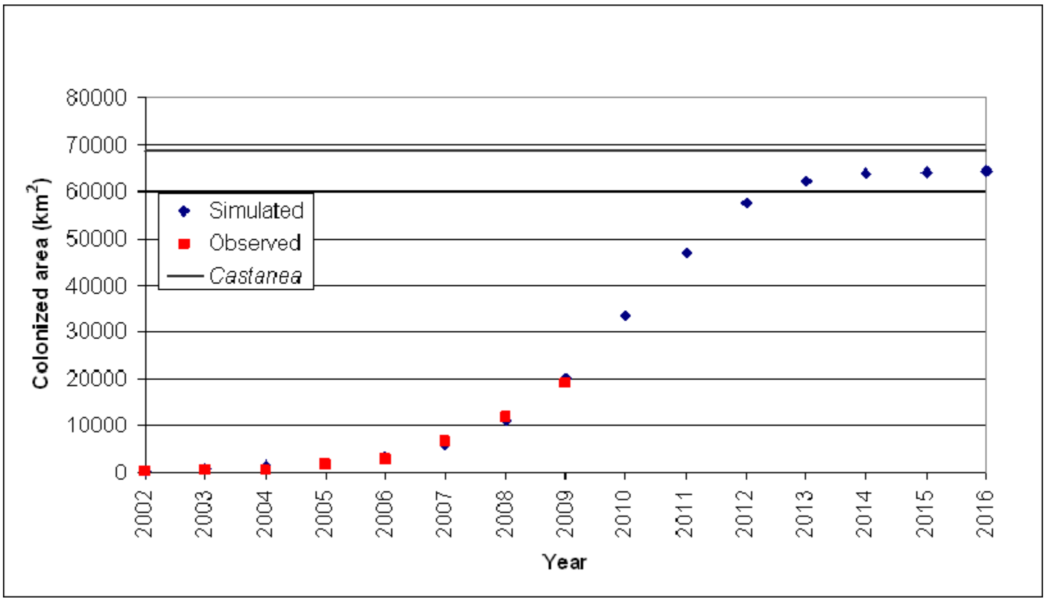


Figure C15: Projection of the area covered by *Castanea* colonized by *D. kuriphilus* in Italy for the period 2010-2017. Simulated data are obtained by model [2.3.] adding long distance dispersal and considering as initial condition the area colonized in 2009 and M = 2.5 equal to the one used during the period 2002-2009. The horizontal line represent the total area covered by chestnut trees in Italy

In the case of *D. kuriphilus* the process of expansion is not-linear and this non-linearity can be explained only by LDD and stratified dispersal (see the blue points in Fig. C14.). In particular, we the are facing the exponential phase of expansion of the colonized area. The model performances are considerably good, simulated data are in close agreement with observations (Fig. C14.).

4.2. Model projections

The pattern of increase shown in Fig. C14. allows us to predict a further growth of the colonization rate and a dramatic increase of the invaded area. In Fig. C15. is reported projection of the colonized area for the period 2010-2016. Simulations have been performed starting form the observed distribution in 2009 and under the assumption of constant LDD parameters. As expected the colonization proceeds according a logistic curve and, provided that all the parameter remain constant, the future scenarios will see *D. kuriphilus* able to colonize the entire suitable area in few years (Fig. C15.). The area colonized increases at a rate of about 15000 km^2/year, that this rate diminishes the area approaching the maximum colonisable area (i.e. the area covered by *Castanea* that is equal to 68641 km^2).

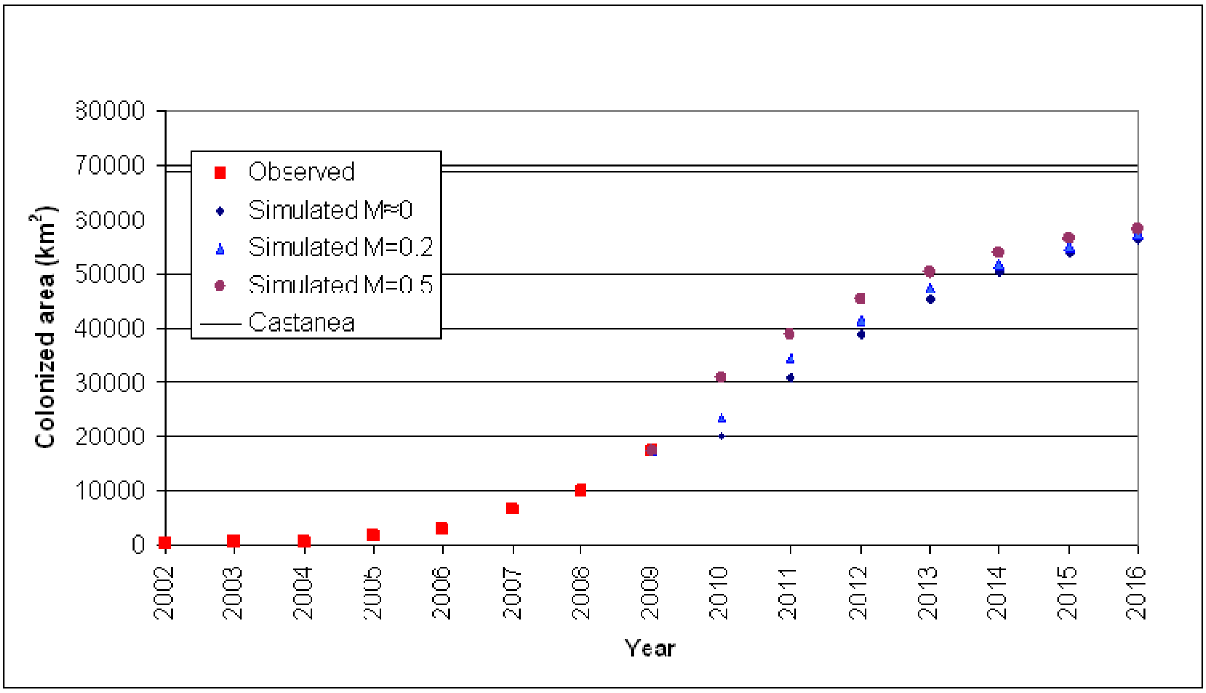


Figure C16: Projection of the area covered by *Castanea* colonized by *D. kuriphilus* in Italy for the period 2010-2016. Simulated data are obtained by model [2.3.] adding long distance dispersal and considering as initial condition the area colonized in 2009 and $M \approx 0$, $M = 0.2$, $M = 0.5$. The horizontal line represent the total area covered by chestnut trees in Italy

LDD is expected to be a key factor in determining the potential for expansion of the pest, as demonstrated by the history of pest invasions including Italy. To better understand the role of LDD a sensitivity analysis on LDD parameter has been conducted. In Fig. C16. is reported the simulated trend of colonized area obtained using the same Gamma distribution [3.1.] as for simulation in Figs. C14. and C15., and with parameter $M \approx 0$ (no contribution of LDD), $M = 0.2$, $M = 0.5$ for the Poisson distribution [3.2.]. Values of *M* are selected to account for future scenarios in which management of *D. kuriphilus* spread drastically reduce the rate of LDD, but do not substantially change the contribution of SDD.

The results (Fig. C16.) show, as expected, a reduction in the rate of colonization, from an initial spread well colonized area the contribution of LDD decreases in its importance because most of the LDD events fall into already colonized area, and b) the major contribution to the colonized area progressively becomes the SDD, and differences among the three simulations gradually appear unimportant.

The simulated spatial distribution for *D. kuriphilus* obtained for the period 2002-2009 is reported in Fig. C17. The spatial location of colonized area in 2009 in detailed in Fig. C18.

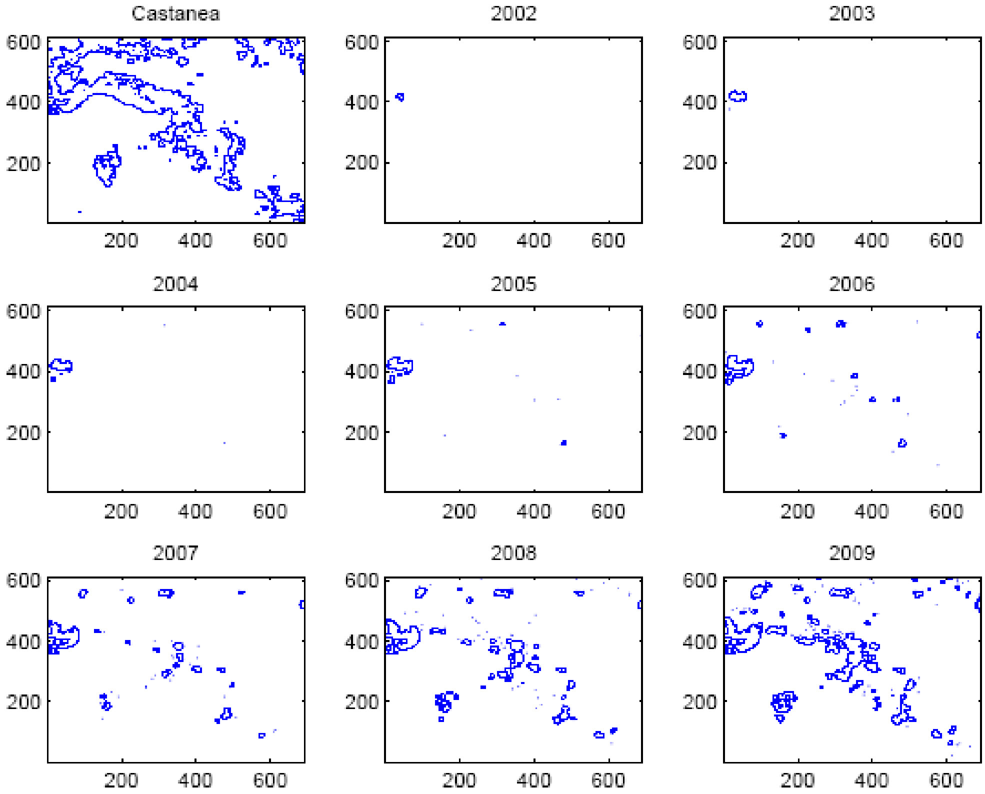


Figure C17: The spatio-temporal dynamic of the simulated *D. kuriphilus* distribution in Italy. The first picture upper-left is the distribution of *Castanea* in Italy. Initial condition is the distribution of *D. kuriphilus* observed in the municipalities of Boves e Pevaragno (Cuneo Province) in 2002

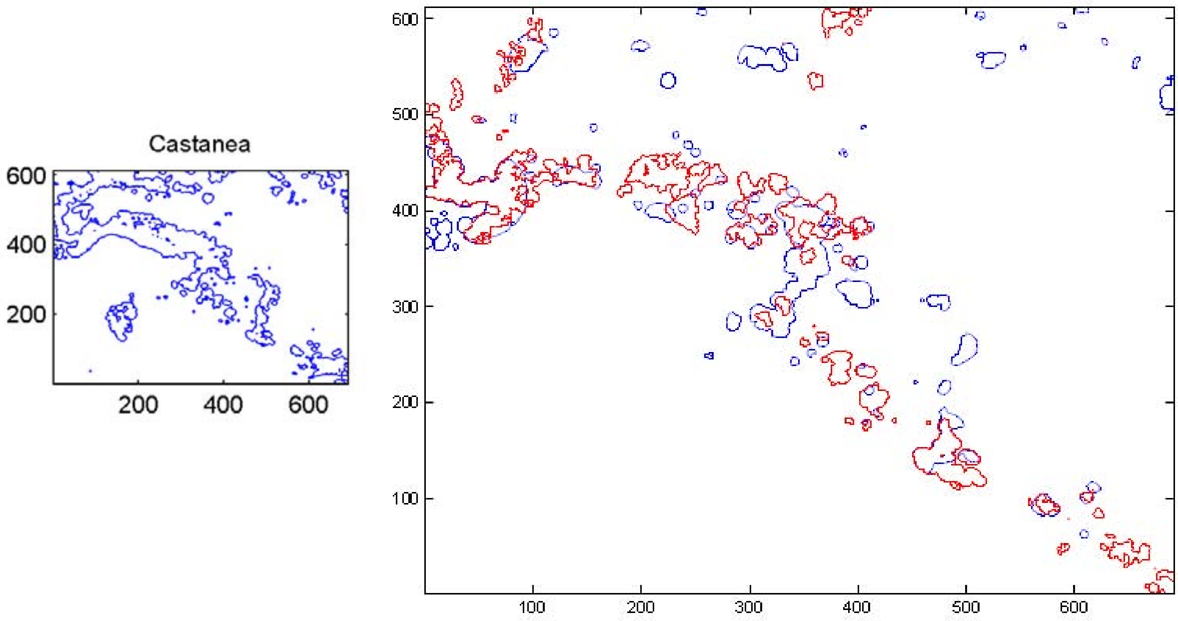


Figure C18: On the left, the distribution of *Castanea* in Italy. On the right, comparison between observed spatial occurrence of *D. kuriphilus* in Italy (red) and the simulated distribution (blu) in the year 2009. Initial condition is the distribution of *D. kuriphilus* observed in the municipalities of Boves e Pevaragno (Cuneo Province, Piemonte) in 2002

In Fig. C19. projections of the total area colonized by *D. kuriphilus* in Europe are indicated, using the same assumptions as for the Italian case, i.e. unchanged Gamma distribution and *M* considered as variable in the sensitivity analysis ($M \approx 0$, no contribution of LDD, and $M = 0.2$ and $M = 0.5$ to account for different frequency of LDD events). Simulation for Europe does not consider higher values of *M*, provided that phytosanitary measures could control most of the events leading to LDD.

Simulated dynamics of colonization reveals important differences from the observed case in Italy. The significant change in the spread observed in the first period of projection can be attributed mainly to the diffusion process occurring in Italy. Only in the second period of simulation, when Italian contribution to the colonized area is less important, the role of M becomes more visible. In fact for $M \approx 0$ colonization proceeds slowly with linear-like patter. In the last years for $M > 0$ the increase in the spread rate is recognizable in a exponential growth trend, even if at the initial phase.

As an important remark, model projections for the period 2010-2016 depend on the initial conditions defined in the model. As stated in section 3.1.2. at the time of model simulation, data from France, Switzerland and Slovenia were not available in the format suitable for the model. The exclusion of an already colonized area in these counties affects the initial condition as well as model outputs. This could result in a slight underestimation of the colonized area.

In Fig. C20., C21., C22. the projected spatial distribution of *D. kuriphilus* are shown for the cases $M \approx 0$, $M = 0.2$ and $M = 0.5$ respectively.

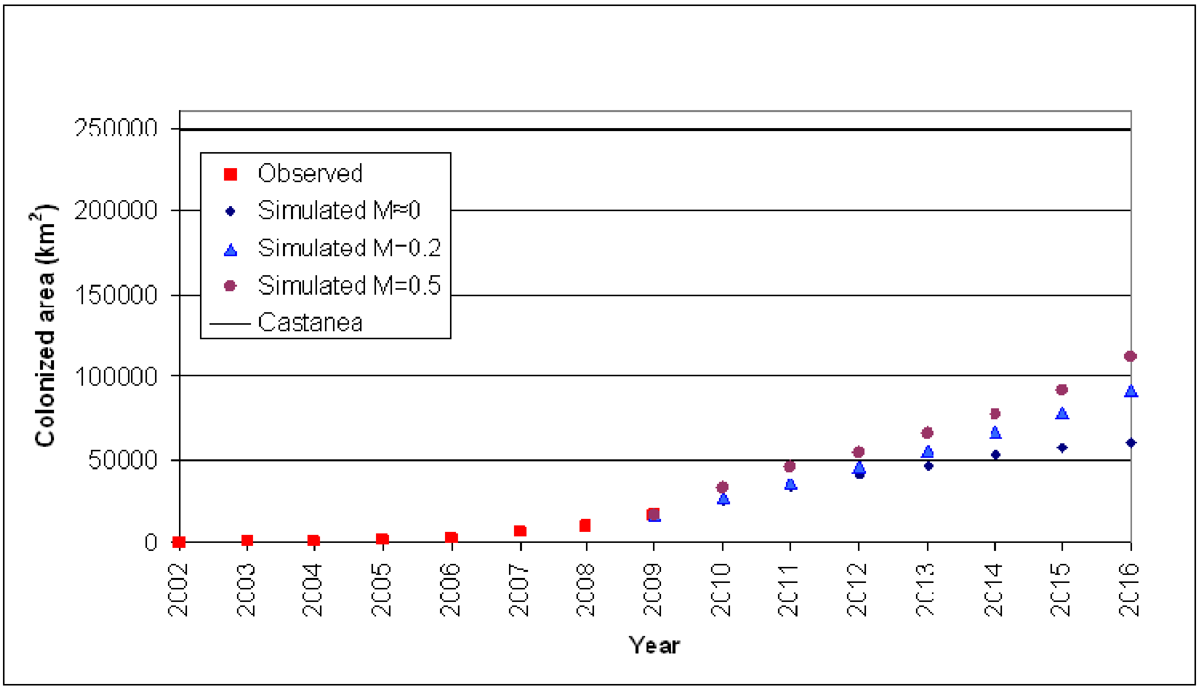


Figure C19: Projection of the area covered by *Castanea* colonized by *D. kuriphilus* in Europe for the period 2010-2016. Simulation has been performed considering as initial condition the distribution of *D. kuriphilus* during 2009. Model [2.3.] has been used and to account for different contribution of LDD the trend of colonized area are obtained for $M \approx 0$ (no contribution of LDD), $M = 0.2$, $M = 0.5$. The horizontal lines represent the total area covered by chestnut trees in Europe

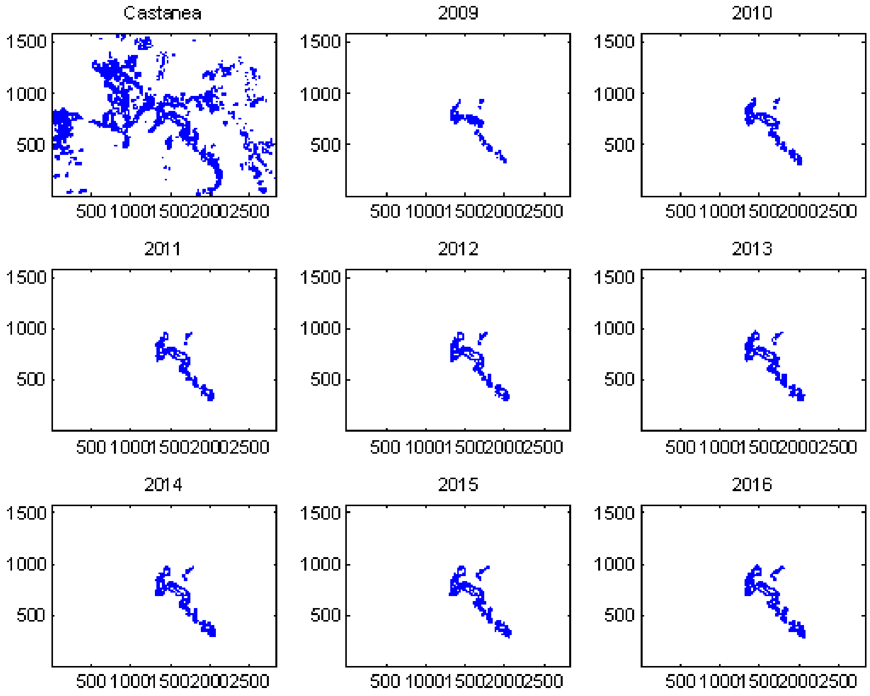


Figure C20: Projection of colonized area in Europe with $M \approx 0$ for the period 2010-2016

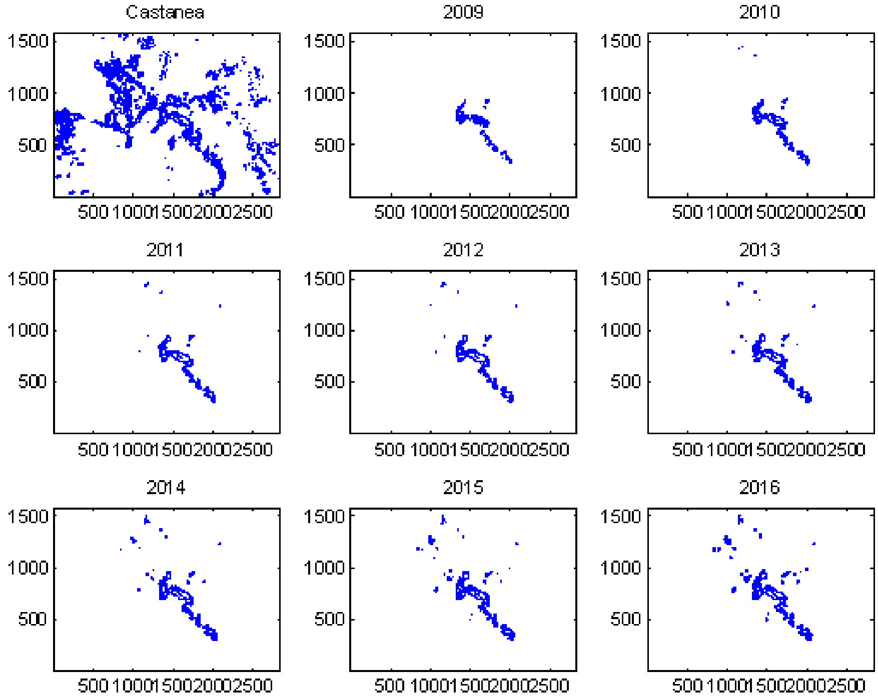


Figure C21: Projection of colonized area in Europe with *M* = 0.2 for the period 2010-2016

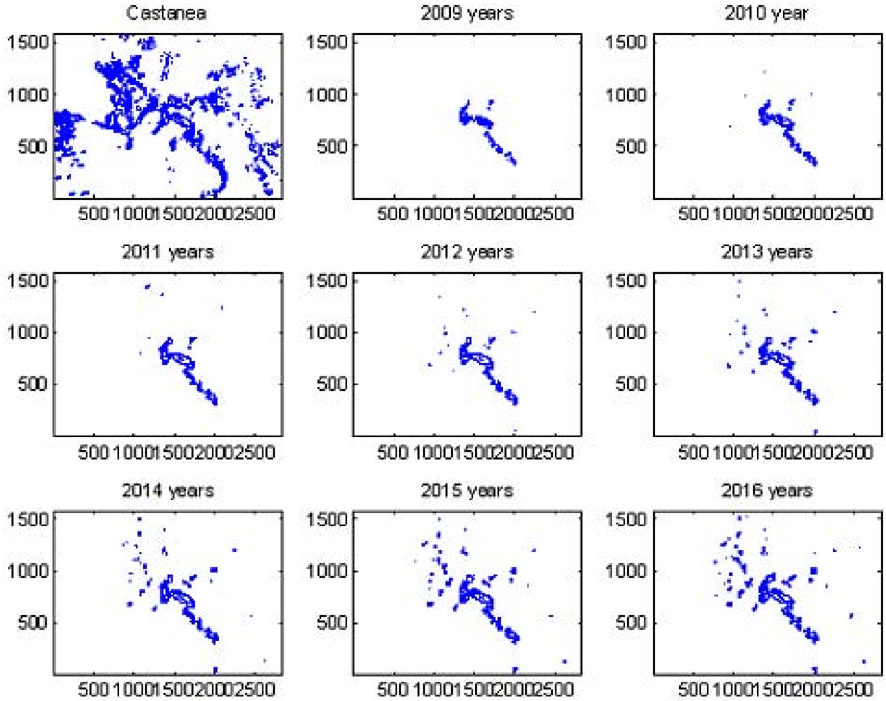


Figure C22: Projection of colonized area in Europe with *M* = 0.5 for the period 2010-2016

5. Implications for management

5.1. Evaluation of spread potential

The data available show that colonization of Italy is in an advanced phase, approximately at 1/3 of the total area covered by chestnut tree (Fig. C15.), and is continuing at a significant rate. Projections obtained by the model and reported in Figure C15. show that if the contribution of the LLD holds steady (i.e. the distribution of travelled distance and the parameter *M* remain the same as in the period 2002-2009), the colonized area will increase with an exponential pattern in the coming years. In three years (2012) it is expected that colonized area can reach about 60000 km^2, about 85 % of the *Castanea* in Italy. In the following years the pattern of increase changes and decelerates towards the maximum area available (Fig. C15.). Different scenarios emerge if measure controlling LDD are implemented, as shown by the modification of the rate of increase of colonized area in Fig. C16.

The colonization of other European countries is primarily limited to areas near the Italian border (France, Switzerland and Slovenia). In all the reported cases of infestation events in these three counties it appears that the colonization was human-assisted, probably through transportation of contaminated plant material from Italy resulting in new centres of infestation by LDD. The important contribution of SSD in *D. kuriphilus* spread and the limited role of LDD is further illustrated by the low rate of increase of the colonized area in these three countries (Fig. C8.)

Based on the *D. kuriphilus* spatiotemporal population dynamics observed in context where the contribution of LDD after the initial colonization is limited, as observed in France, Slovenia, and Switzerland, and the scenarios obtained in model projections under different *M* it can be proposed that:

a) the probability of expansion of *D. kuriphilus* in Europe outside Italy is high;

b) the colonization of Europe, if based on SDD alone ($M \approx 0$), is expected to proceed at a very low rate (se Fig. C19.), with a mean rate of about 6000 km^2/year (see also Fig. C20., showing how the contribution of infested area in Italy over the entire European colonized area remains substantial);

c) as far as the contribution of LDD increases it is expected an increase in the colonization rate as shown in Fig. C19. The rate of colonization is proportional to the parameter *M*. In fact the mean rate of increase in colonized area reaches 10,000 km^2/year for $M = 0.2$ and 13000 km^2/year for $M = 0.5$.

5.2. Demarcated zones for risk management

The estimation of SDD derived by the analysis described can assist in definition of demarcated zones e.g. for pest surveillance. Human- assisted dispersal by movement of planting material is unbounded (see section 3.3. and Fig. C13.) and the pest could create new foci of infestation separated by pest-free areas. Long distance dispersal is not included in consideration of demarcated zones.

According to the dataset used for parameter estimation and model simulations, *D. kuriphilus* can disperse randomly and continuously over space from the focus zone into the surrounding area at an average rate 8 km/year (parameter *c* in Eq. [3.4.]), with a variation comprises in a range of 3-12 km/year (see Fig. C10.). The distribution in Fig. C10. can be interpolated with a truncated Normal distribution. Some remarks:

- Because of the spatial resolution of the data, values of the classes lower than 3-4 km/year are not reported but they can certainly be considered as occurring in the dynamics of *D. kuriphilus* local dispersal over continuous space;
- Properties of the truncated Normal distribution allow higher values of continuous rate of diffusion on the right tail of the curve, even if with low probability;

- Many cases of a hidden LDD (even if at short range) are likely to be present, even if they were not detected because of the spatial resolution of the data. This hidden LLD modifies and the mean and variance of the speed of the front, probably increasing them.

6. Acknowledgements

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APPENDIX D

Supplementary data regarding area and production of *Castanea* in the EU territory

FAOSTAT data

	Harvested area (ha)											
	FAOSTAT | © FAO Statistics Division 2010 | 05 February 2010											
	2003		**2004**		**2005**		**2006**		**2007**		**2008**	
Country												
Albania	150	**F**	150	**F**	150	**F**	150	**F**	150	**F**	150	**F**
Bulgaria	35	**F**	25		25	**F**	25	**F**	25	**F**	25	**F**
France	7264		7264		7289		6967		6965		6992	
Greece	8760		8904		8938		9026		10600		10600	
Hungary	641		600		606		457		684		684	**F**
Italy	23500	**F**	23500	**F**	24000	**F**	24000	**F**	25000	**F**	25000	**F**
Portugal	29885		30227		30276		30265		30300		30300	**F**
Romania	20	**F**	17		20	**F**	3		2		2	
Russian Federation	4000	**F**	3500	**F**	3700	**F**	3800	**F**	4000	**F**	4000	**F**
Slovenia	10		11		11		11		5		5	
Spain	11237		6254		5846		6134		9523		9523	**F**
Turkey	37200		37800		37800		37260		39000	**F**	40000	**F**

F = FAO estimate

EUROSTAT data

	Chestnuts - Area of production (1,000 ha)						
	DS-072421-Fruits and vegetables (annual data) Extracted on 09-04-2010 15:47:32						
	2003	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
Country							
Albania	:	:	:	:	:	:	:
Austria	:	:	:	:	:	:	:
Belgium	:	:	:	:	:	:	:
Bosnia and Herzegovina	:	:	:	:	:	:	:
Bulgaria	0.0	0.0	0.0	0.0	0.0	0.0	:
Croatia	:	:	:	:	:	:	:
Cyprus	:	:	:	:	:	:	:
Czech Republic	:	:	:	:	:	:	:
Denmark	:	:	:	:	:	:	:

Estonia	:	:	:	:	:	:	:
Federal Republic of Germany (excluding ex-GDR)	:	:	:	:	:	:	:
Finland	:	:	:	:	:	:	:
Former Yugoslav Republic of Macedonia, the	:	:	:	:	:	:	:
France	7.3	7.3	7.3	7.2	7.0	7.0	:
Germany (including ex-GDR from 1991)	:	:	:	:	:	:	:
Greece	10.7	10.0	9.5	9.5	10.6	10.6	:
Hungary	0.6	0.6	0.6	0.5	0.7	0.8	
Iceland	:	:	:	:	:	:	:
Ireland	:	:	:	:	:	:	:
Italy	:	:	:	:	:	:	:
Latvia	:	:	:	:	:	:	:
Lithuania Luxembourg (Grand-Duché)	:	:	:	:	:	:	:
Malta	:	:	:	:	:	:	:
Netherlands	:	:	:	:	:	:	:
Norway	:	:	:	:	:	:	:
Poland	:	:	:	:	:	:	:
Portugal	29.9	30.2	30.2	30.3	30.3	30.4	30.4
Romania	:	0.0	0.0	0.0	0.0	0.0	:
Slovakia	0.0	0.0	0.0	0.0	0.0	0.0	:
Slovenia	0.0	0.0	0.0	0.0	0.0	0.0	:
Spain	:	:	:	:	:	:	:
Sweden	:	:	:	:	:	:	:
Turkey	8.8	8.9	9.0	9.0	10.2	10.0	:
United Kingdom	:	:	:	:	:	:	:

ISTAT data

Table 13.12 - Use of the wood, for assortment and species – Year 2006 (*cubic metres*)

	Timber							Wood fuel	Total
	Building logs	Veneerlogs	Logs to be peeled	Sawlogs	Pulpwood (round and split)	Other industrial roundwood[a]	Total		
TOTAL									
Chestnut	220548	8110	3739	77784	73239	163284	546704	417521	964225
Total	451287	193065	351784	762912	809534	495218	3063800	5656332	8720132
FORESTS									
Chestnut	210644	7954	3464	75339	69819	151708	518928	390682	909610
Total	418733	63780	257285	640549	645359	461001	2486707	5141402	7628109
OUT OF FORESTS									
Chestnut	9904	156	275	2445	3420	11576	27776	26839	54615
Total	32554	129285	94499	122363	164175	34217	577093	514930	1092023

***Source:* Istat, wood fellings and removals from forest**

(a): It includes also timber for boards and shingles

Table 13.4 - Forest surface by ISTAT altimetric zone, lands ownership category and type of forest - Year 2004 *(hectares)*

TYPE OF FOREST	Altitudinal horizons			Total	Categories of land ownership			
	Mountain	Hill	Plain		State and Regions	Municipalities	other bodies	Private
Chestnut	*211158*	*60967*	*3669*	*275794*	*3063*	*11123*	*8178*	*253430*
Of which: for fruit	*160899*	*45189*	*3202*	*209290*	*1265*	*8216*	*6086*	*193723*
High forest	2075697	700454	197223	2973374	288468	1106866	162977	1415063
Coppice	1587190	1163636	83036	2833862	156,653	572915	158041	1946253
Coppice-with-standards	386189	363847	33592	783628	37007	159619	28267	558735
Maquis shrubland	26686	205149	34370	266205	29872	37247	3676	195410
TOTAL	4075762	2433086	348221	6857069	512000	1876647	352961	4115461

Source: Forest surface for altitudinal horizons (afforestation, deforestations, reforestation) - Statistical Yearbook 2006

Table 13.20 - Forest surface by ISTAT altimetric zone, lands ownership category and type of forest - Year 2005 *(hectares)*

TYPE OF FOREST	Altitudinal horizons			Total	Categories of land ownership			
	Mountain	Hill	Plain		State and Regions	Municipalities	other bodies	Private
Castagno	*39820*	*17178*	*881*	*57879*	*10551*	*32459*	*1815*	*13054*
Of which: for fruit	*49674*	*49898*	*5149*	*104721*	*7083*	*36890*	*5930*	*54818*
High forest	2076104	701578	197670	2975352	288638	1106958	162998	1,416758
Coppice	1587136	1163616	83030	2833782	156653	572911	158029	1,946189
Coppice-with-standards	386176	363840	33591	783607	37007	159617	28267	558716
Maquis shrubland	26686	205182	34370	266238	29874	37247	3676	195441
TOTAL	4076102	2434216	348661	6858979	512172	1876733	352970	4117104

Source: Forest surface for altitudinal horizons (afforestation, deforestations, reforestation) - Statistical Yearbook 2007

ISTAT data (continued)

Table 8 – Total wood utilization – Years 1996-:-2007
(Amount in thousands of square meters and value in thousands of euro)

YEARS	Amount	Value	Average price (€ / Kg.)
Average 1996 -:- 2000	**994,9**	**46069**	**46,3**
2007	831,8	54392	65,4
Average 2001 -:- 2007	**118,8**	**57116**	**62,1**
Source: Elaboration on ISTAT data – Forests statistics			

Table 3 – Division coverage of chestnut orchards - Year 2007
(hectares)

	Fruit production area					
	Productive orchards		Abandoned orchards		Total	
REGIONS	Absolute	%	Absolute	%	Absolute	%
Piemonte	5350,69	90,7	548,73	9,3	5899,42	100,0
Valle d'Aosta	221,29	94,4	13,08	5,6	234,37	100,0
Lombardia	1084,66	89,4	128,85	10,6	1213,51	100,0
Trentino Alto Adige	70,05	100,0	-	-	70,05	100,0
Bolzano-Bozen	*43,06*	100,0	-	-	*43,06*	100,0
Trento	*26,99*	100,0	-	-	*26,99*	100,0
Veneto	67,32	30,6	152,45	69,4	219,77	100,0
Friuli Venezia G.	4,49	100,0	-	-	4,49	100,0
Liguria	223,15	46,9	252,55	53,1	475,70	100,0
Emilia-Romagna	2223,18	99,2	19,03	0,8	2.242,21	100,0
Toscana	7823,85	87,4	1128,26	12,6	8952,11	100,0
Umbria	369,57	98,9	4,05	1,1	373,62	100,0
Marche	943,73	58,2	678,02	41,8	1621,75	100,0
Lazio	5228,34	90,7	535,02	9,3	5763,36	100,0
Abruzzo	21,18	100,0	-	-	21,18	100,0
Molise	-	-	-	-	-	-
Campania	13.286,75	97,3	371,43	2,7	13658,18	100,0
Puglia	10,48	97,4	0,28	2,6	10,76	100,0
Basilicata	180,19	22,1	634,81	77,9	815,00	100,0
Calabria	10727,71	93,1	789,53	6,9	11517,24	100,0
Sicilia	368,36	100,0	-	-	368,36	100,0
Sardegna	1156,85	79,9	290,25	20,1	1447,10	100,0
ITALY	49361,84	89,9	5546,34	10,1	54908,18	100,0
Northern	*9244,83*	89,2	*1114,69*	10,8	*10359,52*	100,0
Central	*14365,49*	86,0	*2345,35*	14,0	*16710,84*	100,0
Southern Italy	*25751,52*	92,5	*2086,30*	7,5	*27837,82*	100,0
Source: Istat - Farms structure survey.						

APPENDIX E

PRELIMINARY ENVIRONMENTAL RISK ASSESSMENT FOR *TORYMUS SINENSIS*, A POTENTIAL BIOLOGICAL CONTROL AGENT OF THE CHESTNUT GALLWASP, *DRYOCOSMUS KURIPHILUS*

TABLE OF CONTENTS FOR APPENDIX E

1. INTRODUCTION

D. kuriphilus is a member of the oak gall wasp tribe Cynipini, and is one of only two species in this tribe to induce galls on *Castanea* (Felt, 1940; Stone et al., 2002). In China, the country of origin of *D. kuriphilus*, this gall wasp is kept at low densities by naturally occurring biological control agents in several areas, although natural control is not equally effective everywhere, which can result locally in damage (Zhang et al., 2009). Because of successful natural control in parts of China, biological control of the gall wasp was considered by researchers in Japan, USA and Italy following the introduction of *D. kuriphilus*. In Japan, South Korea, the USA and Europe, many indigenous parasitoids attack *D. kuriphilus*, but attack rates of infested shoots were usually below 2 %; the only exception is one North American species, the generalist parasitoid *Ormyrus labotus* which attacks a higher percentage of chestnut galls (Aebi et al., 2006, 2007; Cooper and Rieske, 2007; Murakami et al., 1994, 1995; Ôtake et al., 1982; Payne, 1978; Stone et al., 2002). In Italy, sixteen parasitoid species have so far parasitized the newly appearing *D. kuriphilus*, but their attack rates of infested shoots remain low (< 2 %) (Aebi et al., 2007; Stone et al., 2002).

When releases were made of the exotic parasitoid *Torymus sinensis* Kamijo (Hymenoptera: Torymidae) after the introduction of the gall wasp into Japan and later into North America, populations of the gall wasp decreased to non-damaging levels and biological control appeared a very successful management strategy (Cooper and Rieske, 2007; Moriya et al., 2003). *T. sinensis* is univoltine like its host. Adults emerge from the withered galls in early spring and, after mating, the female lays eggs into newly formed galls, either onto the body surface of the host larva or on the wall of the larval chamber. The parasitoid larva ectoparasitically feeds on the mature host larva and pupates during late winter. Japanese researchers chose *T. sinensis* because it was the only Chinese species with a high host specificity and is phenologically well synchronised with *D. kuriphilus* in Japan. Moriya et al. (2003) report the gradual spread of *T. sinensis* in Japan from a release point in Tsukuba at a rate of less than 1 km/year, followed by more rapid spread of around 60 km/year in later years. At different locations it took from 6 to 18 years until the parasitoid controlled the pest effectively. Effective control implies that the pest population density remains under the damage threshold (Moriya et al., 1989; Murakami et al., 2001), which is suggested as 30 % shoot infestation (Gyoutoku and Uemura, 1985).

Similarly, after introduction of *T. sinensis* in the USA, it has moved with the expanding gall wasp populations in eastern North America (Cooper and Rieske, 2006, 2007; Rieske, 2007) and is reported to have reduced pest numbers.

Due to the successful use of *T. sinensis* in Japan, after the introduction of *D. kuriphilus* in Italy in 2002 and the development of damaging pest populations in chestnut orchards, *T. sinensis* was sourced from Japan and was released in Italy in 2005. Aebi et al. (2007) report that, after two years of trials that were unsuccessful due to early emergence of the imported *T. sinensis* relative to the development of its target in the field, 90 mated Japan-sourced *T. sinensis* females were released for the first time in the field in three localities in 2005 (Aebi et al., 2006). Their establishment was assessed by the collection and rearing of more than 9000 *D. kuriphilus* galls in these localities. In 2006, 1058 couples were released in 11 locations. The source material for these rearings was 25500 galls imported from Japan, producing more than 1660 individuals of a further four unidentified parasitoid species (currently being molecularly identified) in addition to *T. sinensis*: *Torymus* sp., *Eurytoma* sp., *Eupelmus* sp. and *Ormyrus* sp. To facilitate further releases of *T. sinensis*, a mass rearing attempt was initiated in tents containing young chestnut trees infested with *D. kuriphilus.* Mass rearing has been successful and is being continued currently to be able to support the release of the parasitoid at additional sites of chestnut gallwasp infestation in Italy. At two locations where *T. sinensis* was released, the percentage parasitism of *D. kuriphilus* galls increased from <1 % in the first year after release to about 25 % in the fourth year (Ambra Quacchia, University of Turin - Di.Va.P.R.A., personal communication, EFSA meeting in Parma, Italy, 15 September 2009). Although galls may contain more than one *D. kuriphilus*, and the actual percentage parasitism of *D. kuriphilus* is lower than the percentage parasitism of galls, the recent increase in percentage parasitism of galls is promising.

Biological control has the potential to be an effective management option to control the pest in chestnut-growing areas of Europe. However, the potential risks of the agent should be evaluated in order to identify potential negative effects on other organisms and the environment (Bigler et al., 2006). Here, a preliminary environmental risk analysis is presented based on a method specifically developed for natural enemies.

2. Environmental risk assessment of natural enemies and stepwise risk assessment procedure

Risk assessment procedures for biological control agents are usually characterized by questions on four issues:

1. Characterization and identification of biological control agent

2. Health risks

3. Environmental risks

4. Efficacy

The kind of information needed to evaluate these issues and information on the methods to be used to assess non-target effects are addressed in Bigler et al. (2006). Here, we will mainly concentrate on the third issue, the environmental effects, although issues relating to identification of the agent are also addressed in section 3, and efficacy in section 1. No health risks are recorded from hymenopteran parasitoids.

Recently, an environmental risk assessment method was developed consisting of a stepwise procedure which can be used for all types of invertebrate biological control agents in augmentative and classical biological control, for relevant species or biotypes whether they are native, established exotics or not yet established exotics (van Lenteren and Loomans, 2006; van Lenteren et al., 2006). The method is summarized in figure E1 and will be used to make a preliminary evaluation of the potential environmental risks of releasing the parasitoid *Torymus sinensis* in Europe.

T. sinensis is an exotic natural enemy although already established in Europe (question at **step 1**), thus we go to **step 2**. In Europe, the use of *T. sinensis* is proposed for inoculative releases with the goal to have the biological control agent established (a form of so-named classical biological control), so we do not consider **step 3** and go to **step 4** to address the host range of the parasitoid.

Determining the host range of a natural enemy is a complicated issue as it does not only influence conclusions on direct non-target effects, but also indirect non-target effects and potential changes in the functioning of an ecosystem. Such unwanted direct and indirect non-target effects can be dramatic (Louda et al., 2003), but most of the known cases of serious negative effects were caused by large polyphagous exotic predators that were not evaluated before release in new areas (van Lenteren et al., 2006). In this case, the proposed natural enemy for release in Europe to control the chestnut gallwasp is the hymenopteran parasitoid *T. sinensis*. These parasitoids are of small size (millimeters) and – when compared with predators – generally have a very limited host range, due to their special type of development which is often delicately synchronised with the development of the host (Godfray, 1994). Host range studies have been performed extensively during the past 40 years with good predictive results for natural enemies used in biological control of weeds (e.g. Wapshere, 1974). Kuhlmann et al. (2006) used the experience obtained in weed biological control to develop a method for selecting non-target species for host specificity testing of biological control agents aimed at arthropod pests, but this method has not yet been applied for the evaluation of new natural enemies.

Although it is stated in the Japanese literature (e.g. Murakami et al., 1977) that the parasitoid is host specific, these statements are not based on non-target host testing. Also the literature from North America does not provide any detailed information about host specificity of this parasitoid, though Cooper and Rieske (2009; The Nutshell, pp 12-14, June 2009) write that: "*T. sinensis* is a generalist parasitoid of cynipid gall wasps in China, but acts as a specialist on Asian chestnut gall wasp in Japan, and possibly North America… (Stone et al., 2002)." Zhang (2009), however, states that *T. sinensis* is monophagous.

Quacchia et al. (2008) provide the following information on host specificity: "Murakami et al., (1977) based on Askew (1975) described *T. sinensis* as host-specific but in practice its host range has not been clarified yet by complete scientific trials. The results obtained on *M. fagi*, *C. quercusfolii* and *A. kollari*, and the personal experience of S. Moriya who never reared, in Japan, *T. sinensis* from other galls than *D. kuriphilus* support the specificity thesis". The specificity (of *T. sinensis*) was checked according to the indication proposed by van Lenteren et al. (2006). The choice of non-target species was made among the galls present in the field in a stage suitable for oviposition. The only prone galls found (newly formed and big enough to let the parasitoid grow) were those of *Mikiola fagi* (Hartig). Due to their relative abundance, also galls of the agamic generation of *Cynips quercusfolii* (L.) and *Andricus kollari* (Hartig) were chosen. Five galls of each species were tested, a small portion of branch bearing the gall was placed in a small net cage. Mated females were used ten to twenty days after emergence. The behavioural components looked for were: encountering the host (i.e. making contact with the host by means of the antennae), drumming on the host (i.e. inspecting the host with the antennae) and drilling the host (i.e. adopting the oviposition posture and penetrating the host with the ovipositor). These behavioural components were observed continuously, starting when the female was introduced into the observation cage. The observations lasted 2 h, every day and for 10 consecutive days. After the observation period each female was isolated from the gall until the following trial. A positive control was performed using five galls of the target species *D. kuriphilus* obtained by potted chestnuts reared in glasshouse (in order to have fresh galls earlier than in the field). Females supporting and trials were performed at 15 °C. None of the females in contact with the galls of *M. fagi*, *C. quercusfolii*, and *A. kollari* showed the behavioural components looked for and no oviposition was registered; the positive control showed behaviours approaching those in the field, so trials were stopped and no direct effects on these non-target species are expected."

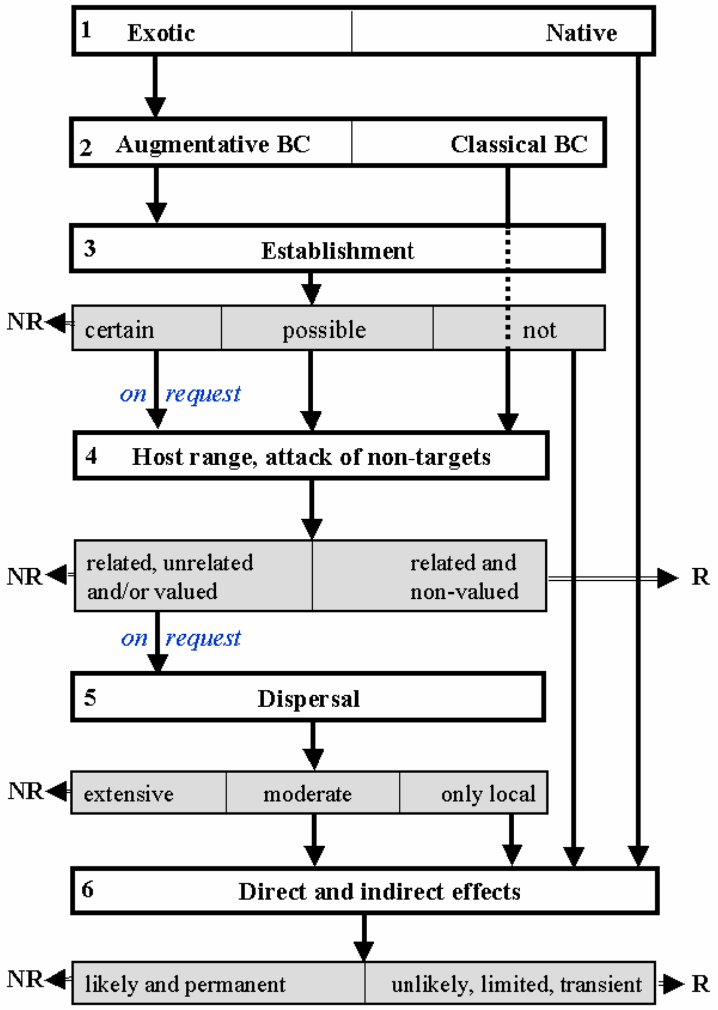

Figure E1: Simplified scheme of an environmental risk assessment of an invertebrate biological control agent. R = release seems not problematic; NR: release is not recommended (after van Lenteren and Loomans, 2006)

Based on information presented above, *T. sinensis* seems to be monophagous or highly oligophagous (i.e. has a very limited host range) and has not been reported to attack any other host species.

With regard to the dispersal of *T. sinensis* (**step 5** of the risk assessment scheme), the following information is available. According to Moriya et al. (1989) and Shiga (1996, 1999) the parasitoid is dispersing slowly (about 1 km year) during the first 5 years after establishment, but later, when larger parasitoid populations have developed, expansion has been observed at an average rate of 60 km per year (therefore per generation). Moriya et al. (2003) summarized the spread of *T. sinensis* from a release point in Tsukuba (Japan): "*T. sinensis* expanded its geographical range soon after its release. During the first few years the parasitoid spread gradually, at a rate of less than 1 km/year, followed by more rapid and accelerated spread in the next few years. In the spring of 1989, *T. sinensis* was detected in an area more than 12 km from the release site. Since then, a steady expansion has been observed at a constant rate of ca 60 km per year (= generation). Consequently, the parasitoids seem to have dispersed, by themselves, several hundred kilometers from the point of release." According to Quacchia et al. (2008): ".. although the time needed to establish the *T. sinensis* populations varied in different localities in Japan (Murakami and Gyoutoku, 1995), after about 6–18 years the parasitoid controlled the pest effectively, keeping its population under the damage threshold (Moriya et al. 1989; Murakami et al., 2001), fixed at a 30 % shoot infestation (Gyoutoku and Uemura, 1985)."

Based on current published information, one might conclude that the species is not expected to cause direct or indirect negative non-target effects and may thus, be suitable for release. However, the Panel has several concerns, among others about the published data identification of the parasitoid and on host specificity, which will be discussed in the following section.

3. Future work concerning environmental risk assessment related to releases in Europe

Reconsideration of the published data on natural enemies of *D. kuriphilus* and potential negative effects of releasing these natural enemies in new areas and consultation of experts resulted in the identification of several issues which need to be considered before large scale, Europe wide releases with these natural enemies can be advised. These are summarized below.

3.1. Confusing taxonomic situation concerning *T. sinensis*

Aebi et al. (2007) report on work in Korea and Japan has shown that *T. sinensis* is part of a taxonomically complex set of closely related species that are biologically diverse, but difficult to distinguish morphologically (Murakami, 1988; Yara et al., 2000; Yara, 2004). Native Korean parasitoids identified morphologically as *T. sinensis* can be divided into two ecotypes on the basis of their adult emergence periods (Murakami et al., 1995). The two ecotypes are thought to be derived from native oak cynipid hosts with differing phenology. Neither of these ecotypes was able to provide effective biological control of *D. kuriphilus*, due primarily to phenological mismatches in both strains between adult emergence and the development of galls of the chestnut gall wasp in the field (Murakami et al., 1995). Further taxonomic complexity in this group is derived from the ability of introduced Chinese *T. sinensis* to hybridize with a closely related species native to Japan, *T. beneficus*. Hybridization was suspected (Shiga, 1999) and in 1992, Moriya and colleagues successfully crossed *T. sinensis* and *T. beneficus* in the laboratory to produce fertile hybrid females. Hybrids were also detected in the field (Moriya et al., 1992, 2003; Yara et al., 2000) and molecular markers proved their hybrid origin (Izawa et al., 1996; Toda et al., 2000; Yara et al., 2000; Yara, 2004, 2006). Female morphology has been used in the past to distinguish *T. sinensis* and *T. beneficus*. The ratio of the ovipositor sheath length to the thorax length (O/T ratio) (Ôtake, 1987) in combination with the adult emergence time was used to identify the two species. *T. sinensis* has a larger O/T ratio than *T. beneficus* (Ôtake, 1987). *T. sinensis* females emerge later than *T. beneficus* females (5th to 23rd of April and 10th of March to 8th of April, respectively, Murakami, 1981). However, analyses by Yara (2004) using Cytochrome oxidase I sequence data (a marker widely used in molecular systematics; Caterino et al., 2000) have shown that the O/T ratio is an unreliable character in discrimination of *T. sinensis* and *T. beneficus*.Thus *T. sinensis* sourced from field populations in Japan may constitute a range of species, ecotypes and hybrids which cannot be reliably distinguished on the basis of morphological characteristics.

3.2. Risk of importing other parasitoid species

Aebi et al. (2007) mentions in relation to releases of *T. sinensis* in Italy in 2006: "The source material for these rearings was 25500 galls imported from Japan, producing more than 1660 individuals of a further four unidentified parasitoid species (currently being molecularly identified) in addition to *T. sinensis*: *Torymus* sp., *Eurytoma* sp., *Eupelmus* sp. and *Ormyrus* sp." This illustrates the potential risk of importation and release of species other than *T. sinensis* alone if a careful quarantine protocol is not followed (EPPO, 2001; ISPM No.3, IPPC, 2005).

3.3. Potential negative interaction with native parasitoid species

Cooper and Rieske (2009) suggest that negative interactions are evolving between the introduced *T. sinensis* and the indigenous *O. labotus*, a parasitoid species which has made a host shift from oak gallers to a chestnut galler.

3.4. Host range of *T. sinensis* in Europe

The host specificity of *T. sinensis* is a key aspect requiring further investigation of potential European host species as potential non-target hosts for this parasitoid. Quacchia et al. (2008) note host range tests undertaken on *Mikiola fagi, Andricus kollari, Cynips quercusfolii* to determine the host range of *T. sinensis*. However, the species selected may not be the most suitable to determine the host range of *T. sinensis*, because they are either phylogenetically far from the normal host gall wasps and/or their phenology is very different from *Dryocosmus* and are not in a suitable developmental stage for attack when ovipositing *T.sinensis* females search for hosts. Other species of non-target oak galls which may be more susceptible to attack during the period that *T. sinensis* females are searching for hosts should be used to further evaluate host specificity (e.g. *Andricus curvator* sexual generation; *Andricus cydoniae* sexual generation; *Andricus grossulariae* sexual generation; *Andricus inflator* sexual generatio; *Andricus lucidus* sexual generation; *Andricus multiplicatus* sexual generation; *Biorhiza pallida* sexual generation; *Dryocosmus cerriphilus* sexual generation; *D. cerriphilus* asexual generation; *Neuroterus quercusbaccarum* sexual generation) (George Melika, pers. com., 2009).

3.5. Ineffectiveness of *T. sinensis* is some areas of China

In China, *D. kuriphilus* is supposed to be kept at low densities by naturally occurring biological control agents in several areas, but such control is not equally effective everywhere, which results in pest problems (Zhang, 2009). Zhang’s paper (2009) is not explicit about the reasons for success or failure of *T. sinensis*. It seems relevant to obtain more information about this issue, particularly about factors which may lead to the failure of biological control and, subsequently, check whether certain areas in Europe might be unsuitable for biological control with *T. sinensis*.

The above information leads to the following concerns:

1. The potential uncertainties concerning identification and the formation of hybrids highlights the need for careful selection of parasitoid individuals to be used for import and release in new areas.

2. There is a potential for importation of galls containing parasitoids other than *T. sinensis* in the absence of adequate quarantine procedures and careful taxonomic identification

4. Conclusions

Classical biological control with the exotic parasitoid *T. sinensis* has been used with good results in Japan and North America and appears to represent the most sustainable management option in areas where *D. kuriphilus* is established in Europe. However, a more thorough environmental risk assessment is recommended in which (1) the host range of the parasitoid is considered in more detail, and (2) the direct and indirect non-target effects including effects on the ecosystem, are evaluated. Also, due to the potential taxonomic confusion and uncertainties relating to the parasitoid complex, further research is needed to be able to reliably distinguish the different species and ecotypes of *T. sinensis*. Further, to prevent the import and release of unwanted insect species, it is advised to use appropriate quarantine and taxonomic referencing of imported natural enemies. Finally, further investigation is needed to determine if *T. sinensis* can hybridise with other European *Torymus* species and the influence of hybridisation on the efficacy of biological control.

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